DIGITAL TECHNOLOGIES AND GAME-BASED LEARNING TO PROMOTE FOOD LITERACY AMONG ADOLESCENTS: A MIXED-METHODS STUDY

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ABSTRACT
This mixed-methods study examined the effectiveness of an eight-week educational intervention based on digital technologies and game-based learning to promote food literacy among adolescents. The programme integrated serious games, collaborative activities, critical analysis of food media, and digital content creation. Results revealed significant improvements in food literacy, healthy eating behaviors, intrinsic motivation, and student engagement, with positive inclusive effects also observed for students with ADHD.

KEYWORDS
Food literacy; Game-based learning; Digital technologies; Adolescence; Mixed-methods; Food education.

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1. Introduction

In the contemporary context, characterised by obesogenic environments and growing pressure from digital media and food marketing, food education requires innovative approaches capable of integrating cognitive, social and cultural dimensions. The proliferation of ultra-processed foods—which are readily available and heavily advertised—is accompanied by a reduced ability, particularly among young people, to make informed food choices. In this context, food literacy (FL) emerges as a key competence for public health and the development of responsible citizenship.

Food Literacy can be understood as a complex and integrated set of knowledge, practical skills and critical abilities that enable individuals to plan, select, prepare and consume food in an informed and sustainable manner (Perry et al; 2017). It involves the ability to navigate increasingly complex food environments, characterised by a wide availability of products and an overabundance of often contradictory information (Vidgen & Gallegos, 2014). Higher levels of food literacy are associated with better dietary habits, greater autonomy in food choices and a reduced risk of obesity and malnutrition, highlighting its preventive and health-promoting role (Truman et al., 2017; Slater et al., 2018; Palumbo et al., 2016).

This competence takes on particular importance during adolescence, a stage of development characterised by profound biological, psychological and social changes. During this period, habits are established that tend to persist into adulthood, whilst decision-making autonomy regarding food choices progressively increases and exposure to the influence of peers and digital media intensifies. Individual development is shaped by the dynamic interaction between interconnected systems – family, school, community and the media environment – which contribute to shaping behaviours, values and lifestyles. From this perspective, the food and communication environment plays a decisive role in shaping nutritional choices.

At the same time, the adoption of healthy behaviours appears to be closely linked to the quality of the motivation driving the individual. The opportunity to feel autonomous, competent and socially connected fosters the development of intrinsic motivation, a central element in learning and behavioural change processes (Ryan & Deci, 2020). In the context of food, this implies the need to move beyond purely prescriptive approaches, promoting instead the development of critical and decision-making skills that enable adolescents to act consciously within their everyday context.

Food literacy is also intertwined with health literacy, helping to strengthen the ability to access, understand, evaluate and use health-related information effectively (Nutbeam, 2017; Sørensen et al., 2012). This integration is particularly significant during adolescence, a phase in which targeted educational interventions can produce lasting effects, influencing not only knowledge but also long-term attitudes and behaviours (Irz, X., & Mazzocchi, M., 2022).

In this context, digital technologies are playing an increasingly central role in educational processes and the development of eating behaviours. The digital environment represents one of the main contexts of socialisation for adolescents, influencing not only learning methods but also the development of identity, values and daily practices. Social media platforms, mobile apps and multimedia content contribute to the dissemination of dietary models often conveyed through persuasive strategies and forms of implicit marketing, capable of profoundly influencing individual choices (Qutteina et al., 2019).

Digital media therefore has a dual significance: it can reinforce dysfunctional dynamics, amplifying exposure to unhealthy food content, but it can also become a powerful educational tool if designed in a critical and informed manner. The ability to analyse, interpret and evaluate digital content related to food becomes an integral part of Food Media Literacy, enabling adolescents to recognise communication strategies, decode implicit messages and develop a reflective attitude towards the information received (Varela et al., 2024).

From this perspective, game-based learning represents a particularly effective approach, as it integrates elements of challenge, storytelling, immediate feedback and active participation, fostering meaningful and lasting learning. Game-based dynamics stimulate emotional and cognitive engagement and facilitate the acquisition of complex skills through direct experience and the simulation of real-life situations (Boyle et al., 2016). The use of serious games in the food sector allows learners to explore the consequences of nutritional choices, understand production chains and reflect on the environmental and social impacts of food.

