



Food waste between environmental education, peers, and family influence. Insights from primary school students in Northern Italy

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ABSTRACT

Education plays a central role in tackling consumers' food waste. However, research on children's food waste at school tends to focus on quantification and logistical factors rather than on the impact of interventions. Furthermore, behavioural elements, including imitation, tend to be neglected despite their well-established role in the food realm. To contribute to filling this gap, we assess the short and long-term impact on food waste levels of a lesson about the environmental consequences of food waste. Innovating on the literature, we control for both behavioural factors and social influence. For this purpose, we developed a longitudinal protocol that factors in altruistic concerns elicited through economic experiments, and the influence of parents and classmates assessed through parents' questionnaires and network questions. We apply the protocol to a sample of 420 Italian primary school students from 20 classes. The lesson was implemented in half of the classes, randomly selected. We find that the lesson only reduces self-declared food waste in the short-term but the impact does not persist after some months. Concerns for the environmental implications of food waste increase significantly, and this effect is still present in the longer-term. Neither the parents' approach to wasting food nor the degree of students' pro-social motivations make a significant difference. In turn, students' food waste is found to align with that of the students sitting nearby in the school canteen, suggesting that imitation through direct observation of behaviours plays an important role. These results call policymakers to take advantage of network effects in social settings to favour the replication of pro-environmental behaviours.

1. Introduction

Food waste is a societal challenge drawing burgeoning attention of scholars and policymakers at different levels, from global to local (United Nations Environment Programme, 2021). This challenge is recognised in Sustainable Development Goal 12.3 of "halving per capita global food waste at the retail and consumer levels and reduce food losses along production and supply chains." In developed countries, the largest share of food waste along supply chains is generated by consumers (European Parliament, 2017). Therefore, while it is key to address systemic factors driving the generation of waste by enterprises along supply chains rather than simply "blame consumers" (Evans,

2011; Southerton and Yates, 2015; Grinberga-Zalite and Zvirbule, 2022), the need to promote less wasteful behaviours cannot be neglected. Indeed, the negative relationship between food waste and social capital¹ (Piras et al., 2021) suggests that environmentally-aware citizens could be less prone to waste. Accordingly, educational initiatives play a central role in the national strategies to reduce food waste in EU countries (Giordano et al., 2020).

However, changing consumers' behaviours is challenging, especially in the realm of food, where well-established routines, habits, embeddedness and cultural norms play a key role (Verplanken and Orbell, 2003; Quedsted et al., 2013; Stöckli et al., 2018; Van Geffen et al., 2020; Soma et al., 2020). Furthermore, food waste is the final outcome of a long

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¹ Social capital refers to "features of social life – networks, norms, and trust – that enable participants to act together more effectively to pursue shared objectives" (Putnam, 1995, pp.664-665).

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chain of decisions centred on the individual consumption of resources (Piras et al., 2021). For these reasons, interventions in early years, when habits and values have not stabilised yet, are likely to be more effective than those focusing on adults, pointing to the role of environmental education in primary schools (Le Borgne et al., 2021).

Despite the sizeable amount of studies that focus on food waste generation in school canteens, there is a lack of counterfactual research on the impact of educational initiatives targeting food waste reduction. The topics addressed include food waste quantification regardless of interventions (Byker et al., 2014); the environmental footprint of this waste (García-Herrero et al., 2019); the impact of macroscopic situational factors like the food service provider and the location of the kitchen (Boschini et al., 2020), or the school context and culture (Derqui et al., 2020). Besides the lack of counterfactual studies, there is limited understanding of how individual preferences,² including the desire to be in tune with others on food consumption (Jackson, 2005), impact food waste generation and interfere with the outcome of educational initiatives. Indeed, education intervenes in a set context characterised by heterogeneous individual preferences; diverse educational approaches and attitudes towards waste of parents; and influence of peers. To accurately assess the impact of educational initiatives, these elements need to be factored in.

To contribute to filling this gap, the goal of our research is to test the impact on food waste generation by primary school students of a lesson about the environmental consequences of food waste. Given that the main actors potentially influencing individual food behaviour at school are peers in the class and parents through their approach toward and opinions about food waste, we control for both these elements. Furthermore, given that avoiding food waste generates little direct gains for a child but large gains for the society (or the social group), we control for individual tendencies to pro-social behaviour. Rather than eliciting these elements through standard questionnaires, we use an innovative longitudinal protocol that combines economic experiments, questionnaires filled by the parents separately, and network questions. Incentivised economic experiments allow to elicit real preferences, which can differ from stated ones especially when there are trade-offs between individual wellbeing and (public) environmental good (Levitt and List, 2007), or a social desirability bias like in the case of food waste (Giordano et al., 2018). Parents' questionnaires allow to detect the latter's behaviours and opinions independently from those of their children, avoiding mutual influence and increasing precision. Social network questions – which allow to reconstruct the full interaction networks of each class – enable direct detection of peers' food waste behaviours by crossing questionnaire data rather than relying on the students' ability to recall what others did in the past. To the best of our knowledge this is the first setup in which both network data and pro-social tendencies are collected with up-to-date methods (behavioural experiment and network questions, respectively) rather than with standard questionnaires. Finally, the longitudinal approach, with three waves implemented respectively before, concomitantly with, and some months after the educational intervention, allows us to check the persistence of its effects in the long-term, which is key to achieve success but to the best of our knowledge is rarely done.

Once the above elements are factored in, our research question becomes: *How do concept-based environmental education, peers' influence, and the family's approach affect the food waste behaviours of primary school children?* By answering this research questions, we will be able to draw

useful recommendation for the design of more effective interventions whose impact persists in the longer-term. We test this research question using data from 20 primary school classes in Northern Italy.

The rest of the paper is structured as follows. In the next section, we provide an overview of the literature about the impact on food waste levels of values and attitudes, education, and social factors, namely peers and caregivers. Then, we illustrate our longitudinal data collection protocol and the estimation strategy. After presenting some descriptive statistics, Section 4 presents and discusses the results. Finally, Section 5 concludes and lists some broader policy implications.

1.1. Literature review

The bulk of the literature on food waste in school canteens focuses on causes ascribable to logistical or situational factors. Type of catering provider, organisation of the service, portioning, presence of vending machines, or the location of the school itself (urban or rural) have all been explored in one or more studies. Cordingley et al. (2011), Byker et al. (2014), Steen et al. (2018) all identified portioning as one of the main causes of food waste in schools. Cordingley et al. (2011) also identified the dining environment and the duration of the meal as important, as later confirmed by Betz et al. (2015), Cohen et al. (2016), Silvennoinen et al. (2015), Wilkie et al. (2015), Eriksson et al. (2017), and Liz Martins et al. (2020). There is a certain consensus also around the role of the kitchen location, whereas schools served by satellite kitchens record more food waste than those with internal kitchens (Eriksson et al., 2017; Boschini et al., 2020; Steen et al., 2018). In the case of an internal kitchen, a certain influence is played by operators-providers, who might encourage children to eat all the food in their plate (Dev et al., 2016; Neff et al., 2015, 2020; Tovar et al., 2016). However, Neff et al. (2020) specify that such influence is stronger on pre-school children. Our sample is made of children in the last two years of primary school and, to shed light on the problem from a different perspective with respect to the extant literature, we do not focus on logistical or situational factors, which do not vary in the schools considered (all rural and with internal kitchen), but on the impact of an educational intervention and behavioural factors.

