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# Smart Multisensory Environment fostering diverse children well-being


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# DECLARATION

I hereby declare that the thesis entitled "Smart Multisensory Environment fostering diverse children well-being" submitted by me, for the award of the degree of *Doctor of Philosophy* to the University of Modena and Reggio Emilia is a record of bonafide work carried out by me under the supervision of Professor Franca Garzotto, Designation, Electronics and Information, Politecnico di Milano and under supervision of Professor Roberta Mineo, Designation, Department of Education and Human Sciences, University of Modena and Reggio Emilia.

I further declare that the work reported in this thesis has not been submitted and will not be submitted, either in part or in full, for the award of any other degree or diploma in this institute or any other institute or university.

# SUMMARY

This thesis is focused on promoting creativity in Diverse Children (DC) inside an interactive Multisensory Environment (iMSE). The thesis promotes specific properties and evaluation of creative settings for activities to aid in educational strategies for children's diversity (CD), to improve their creativity and social behaviors with peers, and within society in general. The term iMSE refers to digitally augmented spaces designed to stimulate a user's perception, train the integration and identification of various stimuli, and engage the user in interactive activities. Such activities help promote different skills and abilities. Children's diversity denotes a broad spectrum of ways of perceiving learning information and different conditions that affect behavior. Creativity refers to the "interaction between aptitude, process, and the environment by which an individual or group produces a perceptible product that is novel and useful as defined within a social context" (Kaufman et al., 2008). This practice-based research is based upon human-computer interaction theory, Universal Design for Learning, and creative process theories and is aided by general theories of embodied cognition, embodiment, and developmental psychology. The research consists of promoting creativity through the design of playful experiences for the target users by following this theory to promote socialization and, collaboration, and evaluation. The design of the experiences has been informed by codesign activities and collaboration with teachers from Reggio Emilia with experience in inclusive education. Topics for analysis included understanding creative thinking, creative action, and the dynamics of social interaction between children in traditional and Multisensory environments with creative settings or with a creative task. Assessment methods consider video-recorded footage, system data, observation data, parent interviews, and teacher focus groups. The main setting of the research is the Research Laboratory Scintillae and the Multisensory Environment Magic Room. Scintillae is a space dedicated to exploration and research on play and learning in the digital age, open to children and adults of all ages, including teachers, educators, and researchers. Magic Room is a floor-and-wall projected multisensory environment equipped with smart objects, lights, and tangible materials. The Multisensory environment enables the testing of interaction-free exploration

activities and evaluates methods of experiences based on the collocation of multiple users within a creative scenario, where they can practice co-construction in a natural and uninhibited manner.

The thesis provides several innovative contributions. Empirical studies were performed to indicate interaction, material, and instruments that can be effective in promoting creativity and fostering social interaction.

Results show the aspects which are the necessary components of the educational Multisensory Environment aimed at promoting creativity. Results have been used to set guidelines for teachers and developers.

Activities, designed with experts, to support developing creativity in individual fragile children and for mixed groups in inclusive education.

The Multisensory Environment Magic Room can provide children with collaborative creative experience within the school setting.

This thesis aims to contribute a set of guidelines and theoretical foundations which will be useful for designing and developing activities for promoting creativity in children with autism, based on a rigorous qualitative and quantitative analysis of a series of sessions of focus-group with teachers and observation of the child inside of the Multisensory environment.

The first step of this research has included reviewing work done in the field through a systematic compilation of published materials, along with consulting professionals in the field of inclusive education and creative education. The knowledge gained from this review has contributed to a secondary goal, which was to define interaction criteria to foster potential creativity. To accomplish this, we let our experts be co-creators of the new interaction design concepts, by attending our focus group and replaying our survey. The principles for design activity are constructed together with experts in human-computer interaction. The interaction criteria are aimed to foster creative thinking which will allow these individuals to be more flexible.

To summarize a comprehensive understanding of current educational practices in developing and applying free exploration activities, this research aims to respond to the following questions:

How can we improve the child’s free exploration during the creative process with peers through designing activities for a multisensory environment and applying them in an inclusive education?

How can we better understand the aspects of activity inside the multisensory environment which create free exploration, creative thinking, creative expression, and engagement for children within the context of children's diversity?