Digital technologies also foster collaborative and participatory learning approaches through online environments, virtual communities and content co-creation activities. Such practices strengthen students' sense of belonging and their active role, supporting the development of cross-curricular skills such as communication, cooperation and digital citizenship (Redecker, 2017). The ability to produce content – such as videos, awareness campaigns or digital narratives – enables young people to move from being passive consumers to active participants in communication processes, further strengthening their critical skills.

A further key aspect concerns the accessibility and flexibility of digital tools, which make it possible to reach students from diverse backgrounds, including those who are most vulnerable or geographically isolated. Online platforms and MOOCs expand educational opportunities and facilitate personalised learning pathways, whilst requiring careful pedagogical design to avoid superficial use of technology (Medeiros et al., 2022).

The integration of digital technologies, game-based learning and food literacy therefore represents not only a methodological innovation but a paradigm shift in education. This approach promotes active participation, critical awareness and social responsibility, contributing to the development of individuals capable of navigating complex food- l environments and actively participating in the construction of fairer and more sustainable food systems. The study is based on an integrated theoretical model combining Food Literacy, Health Literacy, Self-Determination Theory and Food Media Literacy, on the assumption that the development of informed eating behaviours requires the interaction of knowledge, motivation, critical skills and active participation.

Within this framework, the original contribution of this study lies in analysing, within a real-world school context, the effectiveness of an educational intervention based on the integration of digital technologies and game-based learning, not only in terms of nutritional knowledge but also in terms of the development of motivation, eating behaviours, food media literacy skills and inclusive dynamics. In particular, the focus on the participation of students with ADHD allows us to explore, albeit in a preliminary manner, the potential of digital and playful methodologies in supporting more equitable and accessible learning processes.

2. Research Objectives

In light of the complexity of contemporary food contexts and the growing role of digital technologies in educational processes, this study aims to investigate in depth the transformative potential of an educational intervention based on game-based learning for promoting food literacy among adolescents. In particular, the focus is on the possibility that interactive and playful digital environments may foster the development not only of nutritional knowledge, but also of critical and decision-making skills, considered central to the definition of food literacy (Perry et al., 2017; Slater et al., 2018).

A primary objective is to assess the effectiveness of the digital educational intervention in improving students' levels of food literacy. This dimension encompasses both cognitive aspects, related to the understanding of nutritional

information, and operational and critical aspects, which enable the application of such knowledge in daily life (Truman et al., 2017). The literature highlights that well-designed educational interventions can have a significant impact on food-related skills, particularly when they incorporate experiential and participatory approaches (Deterding et al., 2011).

At the same time, the study aims to analyse changes in adolescents' knowledge, attitudes and dietary behaviours, recognising that nutritional choices are the result of a complex interaction between cognitive, emotional and social factors (Varela et al., 2024). From this perspective, improving knowledge represents only one dimension of change, which must be accompanied by greater awareness and a capacity for self-regulation in daily practices (Palumbo et al., 2016).

A further objective concerns the exploration of students' and teachers' perceptions and experiences regarding the use of digital technologies and serious games in educational contexts. Understanding the participants' perspectives allows us to grasp the motivational dynamics, the level of engagement and any critical issues related to the implementation of the intervention, which are fundamental elements for assessing the sustainability and transferability of innovative teaching practices (Boyle et al., 2016; Redecker, 2017). In particular, the use of games in educational contexts is associated with an increase in intrinsic motivation and active participation, key factors for meaningful learning (Ryan & Deci, 2020).

Overall, the research aims to contribute to the development of innovative educational models that integrate digital technologies, playful learning and food literacy, providing useful evidence for the design of effective and sustainable interventions in school settings.

3. Data collection tools

In order to ensure a comprehensive and methodologically robust evaluation of the educational intervention, the research adopts an integrated approach to data collection, combining standardised quantitative tools and qualitative techniques. This approach allows for the analysis not only of measurable changes in dietary skills and behaviours, but also of the experiential and perceptual dimensions of the students and teachers involved, in line with mixed-methods approaches in contemporary educational research (Creswell & Plano Clark, 2007).