1.2. Values, attitudes, and food waste

Generally, food waste in adult consumers is explored with reference to their attitudes and motivations, and there is a strain of literature which relies on the theory of intrinsic motivations (Bénabou and Tirole, 2011). According to this theory, qualities such as altruism or commitment lead to pro-social behaviour – here food waste reduction – due to the benefits it entails for the society in terms of reduced impact on collective natural resources. Relatedly, Knez (2016) concluded that altruism determines pro-environmental behaviour and Piras et al. (2021) showed that food waste is related negatively to social capital and positively to the search for status through food. Another often applied framework is the Theory of Planned Behaviour, which assumes coherence between beliefs and actions (Ajzen, 1991). Both approaches have been questioned due to their overreliance on intention-behaviour coherence, which ignores the context where behaviours happen (Stöckli et al., 2018; Soma et al., 2020). Some studies have analysed the so-called “attitude-behaviour gap” (Kollmuss and Agyeman, 2002; Graham-Rowe et al., 2015; Piras et al., 2022a), or the “behaviour–outcome gap” (Setti et al., 2018), whereby subjects declaring not to waste or to feel disgusted by wasting food, actually waste quantities similar to others without realising it (Schanes et al., 2018; Giordano et al., 2018, 2019; Elimelech et al., 2019), or feel absolved for their own food waste production due to lack of time or for other practical reasons (Van Geffen et al., 2020). Likewise, many scholars have demonstrated that food-wasting habits may not always correspond to awareness of the issue (Evans, 2011; Richetin et al., 2012; Watson and Meah, 2012; Ganglbauer et al., 2013; Spurling et al., 2013; Hebrok and Heidenström,

² In the text, we use “individual preferences” interchangeably with “behavioural traits”, “values and attitudes” to indicate the order that a consumer (here, student) gives to specific characteristics of a good/service, resulting in a decision. In particular, we focus on behavioural elements such as “altruism” or “other-regarding preferences”, which represent deviations from rational maximizing behaviour assumed by standard economic theory (Kagel and Roth, 2020).

2019). Whether children act the same way as adults in the food waste domain, i.e. whether there is coherence between their values and behaviours, remains an open question. To this end, rather than measuring values hypothetically through the questionnaires, we elicit care for common resources through a Public Good Game (PGG) and assess its relationship with food waste behaviour – something that to the best of our knowledge has never been done. From this analysis of the literature, we can then derive our first hypothesis:

Hypothesis 1. Children who contribute more to the public good tend to waste less food.

1.3. Food waste interventions: the role of concept-based education

Sorokowska et al. (2020) observed the creation of emotions such as disgust, and a moral related to food waste already at 3-year-old, and concluded that 10-12-year-olds are then keen to behave according to their moral: specifically, they would not share their food with a person who wastes food. But how to drive the actual rejection of food waste in children is unclear. Indeed, the effectiveness of concept-based education on food behaviours for pupils has been the subject of research only recently (e.g., Favuzzi et al., 2020; Antón-Peset et al., 2021). The success of an intervention seems to depend on a multiplicity of factors. Here we aim to explore whether children receiving a lesson on the environmental consequence of food waste, rather than on its ethical and material implications or a generic class on climate change, approach this problem differently by either showing more awareness or declaring to waste less. Our hypothesis is thus:

Hypothesis 2. Children who receive education on the environmental impact of food waste, waste less both in the short- and in the long-term.

The characteristics of an educational intervention have been found to determine its effectiveness. One-time, single-component interventions show contradictory results. Favuzzi et al. (2020) tested the impact of an educational intervention on food waste in school canteens in Southern Italy, obtaining non-significant impacts: waste quantities did not vary significantly between one week before and one after the intervention. Contrastingly, Antón-Peset et al. (2021) recorded positive results of an educational intervention in Spain but on a small sample of 14 students, which would require confirmation on larger numbers. Noteworthy, both studies focus on the material outcome (quantity) rather than on the behaviour itself, and only measure it in the short-term, which does not allow to assess the persistence of the effect, when significant. In this paper, we focus instead on the act of wasting (frequency), and measure it both in the short-term and after some months to assess the persistence of the effects.

Concerning longer-term interventions, to the best of our knowledge there are no waste-related studies reported in the literature, while there are examples from other food-related domains. Myers et al. (2018) assessed the effectiveness of a 10-week educational initiative to increase the consumption of fruit and vegetables in Australian primary schools. They found a significant improvement for vegetable consumption during the testing period, but not for fruits. Jones et al. (2012) assessed the impact on 9-11-year-olds in England of a multicomponent programme aimed at improving dietary healthiness and sustainability, finding an increase in self-reported consumption of both fruits and vegetables over a period of 18–24 months.

Other scholars (Micha et al., 2018; Murimi et al., 2018) demonstrated that effectiveness is associated to a “whole-school” approach, namely multi-component interventions delivered and supported by school staff and parents. Murimi et al. (2018) systematised literature results on nutritional interventions targeting children from nursery to secondary school. In 46% of the cases, the interventions’ stated goals were met, while the remaining studies achieve them either partially or not at all. The elements identified to characterise a successful intervention include a duration of at least six months; engagement of parents

in face-to-face sessions; identification of specific behaviours to be modified; and high commitment by those delivering the intervention. In a randomised controlled trial evaluating two interventions in Northern Ireland, Brennan et al. (2021) reach similar results: the simple educational intervention was less effective than the more interactive one, which foresaw many practical actions like the provision of healthy snacks, food presentation improvement, and the tasting of locally produced food. Such results suggest that long-term, multi-component interventions based on the inclusion of more actors, primarily parents, work better. However, they bear costs that many schools cannot easily afford. Therefore, we test a multi-component intervention but developed in a single, half-day interactive lesson. The lesson was held by educators of the Centres for Sustainability Education (CEAS), established by the Emilia-Romagna Region and already active in the schools. Besides being informed of the study so that they could provide their consent, parents were also involved by asking them to fill two questionnaires and invited to attend a debriefing seminar.

1.4. Social influence in the food waste domain: peers and parents

Students spend a considerable part of their day in a classroom with the same peers. This environment is thus extremely important for the development of their behaviours and preferences. An entire strain of sociological literature is devoted to the analysis of peer effects and their importance in determining educational developments and behaviour in children or adolescents. Influence of peers has been found, for example, in determining educational attainments (Schneeweis and Winter-Ebmer, 2007; Sacerdote, 2011, 2014); antisocial behaviour (Thornberry and Krohn, 1997); the adoption of stereotypes and bias toward (Grow et al., 2016) or against groups (Boda et al., 2020); smoking (Nakajima, 2007); and drinking (Wilks et al., 1989).

Peer effects are related to different aspects of the social relations in a class. The probability of pupils engaging in a given behaviour has been found to be influenced by individuals they consider as friends (Crosnoe et al., 2003), and those considered popular within the classroom (i.e., “high status individuals”, e.g., Cillessen, 2007; Pál et al., 2016). The relevance of negative ties in the formation of behaviours has also been highlighted in the literature (Boda and Néray, 2015; Marineau et al., 2016; Harrigan et al., 2020; Boda et al., 2020). Beyond the general influence of classmates, an additional effect on test scores has been found to depend on the behaviour of desk mates (Keller and Takács, 2019). The intervention analysed by Antón-Peset et al. (2021) envisaged children becoming “drivers of change by performing a series of activities to raise their schoolmates’ awareness” (p.6), but whether this approach has had a positive impact through imitation has not been assessed. Furthermore, studies analysing the role of classroom networks in the generation of food waste are missing in the literature. To contribute to filling this gap, given on the one hand this evidence on the relevance of peers in the classroom, and on the other hand that food consumption is a social behaviour on which people want to be in tune with others (Jackson, 2005), we formulate the following hypothesis:

Hypothesis 3. Children’s food waste is positively related to the food waste of their peers, including (1) friends, (2) children considered popular, and (3) physically close peers in relevant activities.