How can evolutionary methods be effective for activities that foster creative and co-construction for diverse children in a multisensory environment?

To meet the outcomes determined by experts, what criteria can aid designers and teachers in developing free exploration activities inside a multisensory environment for inclusive education?

This summary highlights the key discoveries and insights from our study, emphasizing the implications and significance of our research in academic and practical contexts. While innovative concepts require perceived usefulness for adoption, collaborative efforts often spark a surge in novel information and knowledge.

In this study, a statistically significant negative correlation between social interactions and overall creativity was identified. While preliminary, the data suggests that social interactions can act as a 'limiter' on creativity. Mathematically, such a strong negative relationship implies that an increase in one variable corresponds to a nearly equivalent decrease in the other.

In this investigation, the results demonstrate substantial neutrality between creativity and engagement. Additionally, a moderate negative correlation between the two primary components of creativity was observed. This implies that as creative thinking levels rise, creative action tends to decrease. Higher levels of creative thinking indicate that individuals spend more time generating ideas or solutions, which may reduce the productivity of creative actions.

The findings of the thesis specially explore the influence of group dynamics on individual creativity. The primary focus is on the correlation between creative ideas and the outcomes generated by groups during the experiments.

To achieve the outcomes set by inclusive education experts and facilitate the development of free exploration activities within a multisensory environment, the criteria were defined in the Social Interaction model, Engagement model, and System Adaptation model are as outlined in the Chapter 4.

**Keywords:** *Smart Spaces, Creativity, Social*

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# 1. CHAPTER - Educational Spaces. Environment

## 1.1. Introduction

Modern society requires people to be flexible and to develop innovative solutions to unexpected situations. Creativity refers to the “interaction between aptitude, process, and the environment by which an individual or group produces a perceptible product that is novel and useful as defined within a social context” (Kaufman et al., 2008).

It allows humans to produce novel ideas, generate new solutions, and express themselves uniquely (Abraham, 2016). Only a few scientific studies have examined the influence of the educational environment on the creativity of individuals (Kuckartz & Radiker, 2019). Some gaps exist in the research on creative thinking, such as the fact that collaborative effort frequently results in the enhanced production of new information and knowledge. Therefore, it is critical to evaluate creativity via social and environmental settings.

The current technologies have a wide range of tools for children’s skill development. However, little work has focused on social interaction through creative tasks.

A promising technology in this field is a Multisensory Environment.

This thesis is focused on identifying the correlations between actions and space settings that are correlated to the expression of creativity and other behaviors. The thesis also aims to identify the temporal evolution of those actions and space settings to understand the effect of the Multisensory experience on creativity.

Another issue that human society faces nowadays is a rapid growth in the number of children with Autistic Spectrum Disorder (ASD). There is no way to pinpoint an exact reason for this increase, but it is likely that significant changes in diagnostic criteria and reporting practices, in addition to greater awareness and possibly environmental factors, are responsible. However, the fact remains, that society asks those children to be a part of the community. The responsibility is usually on the kids and their families, and they have to make themselves suitable for modern society. The younger generation today face issues that are radically different from the issues faced by any generations which have come before them. One of the features of modern society is its rapid development. We can only guess what surroundings the children of today will live in, what technologies they will use, and what jobs they will have.

According to an estimate by the World Bank, 65% of future jobs are still unknown. Due to such criteria, special attention is paid to the knowledge that was underestimated in the past. An important ability that can help a young generation to live well is to be flexible and to be able to solve problems. Gardner enables the thinking that problem-solving might well be a component of creativity (Gardner, 1973). According to the study of Vartanian, flexibility is thought to be crucial to the creative process (Vartanian, 2009).

It is a competitive challenge for the younger generation to adapt to the rapidly changing modern society. This challenge is even harder for children with autism.
How ever, the creative area seems to be promising for children with autism (Best et al., 2015).
Since studies have shown that using technological solutions for children with ASD in combination with traditional interventions from human practitioners can promote children's skills, the number of technological solutions is increasing (Pennisi et al., 2016; Diehl et al., 2012; Simut et al., 2016; Dautenhahn, 2007; Pop et al., 2014). Not only to reduce the human workload but also, technology can produce simple and predictable behaviors. Therefore, children with ASD are less overwhelmed by social cues and more engaged in the play scenarios to learn new skills (Diehl et al., 2012; Ricks & Colton, 2010; Scassellati et al., 2012). The current technologies have a big range of tools for children's skill development. However, little work has focused on social interaction through the creative task in children with autism.