For the quantitative component, internationally validated instruments adapted to the Italian adolescent context were used, with particular attention paid to their psychometric reliability and comprehensibility for first-year upper secondary

school students. The assessment was administered in a school setting, in digital format via an online platform, during school hours. It was supervised by the researchers, in collaboration with class teachers, to ensure consistency in instructions and adequate support in understanding the items.

The adaptation process involved a translation and back-translation procedure, accompanied by a linguistic review aimed at ensuring the appropriateness of the vocabulary for the participants' age and the Italian cultural context. A pilot phase, conducted on a small group of students with characteristics similar to the sample, allowed for the verification of the clarity of the items and the comprehensibility of the response scales, enabling any necessary adjustments before the final administration (Sousa & Rojjanasrirat, 2011).

An adapted version of the Self-Perceived Food Literacy Scale (SPFLS) was used to measure food literacy, which allows for the investigation of several key dimensions of food literacy. In particular, the instrument assesses:

- the ability to plan meals, i.e. the skill of organising balanced meals over time;
- informed food selection, linked to the ability to choose healthy and sustainable products;
- the management of nutritional information, which includes reading and understanding labels;
- critical competence, understood as the ability to assess the reliability of food information and resist external influences (Krause et al., 2018).

Health literacy was assessed using the Health Literacy for School-Aged Children (HLSAC) scale, which measures a comprehensive set of health-related skills. In particular, the tool assesses five main dimensions:

- theoretical knowledge (understanding),
- practical skills (functional health literacy),
- critical thinking,
- self-awareness,
- and active citizenship in health (citizenship) (Paakkari et al., 2016).

These dimensions allow us to assess not only the level of knowledge, but also the ability to actively use information in daily life.

Eating behaviours were analysed using the Adolescent Food Habits Checklist (AFHC), which measures the frequency and quality of daily eating practices. The tool assesses in particular:

- the consumption of healthy foods (e.g. fruit, vegetables),
- the reduction of risky behaviours (e.g. consumption of high-calorie snacks),
- and awareness in daily food choices (Johnson et al., 2002).

This scale therefore allows the reported competencies to be linked to the behaviours actually enacted.

The motivational dimension was investigated using an adapted version of the Academic Self-Regulation Questionnaire (SRQ-A), based on self-determination theory. The tool distinguishes between different forms of motivational regulation, such as:

- intrinsic motivation, linked to pleasure and personal interest;
- identified regulation, based on recognising the value of the action;
- introjected regulation, driven by internal pressures;
- and external regulation, determined by external factors (Ryan & Deci, 2020)

This framework enables an understanding of the degree to which eating behaviours have been internalised and the level of autonomy among students.

Alongside quantitative tools, the research included a qualitative component aimed at exploring the participants' experiences and perceptions, with particular attention to the learning processes triggered by the intervention and the dynamics of student engagement. In particular, the aim was to investigate how adolescents interpret and process the content presented, what meaning they attribute to digital and playful activities, and to what extent these influence their awareness and eating behaviours.

To this end, semi-structured interviews were conducted with students and teachers by the researchers in a school setting or online, using language appropriate to the students' age and including open-ended questions and narrative prompts. The interviews also allowed for an exploration of perceptions regarding the effectiveness of game-based learning, the level of motivation and participation, as well as any critical issues encountered during the intervention. From the teachers' perspective, the focus was on how to integrate technologies into teaching practice, on classroom dynamics, and on the potential transfer of acquired skills to other educational contexts.

The qualitative data collected were analysed using thematic analysis, following Braun and Clarke's approach, which enables the identification, analysis and interpretation of recurring patterns within the textual data through a systematic process of coding and categorisation (Braun & Clarke, 2021).

4. Sample selection

The study was conducted at a secondary school in Naples, involving students enrolled in the first year of the sixth-form (language and science streams). The total sample comprised 110 students, aged between 14 and 15, selected through convenience sampling, as they belonged to classes that had voluntarily joined the research project in collaboration with the teaching staff. This selection method is frequently adopted in educational research in real-world school settings, where access to participants is constrained by organisational and institutional factors (Creswell & Creswell, 2017).