Beyond peers in the classroom, parents and caregivers are the actors who typically share at least one meal per day with the students, so their behaviour matters in the definition of the student’s attitude to food as well (Brown and Ogden, 2004; Scagliioni et al., 2008; Sutherland et al., 2008). Educational programmes seem to be more effective if they include a variety of actors, primarily caregivers (Izumi et al., 2020). Increasing the commitment of families towards food waste reduction has been demonstrated to be a successful strategy by Boulet et al. (2019). On the other hand, more than one study (Daniel, 2016; Holley et al., 2018) have shown that parents worried about food waste tend to accommodate children’s taste, mostly by preparing floury and unhealthy food; hence,

reducing food waste can become a competing goal with healthy diets (Neff et al., 2020). Likewise, pressuring children to eat all of their food can lead to negative affective reactions towards the foods they are pressured to eat (Batsell et al., 2002). Galloway et al. (2006) showed that the use of pressure at home is associated with lower intake of food. Here we are not interested in caregivers' direct contribution to the success of an intervention but in whether there is a relationship between parents' attitude towards food waste and their children's behaviour which pre-exist the intervention and could potentially interact with it. We hypothesise that:

Hypothesis 4. Children whose parents are more concerned about food waste, and/or have a stricter attitude towards wasting food, waste less food.

2. Data and methods

2.1. The protocol

Data for this paper were collected in eight primary schools of the Province of Modena.³ This Province is among the richest in Italy in terms of per-capita income (Eurostat, 2021), and one of those with the highest social capital (Piras et al., 2021). Overall, 20 classes comprising 420 students were involved in the study.⁴ All but two were last-year classes of primary school, with most students aged 10 or 11. The class sizes ranged from 12 to 24. In order to build an environment of confidence, all the activities were implemented in the presence of a teacher and a known educator from the CEAS.

The data were collected in three waves that included the use of both questionnaires⁵ and behavioural experiments. In November 2017 (first wave), the students took part in incentivised behavioural experiments, and filled a questionnaire about their food behaviour and their social relationships within the classroom. Parents were asked to fill another questionnaire with similar questions about the household and food behaviours at home. In January 2018 (second wave), the experts from the CEAS delivered a lesson about the environmental impact of food waste and the methods to reduce it in half of the classes (one per locality, randomly chosen); the other classes had a lesson about energy waste. Immediately afterwards, the students filled a second questionnaire. Finally, in May 2018 (third wave), another questionnaire was proposed to the students and their parents. The translated questionnaires are available as Supplementary Data.

The behavioural experiments run during the first wave aimed at identifying the real pro-social tendencies of individual students, which we could then relate to their food waste behaviour, rather than relying on stated altruistic preferences. The students implemented four tasks in sequence. The first task was a Public Goods Game (PGG; Ledyard, 1994), aimed at assessing their willingness to contribute to the construction of the "common good". The second task was a Dictator Game (DG; Kahneman et al., 1986; Fehr, 2009), which elicits altruistic tendencies. The third task was a Trust Game (TG; Berg et al., 1995), which measured how much the students were willing to entrust (all or part) of their resources to a peer in the hope of receiving back the same amount or more. In other terms, this task measures the sender's expectation of return (Ashraf et al., 2006). The final game, whose results are not used in this analysis, consisted in the Bomb Risk Elicitation Task by Crosetto and

Filippin A (2013), which measures risk-taking attitudes.⁶ The tasks were implemented in the oTree web-based platform (Chen et al., 2016), and performed by children on tablets or laptops.⁷

In line with studies on social influence on behaviour in schools (e.g., Crosnoe et al., 2003; Boda and Néray, 2015; Pál et al., 2016; Boda et al., 2020), to collect data on networks considered important for social influence, during the first and third waves the students were asked to identify their relationships, positive or negative, with peers. Each student was asked to classify each of their classmates according to several scales, including: whether they considered them nice, not nice, or indifferent (likeability); whether they considered them a friend or a rival (friendship); whether the classmate was liked/disliked by others in the class (status, popularity); and whether they would like to have the classmate as their desk mate. Considering the extant evidence on the relevance of desk mates (Keller and Takács, 2019), and given that food behaviours are intrinsically observed during lunchtime, children were also asked to name their current desk mates, up to five classmates with which they spent time during the break, and the classmates sitting near to them when eating at the canteen.

Our dependent variable is the level of food waste, detected through the questionnaires. The literature has shown that quantification through questionnaires can lead to underestimation, allegedly for a "social desirability bias" (Giordano et al., 2018). To our knowledge, no studies have assessed the presence of this bias among children; nevertheless, for robustness, we included more than one question to assess this phenomenon. We asked for the frequency, which "highlights consumers' actions rather than their quantitative effects" (Setti et al., 2016: 1740), and is thus a proxy of their moral perception of the problem and a better measure of their actual behaviour. In the main model discussed below, the dependent variable is the usual frequency with which the students were "leaving food which is still edible in their plate" relative to the number of meals consumed at the canteen. This is an easy-to-understand and easy-to-recall action for the children. Models for the frequency of food waste at home (similarly assessed), and for the children's perception of their food waste frequency at school are provided as Supplementary Data.⁸

The last key variables we measured are the children's and parents' opinions about food waste, appraised through a multiple answer question for the children – who had to select all the food waste-related statements they deemed relevant – and a Likert scale for parents – who were asked to which extent they agreed with each of a series of statements. Statements focused on the environmental impact of waste were used to measure "environmental" opinions; those focused on money and the economy, for "material" opinions; those focused on education and justice towards foodless people, for "ethical" opinions. Parents were considered to "scold" their child if they declared to do it every time they waste; and to "insist" if they demanded their child to always finish their food as part of their approach to food waste.

³ The Italian Provinces correspond to level 3 of the EU Classification of Territorial Units for Statistics (NUTS).

⁴ We set a sample size of 420 students as 385 is the minimum size that allows to detect a proportion of 0.5 with a margin of error of 5% at a 95% confidence interval.

⁵ This research methodology is heavily used in studies about food and food waste (e.g., United Nations Environment Programme, 2021; Puriwat & Tri-popsakul, 2021).

⁶ Similarly to experiments in natural sciences, during behavioural experiments subjects make decisions in a controlled settings. To ensure that decisions are meaningful, i.e., closer to what the subjects would do in a real-life situation, the experiments are incentivised: subjects receive a payoff whose amount depends on their and others' decisions. In a PGG, they are provided with the same endowment, which they can decide to keep for themselves, or invest (totally or partly) in a common project whose return is equally shared regardless of the individual contributions. In a DG, the subjects decide how to share their endowment with a peer who receives nothing. The TG is similar to the DG but the peer receives three times the sum sent, and can return all, part or none of it. In our protocol, the students received a pen as a participation fee, and 0-to-2 cinema tickets depending on their ranking in the class.

⁷ The code of the experiments is freely accessible at the following link: <https://github.com/simonerighi/ExperimentSchools2017> [Accessed 28 October 2022].

⁸ Tables in the Excel sheets "Waste at home" and "Perceived waste at school", respectively.

Table 1

Descriptive statistics for the variables used in the model, both in the single waves and in the pooled sample.