The State-of-Art is divided into 2 Chapters based on the semantic content. Research starts with defining the learning environment and its role in the educational process. Then it describes the importance of a technological learning environment for the modern child. Next, the learning environment is considered in the context of inclusive education, including medically fragile children. After this the author identifies the most demanded skill for the contemporary and for the medically fragile child and the relevance of the research in this field. Finally, the author identified a gap in the literature review. The State-of-Art outcome determined the requirements for the design of the experimental part.

In Figure 2.1 and Figure 2.2 the structure of the State-of-Art is presented.

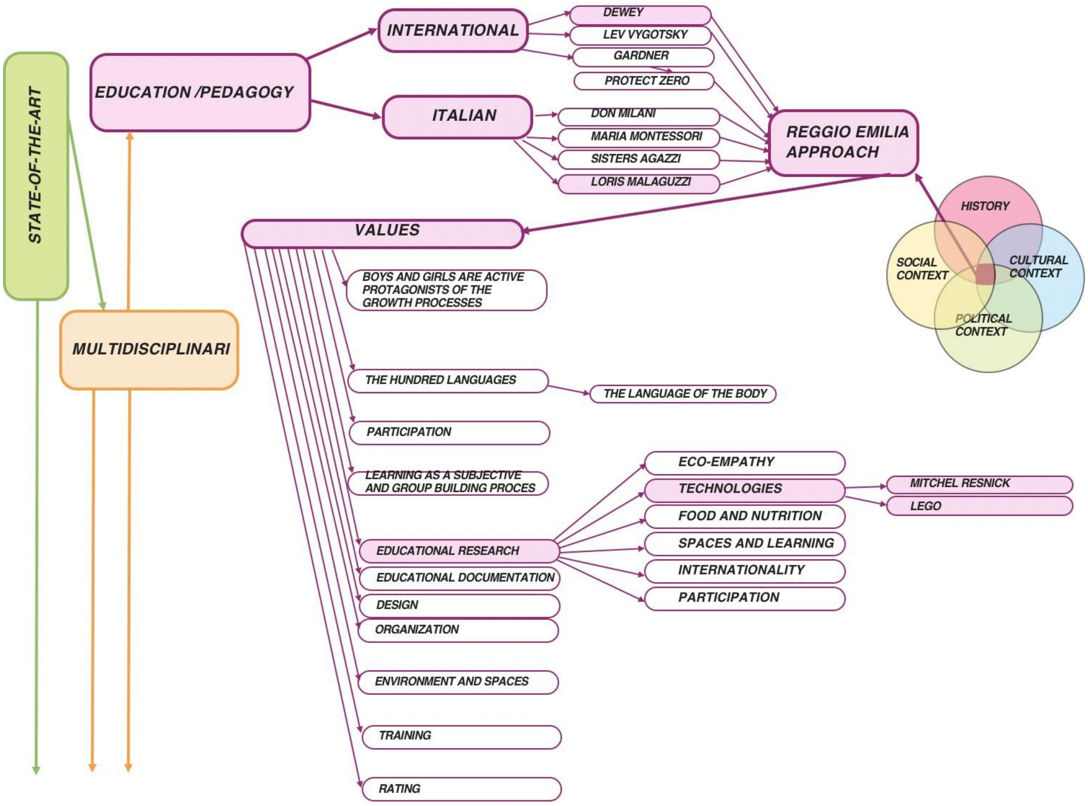



**Fig. 2.1** State-of-Arte in the education field.

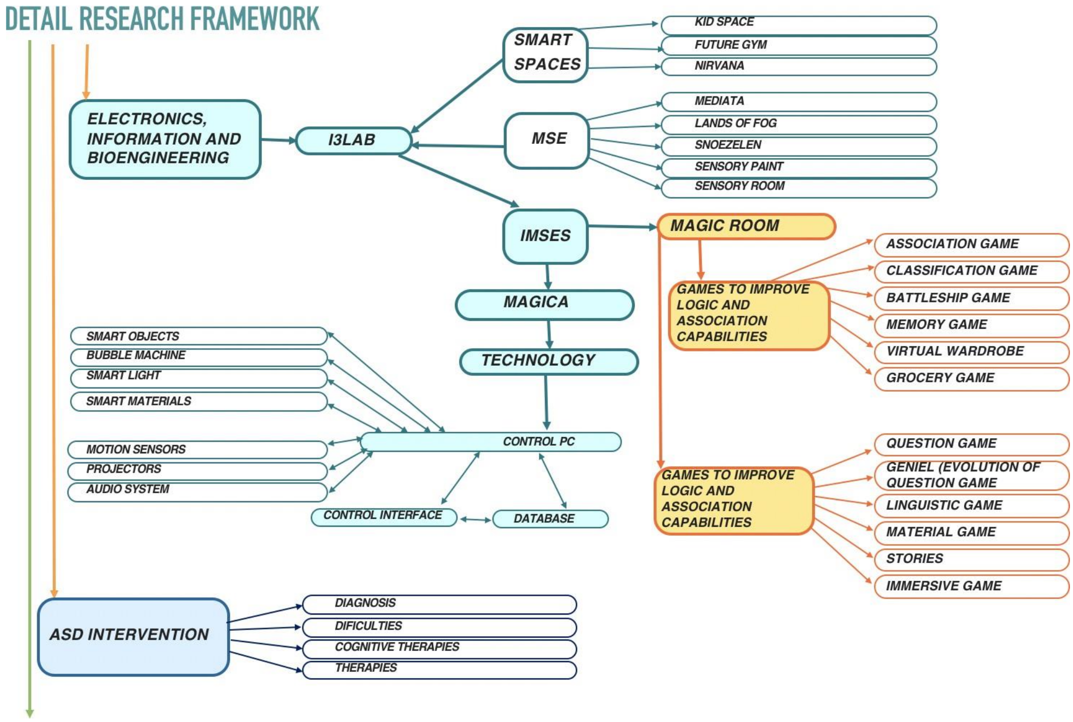



**Fig. 2.2** State-of-Arte in the Smart Spaces.

The central tenet of this section is contained in this sentence by Dewey: “We never educate directly, but indirectly using the environment. Whether we permit chance environments to do the work, or whether we design environments for the purpose makes a great difference” (Dewey, 1916, p. 24).

The scientific community notes that John Dewey’s laboratory school inspired Reggio Emilia’s conception of the atelier (Lindsay, n.d.); (Lindsay, 2015); (Dodd-Nufrio, 2011). Most of the existing articles show Dewey’s philosophical reflection in Reggio Emilia’s education, but none of these focus on educational spaces. In our essay, we consider the core relation between Dewey’s and Reggio Emilia’s educational spaces, their interdependencies, and critical issues. Our focus on the topic of the