To ensure greater robustness of the research design, the students were divided into two groups: an experimental group, which took part in an innovative educational intervention based on digital technologies and game-based learning, and a control group, which continued the educational programme using traditional methods. The division was carried out whilst maintaining, as far as possible, a balance between the groups in terms of size, field of study and general characteristics of the school population, in order to reduce potential bias and ensure greater comparability between the experimental conditions. This approach falls within the category of quasi-experimental designs, widely used in educational research to assess the impact of interventions in natural settings, even in the absence of random allocation of participants (Shadish et al., 2016; Creswell & Plano Clark, 2007).

Within the two groups, there were a total of four students diagnosed with Attention Deficit/Hyperactivity Disorder (ADHD), equally distributed between the experimental group and the control group. This decision was made with the aim of maintaining a homogeneous distribution of sample characteristics and of exploring, albeit preliminarily, the inclusive potential of the proposed educational intervention, in line with current perspectives on inclusive education (Florian, 2019).

The inclusion criteria for the study were: (a) informed consent from the students' legal guardians, in accordance with the ethical principles of research involving minors; (b) attendance of the first year of upper secondary school (language or science stream); (c) no previous year repetitions, in order to ensure greater homogeneity of the sample in terms of educational background; (d) for students with special educational needs, the presence of a diagnostic certification of ADHD. Students without informed consent or with irregular school records relative to their year group were excluded from the study. Compliance with ethical procedures and informed consent is a central element in contemporary educational research, particularly when it involves minors (Race, R., & Vidal-Hall, C. 2019)

Additional contextual variables, such as gender, socio-cultural background and access to digital technologies, were considered during the descriptive phase of the sample analysis, in order to provide a more comprehensive picture of the participants' characteristics and to support the interpretation of the results, in line with methodological recommendations for mixed-methods studies (Creswell, 2021).

Participation in the study was voluntary and conducted in accordance with the ethical principles of educational research, ensuring anonymity, data confidentiality and the option to withdraw at any time.

The composition of the sample and the inclusion of a control group allow for the adoption of a quasi-experimental design, which is particularly suitable for analysing the impact of educational interventions in real school settings. This approach balances methodological rigour with the ecological validity of the research, fostering a more comprehensive understanding of educational phenomena and making the results more transferable to teaching practice (Creswell & Plano Clark, 2007; Anderson-Cook, C. M. 2005).

5. Educational Intervention

The educational intervention was designed with the aim of promoting the development of food literacy through the integration of digital technologies and game-based learning strategies (Plass et al., 2020; Clark et al., 2016). The activity took place during school hours and lasted a total of 8 weeks, with two weekly sessions of 1 hour each, making a total of 16 hours of intervention.

The activities were carried out in person, within the school's classrooms and digital laboratories, and involved two subject teachers for each class (science and language), supported by the researchers. The teachers acted as facilitators, supporting the students and guiding moments of reflection (Redecker, 2017).

The experimental group took part in an educational programme structured in progressive modules, characterised by interactive, collaborative activities based on direct experience (Gillani et al., 2022; Plass et al., 2020).

In the initial phase, students were introduced to the use of an educational serious game focused on healthy and sustainable eating. Within the game, students took on the role of 'decision-makers', tasked with managing everyday situations (such as choosing meals during a school day, grocery shopping or planning a weekly menu). Each choice generated immediate feedback, showing the consequences in terms of nutrition, calories, the environment and cost. This enabled students to gain a

dynamic understanding of the relationship between choices and their impacts (Boyle et al., 2016; Plass et al., 2020).

Subsequently, collaborative problem-solving activities were proposed, in which the students, divided into small groups, worked on authentic tasks. These included:

- designing a balanced menu for teenagers, taking nutritional requirements into account;
- comparing food products by analysing labels (ingredients, nutritional values, presence of additives);
- simulating informed shopping on a limited budget, to develop decision-making skills and critical thinking.

Such activities promote the development of decision-making and collaborative skills in authentic contexts (Hmelo-Silver, 2004; Gillani et al., 2022)

A central part of the programme was dedicated to Food Media Literacy workshops, during which students analysed real content from social media (e.g. influencers, food advertisements, packaging). In these activities, students were guided to recognise persuasive strategies and , implicit messages and distorted representations of food (Varela et al., 2024; Qutteina et al., 2019).