Group	Variable	Unit	Wave 1 (n = 420)		Wave 2 (n = 420)		Wave 3 (n = 420)		All waves (n = 1260)		p-value ^e	Number missing ^f
			n ^d	% ^d	n ^d	% ^d	n ^d	% ^d	n ^d	% ^d		
Food waste (dependent variables)	Food waste frequency at school canteen	never (1)	11	3.0	18	5.3	8	2.2	37	3.5	0.160	201
		very few times (2)	107	29.4	91	26.8	81	22.8	279	26.3		
		less than half of the times (3)	81	22.3	85	25.1	90	25.3	256	24.2		
		more than half of the times (4)	63	17.3	52	15.3	75	21.1	190	17.9		
		almost every time (5)	79	21.7	66	19.5	75	21.1	220	20.8		
		every time (6)	23	6.3	27	8.0	27	7.6	77	7.3		
	Food waste frequency at home	never (1)	103	26.0	97	26.4	95	24.7	295	25.7	0.523	112
		very rarely (2)	194	49.0	198	53.8	206	53.7	598	52.1		
		at less than half of the meals (3)	58	14.7	50	13.6	52	13.5	160	13.9		
		at more than half of the meals (4)	15	3.8	13	3.5	20	5.2	48	4.2		
		at almost all meals (5)	23	5.8	9	2.5	11	2.9	43	3.8		
		at all meals (6)	3	0.8	1	0.3	0	0.0	4	0.4		
	Self-assessed frequency of waste at school canteen	very rarely (1)	36	9.8	41	12.2	38	10.8	115	10.9	0.606	205
		rarely (2)	58	15.9	59	17.6	59	16.7	176	16.7		
		in the right measure (3)	112	30.6	102	30.4	97	27.5	311	29.5		
		often (4)	118	32.2	80	23.8	103	29.2	301	28.5		
		too often (5)	42	11.5	54	16.1	56	15.9	152	14.4		
Children's opinions (dependent variables)	Children's opinion on food waste (environmental)		81	20.4	138	37.8	108	27.4	327	28.3	0.000	104
	Children's opinion on food waste (material)		319	80.4	284	77.4	303	76.7	906	78.2	0.418	101
	Children's opinion on food waste (ethical)		189	47.6	204	55.6	158	40.0	551	47.5	0.000	101
Controls: individual	Gender (female) ^a		199	49.1	199	49.1	199	49.1	597	49.1	–	45
Controls: family	Family members (more than 3) ^a		281	69.9	281	69.9	281	69.9	843	69.9	–	54
	Both parents foreign-born ^a		73	18.5	73	18.5	73	18.5	219	18.5	–	78
	Ownership of more than one car ^a		312	77.2	312	77.2	312	77.2	936	77.2	–	48
Behavioural factors	PGG donation (care for public good) ^a		18.65	13.27	18.65	13.27	18.65	13.27	18.65	13.26	–	57
	Dictator donation (altruism) ^a		29.95	21.77	29.95	21.77	29.95	21.77	29.95	21.75	–	57
	TG donation (trust) ^a		25.54	21.80	25.54	21.80	25.54	21.80	25.54	21.78	–	57
Education	Attended the lesson on food waste (vs on energy waste)		206	49.1	206	49.1	206	49.1	618	49.1	–	–
Social influence: peers	Food waste frequency of those sitting nearby at school canteen (median >3)		162	45.8	137	42.4	154	46.1	453	44.8	0.570	249
	Food waste frequency of friends (median >3) ^b		156	38.9	129	32.3	177	45.3	462	38.8	0.001	68
	Food waste frequency of non-friends (median >3) ^b		124	45.6	104	38.7	99	41.8	327	42.0	0.267	482
	Food waste frequency of those staying together during the break (median >3)		157	41.4	144	39.3	182	51.1	483	43.9	0.003	159
	Food waste frequency of nice classmates (median >3) ^b		161	40.1	140	34.8	181	46.2	482	40.3	0.005	64
	Food waste frequency of popular classmates (median >3) ^b		159	40.4	129	32.7	185	48.4	473	40.4	0.000	90
	Food waste frequency of deskmates (median >3)		157	43.1	146	42.4	171	52.5	474	45.8	0.015	226
	Food waste frequency of desired deskmates (median >3) ^b		154	39.4	131	33.6	168	44.6	453	39.1	0.008	102
	Food waste frequency of non-friends (median >3) ^b		157	41.4	144	39.3	182	51.1	483	43.9	0.003	159
Social influence: parents	Family scolds the child every time they waste ^c		197	53.4	197	53.4	207	56.1	601	54.3	0.697	153
	Strictness (parents insist not to waste) ^c		154	41.4	154	41.4	156	41.9	464	41.6	0.991	144
	Parents' opinion on food waste (environmental) ^c		212	58.1	212	58.1	220	60.3	644	58.8	0.792	165
	Parents' opinion on food waste (material) ^c		356	96.2	356	96.2	362	97.8	1074	96.8	0.341	150
	Parents' opinion on food waste (ethical) ^c		274	75.1	274	75.1	266	72.9	814	74.3	0.744	165

Notes: All the variables are dummy variables apart from food waste (ordered categorical) and behaviours (quantitative discrete).

^a Measured only at wave 1, and inputted at other waves.^b Food waste measured in each wave, but networks measured only at waves 1 and 3 and inputted at wave 2.^c Measured only at waves 1 and 3 using the parents' questionnaire, and inputted at wave 2.^d Number and percentage of observations assuming that value for ordered categorical variable and value 1 for dummy variables; average and standard deviation for quantitative discrete variables.^e Tests on difference between waves (Kruskal-Wallis test for numerical variables, Fisher's exact test for categorical ones).^f Number of missing values after imputation.

Before involving the students in the research, parental approval was sought. The whole data collection procedures and protocols were pre-approved by the ethics committee of the University of Bologna.

2.2. Data preparation and statistical model

The data obtained during the three waves, including from the parents' questionnaires and behavioural experiments, were merged into a single panel dataset, which was analysed using R (R Core Team, 2018). Missing data on independent variables were inputted using two approaches: last observation carried forward (LOCF), and last observation carried backward (LOCB). When possible, the LOCF approach was preferred. Missing values concerning dependent variables were not inputted.

The functional form of the models estimated is as follows:

$$FW_{it} = f(I_i, B_i, F_{it}, P_{it}, T_i * W)$$

where I_i represent time-invariant individual and family characteristics included as controls; B_i are behavioural characteristics; F_{it} defines the opinions and behaviours of the parents; P_{it} indicates the food waste frequency of peers; and $T_i * W$ is the interaction between an indicator T_i of having been treated (i.e., having received the food waste lesson) and the wave W . FW_{it} is the dependent variable, i.e., food waste behaviours.

Given the experimental design and the ordinal nature of the response variable, proportional odds mixed models (POMM) were fitted. The dependent variables are measured on an ordinal scale, whereas the independent variables are binary, except for the results of the behavioural experiments, which after several attempts of discretisation were included as continuous.

Peer influence was assessed by fitting several alternative models, each including a binary independent variable indicating whether the median food waste of the peers belonging to one of the networks was at least "more than half times".⁹ This solution was preferred to using the actual median because the averaging mechanisms caused most values to be located at the centre of the distribution. The networks used include: peers sitting nearby at school canteens; friends; enemies; nice peers; peers with which the respondent uses to spend most time during the break; popular peers ("liked by many" according to the focal individual); desk mates; and desired desk mates. The effects of the food waste education and of the alternative lesson were assessed separately at wave 2 (short-term effects) and at wave 3 (mid-term effects) by adding the $T_i * W$ interaction term. The POMM also includes two random intercept terms, one for each child and one for each class, to adjust for the inter-correlation of answers given by the same individual over time, and for the sparsity of data.

The final POMMs presented includes the number of tokens donated in the PGG as a proxy of care for the public good (behavioural factor), and the food waste of the students sitting nearby at school canteens as a proxy of peers' influence. Significant results obtained with alternative explanatory variables are also discussed. As a robustness check, the same models were estimated with food waste at home and with perceived food waste at school as dependent variables. Finally, the impact of the same explanatory variables on the students' opinions about food waste was assessed using logistic mixed models. The random intercept terms of such models are the same of the POMM.