organization of educational school spaces starts from the revolutionary proposals of activism and the new school (Marcarini, n.d., vol. 10). It was precisely the appearance in 1899 of Dewey’s publication, “The School and Society”, translated into Italian in 1915, that began to question the convictions of the time on the validity of traditional teaching methods and school organization. No other work has aroused so wide an echo of both consensus and dissent or had so many repercussions on practices within the school environment (Dewey, 1954). The effects of this are still relevant today and in Italy: this takes shape in the guidelines on learning spaces and promotes the idea of “space” as fundamental element of innovation together with new technologies for teaching .

However, the guidelines for the construction of new schools stopped in the 1970s. Subsequently, the attention to the topic by Italian researchers and scholars waned.

However, until then, the focus had concentrated on reorganizing the space of the “single classroom”. All Italian literature in the sector, which had supported the principles of activism since the 1920s, had dedicated books and conferences to it; but “when change beckons the signals sooner or later arrive”. Attention to furnishings, shapes, colors, and the variety of environments not only creates a welcoming environment but also implicitly defines roles and activities. They appear as an articulation of laboratories, of ateliers with architectural choices that emphasize their functions (Tosi et al., 2019).

It seems, therefore, that the “Reggio Approach” contains, but at the same time goes beyond, the demands of a pedagogical tradition that has produced reflections on the theme of the organization of educational spaces.