At the same time, the students were involved in active production activities, which involved creating digital content such as:

- short informative videos on healthy eating habits;
- multimedia presentations on topics such as food waste or sustainability;
- micro-awareness campaigns aimed at their peers.

These activities encouraged personal re-elaboration of the content and a shift from a passive to an active and creative role (Redecker, 2017; Voogt et al., 2013).

Each session concluded with debriefing and guided reflection, during which students discussed the choices made, the difficulties encountered and the strategies adopted, fostering the development of awareness and metacognition (Kolb, 2014; Plass et al., 2020).

The control group followed a traditional teaching programme, covering the same topics but using more traditional, less interactive methods.

The activities were based mainly on lectures, during which teachers presented the fundamental principles of nutrition, such as:

- nutrients and their functions (carbohydrates, proteins, fats, vitamins);
- nutritional requirements during adolescence;
- principles of a balanced diet and the food pyramid;
- the relationship between diet and health.

This approach is typical of traditional teaching models centred on the transmission of knowledge.

These lessons were complemented by guided reading and analysis of the textbook and teaching materials, with exercises to test comprehension and summarise information.

Students also took part in guided discussions, in which they were encouraged to answer questions or express opinions on food-related topics, without, however, the use of interactive digital tools or simulations.

Structured individual exercises were also set, such as:

- completing questionnaires on eating habits;
- food classification exercises;
- activities to assess the knowledge acquired.

On some occasions, traditional written work was required, such as short reports or summaries, aimed at revising the content covered.

To ensure comparability between the groups, the control group covered the same core topics as the experimental group, but using traditional teaching methods, without the use of serious games, digital simulations or the production of multimedia content. Both groups covered the same subject content relating to nutrition, health and sustainability, in order to ensure the comparability of the results.

6. Results

Analysis of quantitative data

The analysis of quantitative data was conducted to assess the effectiveness of the educational intervention on the development of food literacy, related skills and eating behaviours among the students involved. The data collected using standardised tools were analysed using statistical software (SPSS), adopting both a

descriptive approach, through the calculation of means and standard deviations, and an inferential approach, through the use of statistical tests.

In the initial phase, the descriptive analysis made it possible to observe the trends in scores across the two groups (experimental and control) in the pre- and post-intervention phases. With regard to Food Literacy, the experimental group showed a significant increase in average scores, rising from an average of 2.84 (SD = 0.41) in the pre-test to 3.67 (SD = 0.38) in the post-test. In contrast, the control group showed a more modest improvement, rising from 2.81 (SD = 0.43) to 3.02 (SD = 0.40). Inferential analysis using a paired t-test confirmed the significance of the improvement in the experimental group ($t(54) = 9.12$; $p < .001$), whilst in the control group the change was more modest, though still statistically significant ($t(54) = 2.87$; $p = .006$). The comparison between the two groups in the post-test, carried out using an independent samples t-test, revealed a significant difference ($t(108) = 8.45$; $p < .001$), in favour of the experimental group.

A similar trend was observed for Health Literacy. The experimental group recorded an increase in mean scores from 3.01 (SD = 0.39) to 3.58 (SD = 0.35), whilst the control group rose from 2.98 (SD = 0.41) to 3.15 (SD = 0.37). Here too, the comparison between the groups in the post-test showed a statistically significant difference ($t(108) = 6.27$; $p < .001$), indicating a more marked improvement in the ability to understand and use health-related information among the students who participated in the innovative intervention.

As regards dietary behaviours, the analysis of the percentages revealed significant changes, particularly in the experimental group. Specifically, daily consumption of fruit and vegetables increased from 42% to 68%, a rise of 26%, whilst consumption of high-calorie snacks decreased from 61% to 39%, a reduction of 22%. In the control group, however, the changes were more limited: fruit and vegetable consumption rose from 44% to 51% (+7%), whilst the reduction in snack consumption was modest (from 60% to 54%, -6%). The comparison between the groups revealed significant differences in healthy behaviours ($\chi^2 = 12.34$; $p < .01$), suggesting a more pronounced impact of the experimental intervention.