The results of POMMs are reported as cumulative Odds Ratios (cOR), whereas results from logistic mixed models are reported as Odds Ratios

(OR).¹⁰

3. Results and discussions

Table 1 presents some descriptive statistics for the single waves and the pooled sample. While the total number of children involved in the study was 420, due to absences and failure to answer some questions, the actual number of observations is smaller, as showed by the number of missing values. The variables included in at least one of the final models are: (1) self-declared food waste behaviours and perceptions (i.e., our dependent variables); (2) individual and household characteristics (controls); (3) behavioural factors; (4) parents' opinions and attitudes towards wasting food; (5) food waste behaviours of the student's peers; and (6) the student's opinions about food waste. Finally, a variable identifies whether the student (their class) has been involved in the lesson about the environmental impact of food waste.

Around half of the participants are female; 70% belong to households of more than three members; around 20% have two foreign-born parents; and almost 80% own more than one car (a proxy of household income). Food waste behaviours and *perceptions* do not change significantly across the three waves. However, the frequency of leaving food in the plate is much higher at school: 46% in the pooled sample declared to do it "more than half of the times", while at home 52% declared to waste "very few times". Furthermore, 43% perceive that they leave food "often" or "too often" at school. The evolution across waves of the food waste variables just discussed is visualised in Fig. 1.

Behavioural games returned an average donation of 18.65 experimental tokens out of 40 in the PGG, 29.95 out of 100 in the DG (altruism), and 25.54 out of 100 tokens entrusted to a peer in the TG. These numbers are in line with the behavioural economics literature showing departure from pure payoff-maximizing behaviour (Kagel and Roth, 2020), and allow to comparatively assess the preferences of the participants.

Around two fifth of the peers in each network have a median food waste frequency of "more than half of the meals": desk mates (46%) and students sitting nearby in school canteens (45%) are the most wasteful networks, friends (39%) the least. However, as shown by the results of the Kruskal-Wallis tests in Table 1, the values assumed by some of these variables (food waste of friends, those sitting together during the break, nice and popular classmates, actual and desired deskmates) differ significantly across waves, being lower at wave 2.

Concerning parents, slightly more than half of the respondents (54%) scold their child if they waste food, but only 42% insist that they finish all of their food. Their opinions about food waste tend to be dominated by *material* concerns (97% of the parents), followed by *ethical* (74%), and *environmental* ones (59%). Students' opinions mimic those of their parents, although their prevalence is much lower: 78% declare *material* concerns, 48% *ethical*, and 28% *environmental*. *Ethical* and *environmental* concerns vary significantly across waves, being much more prevalent during wave 2, i.e. right after the lesson.

3.1. Food waste behaviour in school canteens: values, education and social influence

Table 2 presents the estimates of the model explaining the generation of food waste at school. The dependent variable is the frequency of leaving food in the plate. The models for the students' *perception* of their food waste at school and for the frequency of food waste at home are provided as Supplementary Data.¹¹

Female students waste significantly more food (cOR 2.44, *p*-value

⁹ For each student, the peers belonging to their network were first identified; then, the food waste of these peers was identified; if the median of this distribution was "more than half of the times", the value of the network variable for the focal student is one (1), zero (0) otherwise.

¹⁰ The dataset and the R code used for the analysis presented in this paper are freely accessible in Zenodo (Piras et al., 2022b).

¹¹ Tables in the Excel sheets "Waste at home" and "Perceived waste at school", respectively.

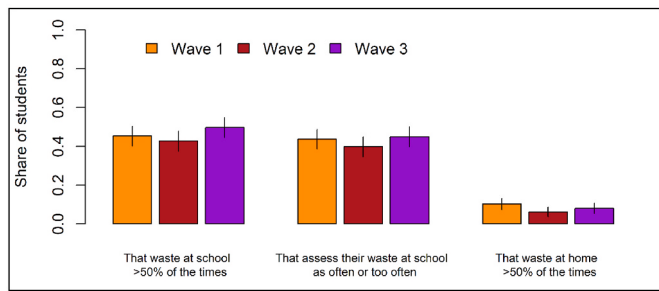


Fig. 1. Students' food waste frequency at school and at home and perceived food waste frequency at school, by wave.

Note: The vertical lines represent 95% confidence intervals, calculated using the standard method for proportions in large samples, i.e., $p \pm 1.96 * \sqrt{p * (1 - p)} / n$, with p being the proportion plotted in the bar and n the sample size.

Table 2

Determinants of children's food waste behaviour at school.

Group	Variable	Effect	cOR	95% CI		p-value
				lower	upper	
Controls: individual	Gender (female)	F vs M	2.44	1.34	4.42	0.003
Controls: family	Ownership of more than one car	Yes vs No	1.37	0.63	2.97	0.427
	Family members (more than 3)	>3 vs ≤3	0.87	0.46	1.64	0.659
	Both parents foreign-born	Yes vs No	0.57	0.24	1.35	0.201
Behavioural factor	PGG donation (care for public good)	+1 token	1.01	0.99	1.04	0.229
Education	Effect of alternative lesson (energy) at short term	Yes vs No	1.41	0.89	2.22	0.139
	Effect of alternative lesson (energy) at mid term	Yes vs No	1.63	1.04	2.56	0.033
	Effect of food waste lesson at short term	Yes vs No	0.42	0.22	0.83	0.013
	Effect of food waste lesson at mid term	Yes vs No	0.75	0.39	1.43	0.379
	Food waste frequency of those sitting nearby	>3 vs ≤3	1.52	1.02	2.26	0.039
	Parents' opinion on food waste (environmental)	Yes vs No	1.30	0.81	2.11	0.276
Social influence: peers	Parents' opinion on food waste (material)	Yes vs No	1.07	0.30	3.80	0.919
	Parents' opinion on food waste (ethical)	Yes vs No	0.75	0.45	1.25	0.275
	Family scolds the child every time they waste	Yes vs No	0.94	0.61	1.45	0.790
Social influence: parents	Strictness (parents insist not to waste)	Yes vs No	0.87	0.57	1.35	0.546
	Difference at baseline (Wave 1)	Yes vs No	1.17	0.37	3.68	0.784

Notes: 823 observations (65.3% of the total) on 307 subjects (73.1% of the total). cOR = cumulative odd ratio.

0.003), in line with Favuzzi et al. (2020) and by Liz Martins et al. (2020) for children of similar age. Since in most canteens the portions are fixed, and we do not control for the amount of food served, this could be due, among other factors, to the lower caloric requirements for female students, as also pointed out by Favuzzi et al. (2020). Instead, none of the family variables (car ownership, household size, foreign parents) is significantly related to the frequency of food waste.

The non-significant cOR associated with the number of tokens donated in PGG (cOR 1.01, p 0.229) allows us to support the following:

Result 1 (R1). *The generation of food waste is unrelated to children's contribution to the public good.*

This finding is in line with previous literature observations that food waste is the final outcome of a long chain of actions, from food purchase to leftover management, which leaves a limited role to intentionality and causes the emerging of an "intention-action gap" (Evans, 2011; Richetin et al., 2012; Watson and Meah, 2012; Hebrok and Heidenström, 2019; Giordano et al., 2018, 2019; Piras et al., 2022a). It is also in line with Sorokowska et al. (2020), whereby children perceive food waste as something bad but do not act accordingly. It suggests our sample, including those who show care for the public good when making abstract decisions in the experiments, do not frame their food waste as a *public bad*, and their food decisions are probably driven by immediate individual needs. This finding diverges from Piras et al.'s (2021) conclusion that food waste is inversely related to local social capital as well as from Knez's (2016) point that altruism is associated to pro-environmental behaviour. However, it should be noted that these two studies base their conclusions on adults, and that the students in our sample come from a high social capital Province. Furthermore, while preferences and behaviours are assessed in most of the above studies through questionnaires and are thus subject to "social desirability" (Giordano et al., 2018) or "hypothetical bias" (Loomis, 2011) that could have driven the positive relationship, we elicit altruism by means of incentivised experiments. Only Sorokowska et al. (2020) implement a DG, but to elicit children's attitudes towards a person who wastes food, rather than their own altruism levels. This difference, however, suggests the need for more studies focused on this subject.