Before dealing specifically with the organization of school spaces and making a parallel between the work Dewey carried out in the Chicago Experimental Elementary School, and that of the infant-toddler centers and schools of Reggio Emilia, it will be necessary to clarify which of these are the assumptions and principles from which the organizational choices relating to spaces are derived and which have given them a foundation. This observational essay will describe the features of the influence of Dewey’s philosophy on the schools of Reggio Emilia. However, to understand how this perspective was an inspiration for the “Reggio Approach”, we will start from an analysis of the role of the “environment” in educational processes according to Dewey’s theories. Our study focuses on the following questions: What are the preferable forms (physical and philosophical) for educational spaces in Reggio Emilia’s and Dewey’s vision? Is the environment only one part of the educational process or is it like a neural network going through the whole body of education? What is the semantic meaning of the word “environment”? How is it formed?

These questions began to interest us from the very beginning of our research. In the Reggio Emilia Approach, there is no ready-made framework that can be applied or copied. There is only a personal interpretation which is based on an understanding of historical influence and reflections. As Aden and Theodotou wrote, “Reggio Emilia is an inspirational early year’s approach” which “is not an educational model in the formal sense, with defined methods, teacher certification standards, and accreditation processes” (2019, p.158). Rather, it “embraces a progressive vision of education in seeking new kinds of schools for young children” (Aden & Theodotou, 2019, p. 158; Edwards & Gandini, 2018, p. 365). Consequently, for the logical construction of this research, we decided to study the historical heritage and development that shaped the richness of the special educational environment in Reggio Emilia.

## 1.2. The Environment

We assume that for different individuals, the term "environment" consists of human factors. It is related to numerous assumptions and ideals which are now no longer regularly expressed but can still be strictly adhered to. For instance, Barrow (2005) states that the term "environment" has extensive uses and has a wide range of definitions, meanings, and interpretations. In a popular implementation, the term "environment" simply means "nature". Literally, "environment" simply means 'surroundings'. The environment of an individual, subject, component, or system includes all the possible and varied structures with which it is surrounded. Individuals, objects, features, and systems seldom exist in isolation; instead, they usually interact with the entities around them. Therefore, it makes no sense to conceptualize "environment" without including the concept of relationships in this conceptualization (Barrow, 2005; Park, 2001; Spoolman & Miller, 2012). Barrow in his definition of the term environment, noted that: "Individuals, objects, elements, and systems influence - and are in turn influenced by their surroundings. Indeed, the networks of relationships that exist between different entities may, in some cases, be extensive and highly complex. Thus, the environment may be regarded as a 'space' or a 'field' in which networks of relationships, interconnections, and interactions between entities occur".

The term environment most often goes with a clarification of context and historical influences. We decided to turn to the historically rich heritage of Reggio Emilia to understand the peculiarities of the formation of a new approach to education and a unique learning environment. Our attention focuses on relations and reflections.

As Wharton (1902) writes, "There are two ways of spreading light: to be the candle or the mirror that reflects it" (Wharton, 1902). As argued by Dewey (1916) "the words 'environment' and 'medium' denote something more than surroundings which encompass an individual. They denote the specific continuity of the surroundings with his own active tendencies. [...] In brief, the environment consists of those conditions that promote or hinder, stimulate, or inhibit, the characteristic activities of a living being" (Dewey, 1916, p. 13).

## 1.3. What type of educational environment exists?

This part introduces traditional and experimental learning spaces which have great influence in world education practice. To give an overview, at the beginning it is important to mention the practice in Dewey's laboratory school. The activities carried out in the workshops were reproductions of what was typical of the social structure (the industrial one) that was emerging. The students were invited not to be mere performers of activities or mere "technicians", but to reflect on the meaning of their work and to acquire a scientific habit. In this way the school enabled students to focus on the process that led to the realization of their work, rather than on the product or the economic goal. This was the knowledge, not in merely “doing”, but in reflection on “doing the process.” The concept of the educational environment was further developed in the work of Montessori, Piaget and Vigotsky, and the final example is in the Schools of Reggio Emilia. The Reggio Emilia school is a collaborative environment based on participation, community management, collegiality, conviviality, and shared values and objectives (Ceppi & Zinni, 2011). The Reggio Emilia environment is a place for multiple dimensions, a hybrid environment in which space is shaped by the relationship created within it.