The motivational dimension also showed significant variations. The experimental group showed an increase in intrinsic motivation, rising from an average of 3.12 (SD = 0.52) to 3.89 (SD = 0.47), whilst in the control group the increase was more modest (from 3.08; SD = 0.50 to 3.29; SD = 0.48). The comparison between the two groups in the post-test confirmed the presence of a significant difference ($t(108) = 5.96$; $p < .001$), indicating greater engagement and a higher degree of internalisation of behaviours in the experimental group.

An exploratory analysis was also conducted on the subgroup of students diagnosed with ADHD (n = 4), who were evenly distributed between the two groups. In the experimental group, students with ADHD showed an improvement in Food Literacy scores, rising from an average of 2.60 (SD = 0.35) to 3.40 (SD = 0.30), and in intrinsic motivation, from 2.90 (SD = 0.40) to 3.70 (SD = 0.33). In the control group, however, the improvements were more modest: Food Literacy rose from 2.65 (SD = 0.38) to 2.85 (SD = 0.42), whilst intrinsic motivation rose from 2.95 (SD = 0.36) to 3.05 (SD = 0.39). Although the small size of the subgroup does not allow for generalisable statistical inferences, the data suggest a trend towards greater benefit from the innovative teaching approach even for students with special educational needs, accompanied by less variation in the results.

Overall, the quantitative results show that the experimental group recorded significantly greater improvements than the control group across all variables considered. The reduction in standard deviations observed across various measures also suggests greater uniformity in the levels of competence achieved. At the same time, the increase in healthy eating behaviours and intrinsic motivation indicates that the intervention has had an impact not only on cognition but also on behaviour and attitudes. This evidence supports the effectiveness of the educational approach based on digital technologies and game-based learning in promoting meaningful learning and lasting changes in adolescents' behaviours.

Analysis of qualitative data

The analysis of qualitative data was conducted with the aim of exploring the experiences, perceptions and meanings attributed by participants to the educational intervention, thereby complementing and enriching the quantitative results. The semi-structured interviews, conducted with students and teachers, were analysed using a thematic analysis approach, which enabled the identification of recurring patterns and significant differences between the experimental group and the control group. Three main themes emerged from the thematic analysis: the active engagement generated by the digital activities, the perception of greater applicability of the content to everyday life, and the inclusive value of playful and multimodal methodologies. These themes guided the interpretation of the data, allowing the qualitative evidence to be organised coherently and linked to the students' learning and participation processes.

The guiding questions posed to the students covered aspects such as: *"How did you find the activities offered during the programme?"*, *"Do you think you have learnt anything new about food and nutrition?"*, *"Have the activities helped you to change your habits?*". Teachers, on the other hand, were asked: *"How would you rate the*

level of student engagement?", *"What changes have you observed in the pupils' behaviour or attitude?"*, *"What challenges or strengths did you identify in the intervention?*".

Analysis of the interviews reveals a clear difference between the perceptions of students in the experimental group and those in the control group. Students involved in the intervention based on digital technologies and game-based learning expressed high levels of engagement and interest. Many of them described the experience as stimulating and meaningful, emphasising the value of active learning. One participant said: *"I liked it because it wasn't the usual lesson; it almost felt like a game but I was actually learning"*, whilst another noted: *"I understood better what I eat and why some things are bad for you, because I could see it directly in the game*". The interactive activities and the opportunity to make decisions in simulated contexts were perceived as key elements of the learning process: *"When we had to choose what to buy or what to eat, I could tell straight away whether it was the right choice or not*."

In the control group, however, students described a more traditional and less engaging experience. Whilst acknowledging the usefulness of the information received, many highlighted a lower level of active participation. Some students stated: *"We learnt things, but it was like other subjects—explanation and study"* or *"Sometimes it was a bit boring, even though the things were important*". In general, a perception of learning emerges that is more linked to memorisation than to direct experience.

As regards students with ADHD, the qualitative analysis highlights particularly significant differences between the two groups. Students with ADHD in the experimental group reported finding it easier to maintain their attention and participate in activities. One of them said: *"I usually get distracted, but with the game I was able to follow along because I had to do things"*, whilst another pointed out: *"I liked it because I could take part; I didn't just have to listen*". The dynamic and interactive activities appear to have encouraged engagement and reduced attention difficulties.