In our model we include the PGG donation instead of the DG because the natural resources used to produce food are a common good. However, similarly non-significant results are obtained if the PGG is replaced with the DG contribution (altruism, cOR 1.00, p 0.740), or the tokens transferred in the TG (trust, cOR 1.01, p 0.220).¹² The models with *perceived* food waste at school and with self-declared food waste at home as dependent variables yield similar results when using the PGG donation (respectively cOR 1.02, p 0.200, and cOR 1.00, p 0.704).¹³

Having attended the lesson about the environmental impact of food waste results in a significantly lower frequency of food waste at school in the short-term, i.e., in January (cOR 0.42, p 0.013); however, this impact does not persist in May (cOR 0.75, p 0.379). In turn, the students who attended the alternative lesson on energy waste show an increase in their food waste, which is not significant in the short-term (cOR 1.41, p 0.139) but becomes significant in the mid-term (cOR 1.63, p 0.033). The evolution across waves of the food waste frequency of the students who received each of the lessons is shown in Fig. 2. It should be noted that since the January questionnaire was filled right after the lesson, the latter could not have affected the food waste frequency. This effect rather suggests that the food waste lesson increased the students' awareness of the problem, leading them to declare less food waste for "social desirability" (Giordano et al., 2018). In turn, the energy lesson might have increased the salience of goals alternative to food waste

¹² Supplementary Data, tables "Dictator Game" and "Trust Game" in the Excel sheet "Dictator & Trust Game".

¹³ Supplementary Data, tables "Sitting nearby at school canteen" in the Excel sheet "Perceived waste at school" and "Sitting nearby at school canteen" in the Excel sheet "Waste at home".

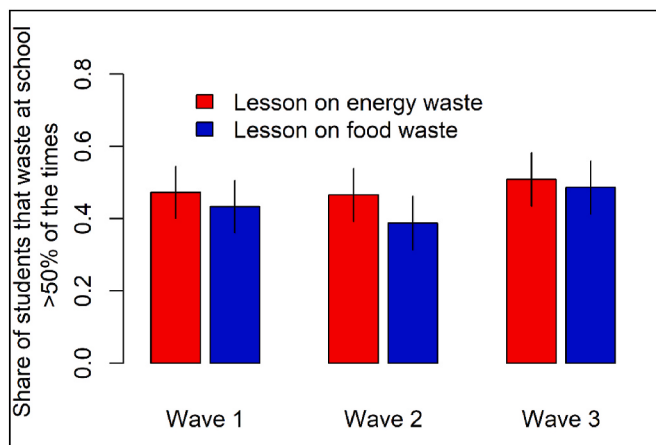


Fig. 2. Students' food waste frequency at school, by lesson received and wave.

Note: The vertical lines represent 95% confidence intervals, calculated using the standard method for proportions in large samples, i.e., $p \pm 1.96 * \sqrt{p * (1 - p) / n}$, with p being the proportion plotted in the bar and n the sample size.

reduction. Based on these findings, we can sustain the following:

Result 2 (R2). *Receiving education on the environmental impacts of food waste has the only effect of reducing self-declared food waste in the short-term.*

The non-significant cOR for the interaction between the treatment variable and the first wave shows that there was no significant difference in the baseline food waste of treated and untreated children, as it should be if the randomisation of the classes has been properly implemented (cOR 1.17, p 0.784). Furthermore, the short-term food waste reduction remains significant (but the cOR lower in most instances) if the variable for peers' influence is replaced with the values derived from other networks.¹⁴

Our results are not directly comparable with the few studies that assess the impact of interventions, since our target variable is the frequency, while the latter use quantities; however, we can compare the sign and significance of the impact. In line with us, Antón-Peset et al. (2021), who also kept a control group, detected a short-term positive effect (30% reduction), but their intervention lasted three weeks. Favuzzi et al. (2020) implemented a "simple" intervention like ours, but the reduction measured (1% on average across schools) was not statistically significant. In turn, our finding that the alternative lesson is linked to higher waste diverges from Neff et al. (2020), who showed that interventions pursuing alternative goals (in their case healthy eating) did not cause increase in food waste. Compared to the extant studies, we innovate by also assessing the long-term impact, which we find to be non-significant. This suggests that awareness of environmental consequences does not necessarily lead to sustained action to overcome food waste in children – an issue that requires further attention given the large amount of resources and time dedicated to educating students to pro-environmental behaviour. Surmising that the impact detected in January measures the perception of food waste as something bad, which according to Sorokowska et al. (2020) is already present in 3-12-year-olds, then we can argue that this perception does not persist after a few months.

The lesson on food waste has no significant impact on food waste at home, either in the short (cOR 1.01, p 0.975), or in the long-term (cOR

1.33, p 0.433).¹⁵ Equally, it has no significant effect on the children's perception of their food waste at school, both in the short (cOR 0.82, p 0.566), and in the long-term (cOR 1.43, p 0.296).¹⁶

The variables measuring peer influence yield interesting results. Based on the model estimates in Table 2, and on the estimates with alternative network variables provided in Table 3, we can sustain the following:

Result 3. *Children's food waste is unrelated to the food waste of (1) friends (R3.1) and (2) children considered popular (R3.2), but is positively related to the food waste of (3) immediate peers in related activities, namely sitting nearby in school canteens (R3.3).*

This result extends the literature's findings about peer influence on social and antisocial behaviours to the food waste domain. While there is understanding that influence between schoolmates could boost the impact of interventions against food waste, and measures have been proposed to facilitate it (Antón-Peset et al., 2021), to the best of our knowledge this has not been measured previously. However, what matters here is the direct observation of peers' behaviour within the food consumption *loci*: joint implementation of desk-based activities or sharing of opinions are not enough. Indeed, the students' food waste is significantly and positively related to that of the mates sitting nearby at school canteens (cOR 1.52, p 0.039). While the literature on social influence has highlighted the role of school friends (Crosnoe et al., 2003), and of popular pupils (Gillesen, 2007; Pál et al., 2016), here none of these and other networks yield a significant effect at 5% level, although desired desk mates yield a marginally significant effect at 10%. This confirms what argued by Piras et al. (2022a) for adults, that since food waste behaviours deviate from stated opinions, social interactions not implying direct observation can barely result in convergence of behaviours, although this cannot be excluded in the long-term.

Food waste at home is unrelated to the network variables considered. Only the network of "nice classmates" generates marginally significant results at 10% (cOR 1.48, p 0.058). This suggests that food waste behaviours at school and at home are also unrelated. While this might be due to the limited ability of young pupils to directly influence food preparation and consumption at home, this result might represent a challenge for the diffusion of virtuous behaviours learned at school. Equally, the students' perception of their food waste at school is unrelated to the network variables considered.

Finally, the cOR of the variables describing parents' opinions and attitudes are all non-significant, leading us to sustain the following:

Table 3

Influence of alternative network variables on food waste at school canteens.

Network variable	cOR	95% CI		p-value
		lower	upper	
Food waste frequency of those sitting nearby at school canteens	1.52	1.02	2.26	0.039
Food waste frequency of friends	1.03	0.66	1.62	0.887
Food waste frequency of non-friends	0.90	0.54	1.48	0.669
Food waste frequency of nice classmates	0.90	0.59	1.39	0.646
Food waste frequency of those staying together during the break	1.12	0.74	1.70	0.593
Food waste frequency of popular classmates	1.17	0.74	1.85	0.499
Food waste frequency of desk mates	1.04	0.72	1.51	0.824
Food waste frequency of desired desk mates	1.47	0.95	2.28	0.085

Notes: The full models are provided as Supplementary Data, Excel sheet "Waste at school." cOR = cumulative odd ratio.