## 1.4. What limitations does the educational environment have?

The school limits children’s experiences and works mainly on theoretical material, idealized and often not responding to real life. In the (ideal) school, the child’s life becomes the goal that overrides all others. All the means necessary to promote the development of the child meet here. Must learn? Certainly! But first the child must live and learn through, and concerning, this life (Dewey, 1954, pp. 25–26). Nowadays, practical action and everyday experience replaced abstract reasoning and objective meaning.  At the same time, we increasingly see computers incorporated into devices other than the traditional PC. These two trends suggest that we need new ways of approaching the educational environment which are better tuned to child needs and abilities.

In most educational practices, the teacher is the leader in the process, and the personality of the child goes by the wayside. Nevertheless, it is necessary to consider that the child is a central figure in education. Inside the child is a little teacher. Only expression is one of range; he has the power to make his language yet.

Traditional educational practices consume a lot of materials such as paper and plastic (paints, notebooks, books, panels) that are not environmentally friendly. Contemporary thinking advocates the reduction in use of consumables or otherwise tends to regard them as being unnecessary costs.

Society is an interconnection between people placed in the same framework in or- der to reach personal or group goals. However, traditional educational spaces are focused on individual education and not group cooperation in academic settings, contrary to the nature of society.

## 1.5.The role of the environment in educational processes

This section aims to analyze the role of the environment in educational processes starting from the theories of John Dewey, by attempting to find a relationship between John Dewey's theories and the Reggio Emilia Approach. Most of the existing articles show Dewey's philosophical reflection in the Reggio Emilia approach to education, but none focuses specifically on educational spaces. This part of the thesis adopts a similar approach in attempting to analyze and explore the assumptions and principles that shape the choices associated with spaces. It compares the work carried out by Dewey in the University of Chicago Laboratory Schools and those of Reggio Emilia through a comparative analysis. Finally, it examines the impact of Dewey's educational philosophy on the Schools of Reggio Emilia and identifies similarities and differences between the two in our outcome. In observation of both approaches, two types of relationships were founded. The first one is a full-scale relationship in which a detailed study and practical application of the same topic can observe, with the assignment of similar values by both Schools. The second type is the germ of the idea. In this case, we see the birth of an idea in the works of Dewey, but the Laboratory School was not technologically ready for its full disclosure. Therefore, this idea finds its logical evolution in the Atelier of Reggio Emilia. The technological development of the laboratory, based on traditional educational practices, is one of the driving forces in this thesis work.

In order to understand what role, the environment plays within the educational processes in Dewey's discussions, we need to refer to his "revolutionary" philosophical approach that he put in close connection with the "new" psychology (Heidegger, 2007, p. 75). Why Revolutionary? Because Dewey's educational philosophy is as important to education as the revolutionary discoveries of Copernicus to physics and Darwin to biology. These discoveries made it necessary to rethink and reformulate the relationship that exists between the organism and its environment, both in strictly biological terms and in social and cultural terms. Dewey, therefore, tried to bring the revolution that had begun in the biological and physical sciences into the context of what we would now call the "human sciences". In the more strictly educational context, an area that is of interest for the purposes of this essay. Dewey (1954) applied these revolutionary theories in trying to shift the "center of gravity" of the traditional school that was. He wrote: "Outside the child, it is in the teacher, in the school text, in what you want, and where you want, except in the instincts and in the immediate activity of the boy himself [...]. Now, in our education, the shift of the center of gravity is taking place. It is a change, a revolution, no different from that caused by Copernicus, when he shifted the center of astronomy from the earth to the sun. In our case, the child becomes the sun around which the tools of education

revolve. It is the center around which they are organized" (Dewey, 1954, p. 24).
In the writer's opinion, this revolutionary vision that puts the "child at the center" is the same as the one we find in the Reggio Approach. In this thesis, therefore, author will assume a perspective that places the Reggio Approach in the wake of that pedagogical revolution and social change hoped for by Dewey.
The new vision led to the overcoming of the traditional dualism between man and environment, internal and external, freedom and control, subject and object, and theory and practice. This vision, in fact, according to Dewey, allowed experience to be placed in relation to each term in a rich dynamic of continuity and no longer of antithesis.