In contrast, students with ADHD in the control group reported greater difficulty in maintaining concentration during lectures. One participant said: *"When they explain a lot, I get lost*; *I struggle to pay attention"*, whilst another reported: *"I understood some things, but after a while I got bored and thought about other things*". These findings suggest that the traditional approach may be less inclusive for students with special educational needs.

From the teachers' perspective, assessments emerged that were consistent with the students' perceptions. Teachers in the experimental group highlighted a high level of engagement and active participation. In particular, one of them observed: *"The students were much more engaged, even those who are usually less involved"*, whilst another emphasised: *"The game facilitated understanding, because the students could immediately see the consequences of their choices*". Greater peer interaction and more inclusive participation were also noted: *"I noticed that even the students who struggled the most were able to take part in the activities*".

Teachers in the control group, on the other hand, described a more traditional lesson format, noting varying levels of attention and less active participation. One teacher stated: *"The students were following along, but not everyone was engaged in the same way"*, whilst another observed: *"Some participated, others were more passive, as often happens in lectures*". Whilst acknowledging the importance of the content covered, a lesser impact on motivation emerged.

Overall, the qualitative analysis highlights how the intervention based on digital technologies and game-based learning fostered greater emotional and cognitive engagement, more active participation and a better understanding of the content, compared to the traditional teaching model. These results are particularly relevant from an inclusive perspective, highlighting the potential of the innovative approach in supporting students with specific educational needs, such as those with ADHD.

7. Discussion

The study's findings confirm the relevance of digital technologies and game-based learning as effective educational strategies for promoting food literacy among adolescents. The improvement observed in the experimental group, both in Food Literacy scores and in dimensions related to Health Literacy, suggests that an intervention based on interactive activities, simulations, immediate feedback and authentic tasks can foster a deeper, more integrated and applicable understanding of food-related content. These results highlight how learning, when mediated by active and contextualised experiences, enables students to link theoretical knowledge to everyday practices, making that knowledge more meaningful and lasting. This evidence is consistent with a conception of Food Literacy understood not as the mere acquisition of nutritional information, but as a structured set of knowledge, practical skills and critical abilities useful for navigating complex and dynamic food environments (Perry et al., 2017; Truman et al., 2017; Vidgen & Gallegos, 2014).

A comparison between the experimental group and the control group highlights how the mere transmission of knowledge, whilst useful for acquiring basic information, appears to have a more limited impact on students' behaviour and motivation. In the experimental group, however, the increase in fruit and vegetable consumption, the reduction in high-calorie snacks and the improvement in intrinsic motivation indicate a broader and deeper impact, involving not only the cognitive dimension but also the behavioural, emotional and attitudinal dimensions. The opportunity to experience situations close to everyday life, such as choosing a meal, reading labels or critically evaluating advertising messages, has likely fostered a greater internalisation of the content and a more effective translation of knowledge into concrete behaviour. This finding is consistent with self-determination theory, according to which learning is most effective when students perceive autonomy, competence and active engagement—elements that foster the emergence of intrinsic motivation and self-regulatory processes (Ryan & Deci, 2020). One possible interpretation of the results also concerns the novelty effect associated with the introduction of digital tools and playful activities, which may initially have increased students' interest and engagement. However, the consistency between the quantitative and qualitative data, as well as the structured and reflective nature of the proposed activities, suggest that the observed improvement is not attributable solely to the initial interest in technology, but also to the pedagogical quality of the intervention and its ability to promote meaningful and transferable learning.

The qualitative evidence further reinforces the quantitative findings, offering a deeper understanding of the learning dynamics triggered by the intervention. Students in the experimental group described the experience as more engaging, practical and meaningful, emphasising how the use of digital tools and playful activities made learning more accessible and stimulating. Game-based learning thus emerges not only as an effective teaching strategy, but also as an environment that fosters exploration, experimentation and the active construction of knowledge (Boyle et al., 2016; Plass et al., 2020). The opportunity to simulate food choices , analyse labels, evaluate advertising messages and produce digital content has promoted situated and reflective learning, facilitating the transition from a passive stance to active and informed participation. In this sense, the intervention has helped to develop in students a greater capacity for critical analysis of food-related media content, in line with perspectives on digital citizenship and Food Media Literacy (Redecker, 2017; Varela et al., 2024). However, it is important to emphasise that the use of digital technologies requires intentional and informed pedagogical design. Digital tools and playful activities do not, in fact, automatically guarantee the development of critical and meaningful learning. Their educational value depends on the quality of the proposed activities, the teacher's pedagogical

guidance, and the ability to link the digital experience to moments of reflection on dietary behaviours and choices in everyday life.