¹⁴ Supplementary Data, tables "Friends", "Not friends", "Nice peers", "Spend time during the break", "Popular peers", "Deskmates" and "Desired deskmates" in the Excel sheet "Waste at school".

¹⁵ Supplementary Data, table "Sitting nearby at school canteen" in the Excel sheet "Waste at home".

¹⁶ Supplementary Data, table "Sitting nearby at school canteen" in the Excel sheet "Perceived waste at school".

Result 4 (R4). *Neither parents' opinions about food waste, nor the strictness of their attitude towards their children wasting food make a difference for the children's food waste behaviour.*

Whether the parents link food waste to *environmental*, *material* or *ethical* concerns, and whether they scold their child, or ask them to finish their own food, do not seem to make any difference for the child's food waste at school. This partly contradicts the literature finding that increasing the family's commitment can boost the impact of interventions targeting food behaviours (Jones et al., 2012; Myers et al., 2018; Murimi et al., 2018), including food waste reduction (Boulet et al., 2019), and also suggests that constraints set by parents at home do not necessarily result in behavioural change in the same domain at school. In turn, one may expect that parents more worried about waste, who tend to accommodate their children's taste (Daniel, 2016; Holley et al., 2018), end up favouring food waste in settings where this cannot be accommodated, like school canteens. This hypothesis is not verified in our data. Also, contrarily to the studies showing that a stricter attitude of parents leads to a counterreaction in children (Batsell et al., 2002; Galloway et al., 2006), our results suggest that this does not happen with reference to food waste at this age.

Parents' opinions and attitudes are not even related to the frequency of food waste at home, where we would expect the link to be stronger. This result holds regardless of the network variable included. Similarly, parents do not seem to significantly affect the children's *perception* of their own food waste at school. The only exception is represented by parents concerned about the *environmental* impact of food waste (regardless of the lesson): their children *perceive* their food waste at school as significantly lower (cOR 0.59, p 0.047).¹⁷ Further research could verify whether this is a case of "self-absolving" driven by "social desirability" (Giordano et al., 2018). We do not test the differential impact of the parents' involvement in the intervention but rather the relationship between the students' food waste, and their parents' approach; and even the extant literature seems to assume that the involvement of the parents is beneficial without testing it. However, in their assessment of a short-term intervention, Favuzzi et al. (2020) conclude that despite their enthusiasm, "once ended the school work, both parents and children return to their usual habits" (p.12), suggesting that adults' behaviour are sticky and can have a counteracting effect.

3.2. A focus on students' food waste opinions

As a final step, we assess whether the factors considered as potential determinants of food waste frequency have also a significant impact on the students' opinions about food waste (*environmental*, *material*, and *ethical*). The models are presented in Table 4, while the evolution across waves of the share of students expressing each of the three opinions is visualised in Fig. 3.

First, concerning the children's opinion about the *environmental* consequences of food waste, whose evolution is shown in Fig. 4, we find that the lesson has a strong short-term impact on it (OR 15.83, p 0.000). This impact persists in the long-term despite becoming weaker (OR 3.33, p 0.015), allowing us to add some nuance to R2:

Result 2b (R2b). *sReceiving education on the environmental consequences of food waste raises students' concern for these consequences, and this awareness persists in the long-term.*

Hence, the students take in the message of the lesson, but increased awareness is not translated into lower food waste, as already demonstrated by many scholars (Evans, 2011; Richetin et al., 2012; Watson and Meah, 2012; Hebrok and Heidenström, 2019).

Second, we find that female students show significantly higher *material* concerns for food waste (i.e., they think that it is a waste of money and a behaviour typical of rich people) (OR 2.49, p 0.000). Since

significantly more female respondents had helped prepare food at home in the previous week (73.2% vs 60.2%, p 0.000), this could have resulted in a higher perceived value of food and of the resources embedded in it.

Third, more frequent food waste of the children sitting nearby at school canteens (measured by the network variable) is significantly and positively related with *ethical* concerns for food waste (OR 1.59, p 0.027). This confirms Sorokowska et al.'s (2020) findings that observing others wasting (more) food triggers negative emotional reactions in young children, although this does not necessarily result in behavioural change.

4. Conclusions

We tested the impact on the food waste of primary school students of a lesson about the environmental consequences of food waste, controlling for the students' behavioural characteristics and for their peers' and family's influence. Despite the scientific and policy relevance of this topic, there have been very few studies addressing it with a counterfactual approach (see Favuzzi et al., 2020; Antón-Peset et al., 2021). Compared to most of the literature on food waste in school canteens, which focuses on *quantities*, we analyse the *frequency* of behaviours, arguing that it is a better proxy of consumers' moral perception of the problem and that it is easier to recall. To enhance the scientific value of our contribution, we also innovate methodologically by assessing the impact of the lesson both in the short and in the long term, and using tools from experimental economics and network analysis to detect individual preferences (care for the public good) and peers' influence. Rather than a long-lasting intervention, we implemented a single, half-day interactive lesson. Indeed, even if Murimi et al. (2018) argue that longer duration, and involvement of a wide range of stakeholders in diverse activities might increase effectiveness, such complex interventions are unlikely to be economically sustainable for many schools – an aspect not considered in the extant literature, which tends to focus on effectiveness *tout court* rather than cost-effectiveness.

We found that such concept-based educational initiative is not successful in reducing food waste but only impacts on the students' self-assessment of this behaviour in the short-term, and this impact is not visible after some months (R2). In turn, the message that food waste has negative environmental consequences is passed on to the students, and this awareness persists after several months (R2b), though it does not result in behavioural change. Concerning individual preferences (care for public good, and altruism), we found that these are unrelated to food waste (R1), suggesting that students do not perceive the latter as a *public bad* or, equally, that this behaviour is not driven by intentionality, in line with the "attitude-behaviour gap" already observed among adults (Kollmuss and Agyeman, 2002; Graham-Rowe et al., 2015; Piras et al., 2022a). We also found that there is no cross-contamination of behaviours between school and home. First, the parents' approach to wasting food, and their opinions on food waste are unrelated to their children's behaviour in both settings (R4). Only the students whose parents link food waste to its environmental impacts tend to *perceive* their food waste at school as lower – a result that deserves further exploration. Second, the lesson has no impact on food waste at home.

What seems to matter most for the students' food waste is social influence through the direct observation of peers' behaviours in the food consumption *loci*, i.e., the school canteen (R3.3). Opinions and concerns which do not imply direct observation are only associated to worsened perception of the target behaviour in the short-term, even if it is expressed by relevant others such as educators or parents. Equally, networks which do not imply a joint engagement in related activities (e.g., likeability, friendship and popularity), and thus require observation to be replaced and accompanied by communication, do not have time to develop their full effects in the context of a one-time intervention (R3.1; R3.2). To the best of our knowledge, these dynamics of peers effects have never been assessed before in the food waste domain, and even less among primary school students.

¹⁷ Supplementary Data, table "Sitting nearby at school canteens" in the Excel sheet "Perceived waste at school".

Table 4
Determinants of children's opinions about food waste (environmental, material, and ethical).