In this way, the experience was configured as a "transaction" between a world of things that condition man and the man himself who works on things conditioning them (Dewey's humanistic naturalism). The environment, therefore, was no longer an abstract entity that existed outside the subject that inhabited it, but was one with it; a philosophy then, which also contained within itself a pedagogy that became the instrument (Deweyan instrumentalism) necessary to know and understand the reality in which we are immersed and which we modify by experimenting.
The Deweyan philosophy is pragmatic, not metaphysical; and is a tool that serves to intervene in social reality (Papi, n.d.). The man is immersed in the reality in which he lives. We deduce that the universe is no longer an idealized and rationalized transcendent entity with respect to which man has no responsibility. In this perspective there is no man, the individual, and society in the abstract, but only the historical man who realizes himself in a determined society composed of certain individuals; therefore, there cannot exist a philosophy and a pedagogy with univocal and immutable solution (Heidegger, 2007). Once again, we find a strong connection with the Reggio Approach, when Carla Rinaldi discusses the theme of educational spaces: "there is no ideal space, pedagogy, child or man, but a child or man in relation to their history, time and culture" (Ed Ed, 1998, p. 115).
Szpunar et al. (2004), make this relationship explicit by linking the theory of biography to the theme of the man-environment relationship that runs through Dewey's entire work. She says that the importance of the biography of the individual is a direct consequence of Dewey's rethinking of the figure of the subject, following which the abstract, being of the metaphysical tradition, gives way to the concrete individual in flesh and blood.
Again Dewey (1954) wrote that the world outside its relationship with human activity is not a world. He said: "Only by virtue of the occupations determined by this surrounding environment has humanity progressed in history and politics. It was these occupations that promoted the intellectual and sentimental interpretation of nature. Through what we do in the world and with the world, we have learned to realize its

meaning and to measure its value" (Dewey, 1954, p. 12).

It follows that educational action was a moral and political action that gave importance to the question of responsibility. In the Reggio Approach, this element is fundamental. "Education is political", in the broadest sense of the term because it supports and is supported by the construction of social bonds as well as it draws nourishment from the community and at the same time nourishes and renews it. Within this conceptual framework, we can understand what role the school should have played for Dewey. The school had to be a "privileged environment" in which the student had the opportunity to understand and investigate their relationship with the world. At school, therefore, the problem of the man-environment relationship became the problem of knowledge. The ideal school for Dewey was a place where the child advanced in knowledge of the world around them; where they were organized, (not casually, as could happen at home), and disciplined in their relationship with the world; "a world more varied than that with which individual personal experiences could put him in contact since the school was the place where to experience a freer and richer social life that is possible" (Dewey, 1954, p. 25). The school, therefore, is a "regulator" of the man-environment relationship.

Dewey denounced the fact that the opposite usually happened at school. He argued that the school limits children's experiences and works mainly on theoretical material, idealized and often not responding to real life. In the (ideal) school, the life of the child becomes the goal that overrides all others. All the means necessary to promote the development of the child meet here. Must learn? Certainly! But first, the child must live, and learn through, and in relation to, this life (Dewey, 1954, pp. 25–26). For this reason, in Dewey's laboratory school, the activities carried out in the workshops were reproductions of what was typical of the social structure (the industrial one) that was emerging, but the students were invited, not to be mere performers of activities or mere "technicians", but to reflect on the meaning of their work and to acquire a scientific habit. Hence, the school must enable students to focus on the process that led to the realization of their work, rather than on the product or the economic goal. This was the knowledge, not in merely "doing", but in reflection on "doing the process".

## 1.6. Educational Environment

The child is endowed with unknown power, and this strange power guides him. Therefore, education can no longer be the giving of knowledge only; it must take a different path. The consideration of personality and the development of human potentialities must become the center of education. Observation, general and widespread, has shown that small children are endowed with unique psychic nature.

This leads us to a new way of imparting education. This section aims to analyze the role of the environment in educational processes starting from the theories of John Dewey, by attempting to find a relationship between John Dewey's theories and the Reggio Emilia Approach. Most existing articles show Dewey's philosophical reflection in the Reggio Emilia approach to education, but none focuses specifically on educational spaces. This part of the thesis adopts a similar approach to analyze and explore the assumptions and principles that shape the choices associated with spaces. It compares the work carried out by Dewey in the University of Chicago Laboratory Schools and those of Reggio Emilia through a comparative analysis. Finally, it examines the impact of Dewey's educational philosophy on the Schools of Reggio Emilia and identifies similarities and differences between the two in our outcome. In observation of both approaches, two types of relationships were found. The first one is a full-scale relationship in which a detailed study and practical application of the same topic can be observed, with the assignment of similar values by both Schools. The second type is the germ of the idea. In this case, we see the birth of an idea in the works of Dewey, but the Laboratory School was not technologically ready for its full disclosure. Therefore, this idea finds its logical evolution in the Atelier of Reggio Emilia. The technological development of the laboratory, based on traditional educational practices, is one of the driving forces in this thesis work.