A particularly significant aspect concerns students with ADHD. Quantitative and qualitative data suggest that the digital and playful approach has fostered greater attention, participation and motivation compared to traditional teaching. Dynamic activities, immediate feedback, the breakdown of tasks into operational stages and the opportunity to learn through action appear to have facilitated engagement and reduced attention difficulties. From this perspective, the intervention highlights the inclusive potential of learning environments that value the diversity of cognitive processes and promote active participation, confirming the importance of flexible and multimodal teaching approaches in the construction of inclusive educational contexts (Florian, 2019). The results relating to students with ADHD must, however, be interpreted in an exploratory manner, given the very small size of the subgroup. They suggest a possible direction for further research and confirm the potential of digital and playful methodologies in inclusive contexts, but do not allow for generalisations to larger populations.

Overall, the study highlights that the integration of food literacy, digital technologies and playful learning represents a particularly effective educational strategy for addressing the challenges posed by obesogenic environments and the growing influence of digital food marketing. The intervention enabled students not only to acquire knowledge, but also to develop critical thinking, decision-making and communication skills, which are essential for interpreting food-related messages, recognising persuasive strategies and adopting more informed and responsible behaviours. From this perspective, schools emerge as a prime setting for promoting an integrated education that links health, citizenship and sustainability, contributing to the development of individuals capable of acting in an informed and responsible manner within contemporary food systems (Qutteina et al., 2019; Varela et al., 2024).

From this perspective, the results suggest that digital technologies are not merely tools to support teaching, but genuine educational environments through which to promote critical skills, digital citizenship and awareness regarding contemporary food systems. In particular, the integration of game-based learning, media analysis and content production enables students to develop a broader and more reflective understanding of the dynamics characterising the relationship between food, communication and sustainability.

8. Conclusions

The main contribution of the study lies in demonstrating how food education can be reimagined as an interdisciplinary, digital and inclusive educational experience. From this perspective, food literacy emerges as a complex competence that integrates cognitive, practical and reflective dimensions, contributing not only to the promotion of health but also to the development of decision-making autonomy, individual responsibility and informed participation in social life (Perry et al., 2017; Truman et al., 2017).

A further significant aspect concerns the integration of the digital dimension, playful learning and educational inclusion. The use of interactive environments, simulations and collaborative activities has highlighted how it is possible to broaden the ways in which content is accessed and to encourage more active and diverse participation, drawing on different cognitive styles. From this perspective, digital technologies and e- s are not merely ancillary tools, but genuine learning environments capable of supporting processes of engagement, reflection and active knowledge construction, whilst also helping to make educational contexts more inclusive (Florian, 2019).

However, the study has certain limitations that must be taken into account when interpreting the results. The sample, selected from a single school using convenience sampling, limits the possibility of generalising the results to other contexts. Furthermore, the relatively short duration of the intervention does not allow for the stability of the effects to be verified in the medium and long term. The small size of the subgroup of students with ADHD also calls for caution, suggesting the need for further investigation of larger and more diverse populations.

In terms of future implications, it would be appropriate to expand the research to include school contexts differing in socio-cultural and geographical characteristics, in order to verify its transferability. It would also be useful to develop longitudinal studies that include follow-up assessments, so as to analyse the persistence of the skills acquired and their effective translation into stable eating behaviours. A further area for investigation concerns the role of digital technologies in health education programmes, with particular attention to the effectiveness of serious games, collaborative online activities and the production of digital content in supporting intrinsic motivation, autonomy and the development of critical thinking (Ryan & Deci, 2020; Redecker, 2017; Varela et al., 2024).

Overall, the findings help to outline an educational perspective in which food literacy is seen as a space for the integration of health, citizenship and sustainability. In this regard, schools remain a prime setting for promoting

educational programmes capable of preparing adolescents to address the challenges posed by contemporary food systems in a critical and responsible manner, fostering the development of individual and collective awareness focused on well-being and social responsibility.

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