Group	Variable	Environmental		Material		Ethical	
		OR	p-value	OR	p-value	OR	p-value
Controls: individual	Gender (female)	1.36	0.286	2.49	0.000	0.65	0.072
Controls: family	Ownership of more than one car	1.22	0.607	1.57	0.167	0.80	0.481
	Family members (more than 3)	1.22	0.538	0.93	0.796	0.73	0.235
	Both parents foreign-born	0.97	0.934	0.80	0.533	1.21	0.582
	PGG donation (care for public good)	0.99	0.221	0.99	0.318	0.99	0.509
Behavioural factor	Effect of alternative lesson (energy) at short term	0.81	0.572	0.95	0.877	1.62	0.093
Education	Effect of alternative lesson (energy) at mid term	1.03	0.939	1.19	0.626	0.64	0.124
	Effect of food waste lesson at short term	15.83	0.000	0.74	0.530	1.56	0.290
	Effect of food waste lesson at mid term	3.33	0.015	0.57	0.253	1.42	0.392
	Food waste frequency of those sitting nearby	0.85	0.504	0.85	0.468	1.59	0.027
Social influence: peers	Parents' opinion on food waste (environmental)	1.51	0.147	1.04	0.869	0.91	0.680
Social influence: parents	Parents' opinion on food waste (material)	1.08	0.923	0.92	0.902	0.83	0.751
	Parents' opinion on food waste (ethical)	1.36	0.335	0.56	0.050	1.60	0.074
	Family scolds the child every time they waste	0.64	0.082	1.27	0.321	0.81	0.333
	Strictness (parents insist not to waste)	1.47	0.145	0.78	0.297	0.78	0.263
Difference at baseline (Wave 1)		1.41	0.423	0.76	0.458	0.90	0.785
Number of observations (% of the total)		824 (65.4%)		825 (65.5%)		825 (65.5%)	
Number of subjects (% of the total)		307 (73.1%)		307 (73.1%)		307 (73.1%)	

Notes: Full model details are provided in Supplementary Data, Excel sheet "Opinions." OR = odd ratio.

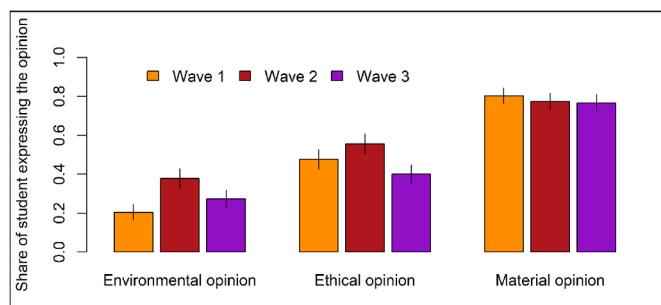


Fig. 3. Students expressing *environmental, material or ethical* opinions on food waste, by wave.

Note: See note to Fig. 1.

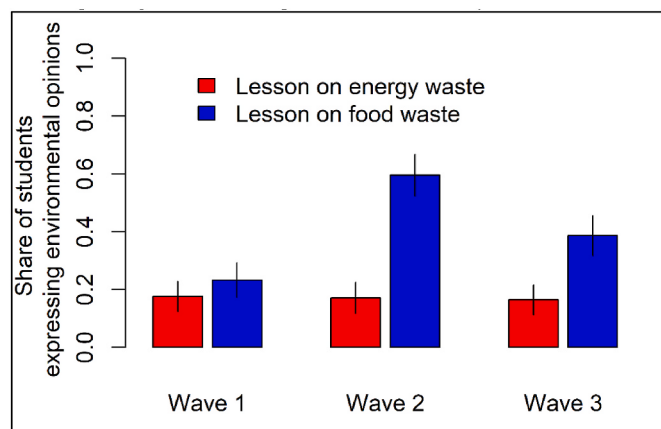


Fig. 4. Students expressing *environmental* opinions on food waste, by lesson received and wave.

Note: See note to Fig. 2.

Our findings have relevant implications for the design of policy programmes against food waste. At a general level, they allow us to second Sorokowska et al.'s (2020) point that "interventions could start in middle childhood and [...] should preferentially target behavior, as children seem to know that food waste is wrong" (p.6). More concretely, immediate networks based on observation and, in the longer-term, those

based on communication, can and should be leveraged to amplify impact. Therefore, on the one hand, environmental education should be part of an enduring strategy, and non-occasional. On the other hand, it should include behavioural monitoring, selection of social referents, and the boosting of social imitation by means of social interactions, without neglecting social and cultural differences (e.g., desk mate turnover in school canteens, eating-focused community events, engagement of social media influencers; etc.). Face-to-face interactions are likely to be more effective than virtual ones in modifying actual behaviours (Piras et al., 2022a). In the school environment, the identification of waste reduction "champions" (social award) can represent a useful follow up of even short-term interventions. To maximize impact, such champions could be chosen by combining their popularity in the classroom with the strength of their altruistic motivations.

Besides behavioural interventions, a focus on the wider food industry is needed. In the same way in which "blaming consumers" (Evans, 2011) will not help solve systemic supply chain conditions that determine high food waste levels, convincing children to reduce their plate leftovers will only have limited global environmental impact if wider conditions leading to high waste remain in place. For instance, to limit our focus to the school domain, canteen providers could customize food services to take account of individual preferences and needs as much as possible (e.g., the different caloric needs of male and female students). Accordingly, the schools' green procurement policy could foresee involvement of young citizens' representatives in the decision process, and introduce criteria related to food waste reductions when selecting service providers for public institutions.

While our conceptual and methodological innovations are of clear scientific value, our research has also a number of limitations. First, since the literature (see, for instance, Giordano et al., 2018) has detected a relevant gap between actual waste and one's perception, the assessment of food waste through questionnaires is likely to be subject to bias (although in the same direction for every subject). The difficulty in quantifying food waste is another reason we focus on the frequency of behaviour. Our definition of waste ("edible food left in one's plate") corresponds to an easy-to-understand and easy-to-recall action for the students. Nevertheless, the actual frequency could be observed in school canteens along a given period – something we were unable to do due to budget and logistic constraints. Second, additional control variables should be included in the model to isolate "unnecessary" food waste, namely the students' body mass index and thus their individual caloric requirement. The students were asked their weight and height, but due to the many missing values and outliers, this information could not be

used. Third, more diversity in socio-economic and logistical terms between the schools (and their canteens) would be needed to extend the validity of the findings. This would further help highlight the effect of idiosyncratic pro-social tendencies on food waste decisions.

Building on our results and methods, future research could analyse more in depth the impact of social networks on the diffusion of food waste reduction, and more generally pro-environmental behaviours, among young children by integrating the collection of information in the classroom with the implementation of randomised control trials that foresee the detection of actual behaviours in the school canteen. Our study also shows the importance of adopting a longitudinal approach: the long-term sustainability of the effects is key for the success of an intervention. Finally, while the literature suggests that long-term, interactive interventions are needed to achieve significant results, the issues of affordability and *cost-effectiveness* are key, and should possibly be factored in by future studies.

Ethics

This work involves human subjects. All the procedures were performed in compliance with relevant laws, institutional guidelines, and the Research Ethics Statement of the Behavioural and Experimental Laboratory of the University of Modena and Reggio Emilia (REBEL). The procedures were approved by the REBEL's Research Ethics Committee. Informed consent was obtained from the students' parents for their children's participation in the research. Participants' privacy rights were guaranteed, and always observed during the processing of personal data.

CRediT authorship contribution statement

Simone Piras: Conceptualization, research protocol, research question, Data curation, Investigation, Methodology, questionnaire, theoretical model, Visualization, Formal analysis, Writing – original draft. **Simone Righi:** Conceptualization, research protocol, Data curation, experiments, Investigation, Methodology, networks, experiments, Software, experiments, Supervision, experiments, Writing – original draft. **Federico Banchelli:** Data curation, Formal analysis, Methodology, statistical model. **Claudia Giordano:** Conceptualization, food waste, Writing – original draft. **Marco Setti:** Conceptualization, research protocol, Investigation, Funding acquisition, Project administration, Resources, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

The dataset and R script used to produce the analysis presented in this article are available in Zenodo (Piras et al., 2022b).

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the lessons on the environmental impact of food waste.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jclepro.2022.135461>.

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