## 1.7. The School and the organization of space

A lot of Dewey's ideas about educational environments are paralleled with the key praxis in Reggio Emilia. We analyze the relationship between the idea of environment proposed by Dewey in the primary schools of Chicago and the suggestions proposed by the organization of spaces in the Kindergartens and Schools of Reggio Emilia.
According to Dewey (1916) "the only way in which adults consciously control the kind of education which the immature get is by controlling the environment in which they act, and hence think and feel. We never educate directly, but indirectly by means of the environment" (Dewey, 1916, p. 22).
The main framework of John Dewey's conception of an educational environment in practice is very much dependent upon the political place of the country at the time since this influences the educational policy and its aims. In Dewey's theory, learning is socially constructed and based on experiences. He also holds that learners become collaborators with other learners and teachers to create their own understanding by solving problems they face in different situations. Therefore, educational processes should be organized in real-life experiences that give a context for the information. It is an experimental approach to pedagogy in the results-driven environment with the teacher presented as a co-collaborator. Based on this theory two questions come up:

What is the role of the teacher? What is a teacher's responsibility in terms of the achievement and progress of the learner? The teacher's role is to organize the search for meaning and facilitate the real-life experience, where the experiences are based on the capabilities and preparation of the learners (Hanna, 2016).

In Dewey's schools, study and learning start from experiences. The experience takes place during the workshops, where the child must solve concrete problems and pursue production objectives. In the workshop, the teacher changes his role. He is no longer a decant of knowledge, but he activates experiences through the organization and preparation of the environment, and the classroom. Dewey's schools also integrate intellectual activity with concrete manual activity, thereby promoting "learning by doing" (Marcarini, n.d.). However, the traditional school creates immobility by thinking of developing intellectual mobility independent of the action.

The Reggio Emilia environment is a place for multiple dimensions, a hybrid environment in which space is given shape by the relationship created within it. It is a multisensory place, not so much in the sense of being simply rich in stimuli but having different sensory values so that each individual can tune in to his or her own personal reception characteristics. In other words, standard univocal solutions cannot be conceived for everyone. The Reggio Emilia school is a collective environment, based on participation and community management, collegiality, conviviality, and shared values and objectives (Ceppi Zinni, 2011). Giudici et al. (2001, 2005), explains the pedagogy and architectural impact of designing schools: "Designing the space of a creche or a preschool - or perhaps we could just say designing a school - is a highly creative event not only in terms of pedagogy and architecture but more generally in social, cultural and political terms [...] And thus, designing a school means, first and foremost, creating a space of life and the future. This requires the shared research of pedagogy, architecture, sociology, and anthropology; disciplines, and fields of knowledge that are called upon to state their own epistemologies and to compare their languages and symbolic systems, in a new freedom born of the desire to dialogue and exchange ideas (Giudici et al., 2001).

From the above material, we can conclude that for Malaguzzi and Dewey, the foundation for educational spaces is something Ceppi and Zinni (2011) defined as Relational Spaces. "A relational space is an environmental fabric rich in information, without for- mal rules. It is not the representation of School, but a whole made up of many different identities, with a recognizable feel about it, in harmony with a set of values and references that guide each choice line of research" (Ceppi Zinni, 2011).

Now let's turn to another relationship that we can observe: the sense of community in the Reggio Emilia schools. Community is a form and a quality of the space that fosters encounters, exchange, empathy, and reciprocity (Ceppi Zinni, 2011b). This sense of community generates the spatial characteristics of the school, such as the centrality of the Piazza, the non-hierarchy of spaces (workspaces for adults, kitchen, unisex bathrooms, and the horizontality of the overall distributive layout. Dewey (1907a) focuses on the needs of children for community life: “as ways in which these needs have been met by the growing insight and ingenuity of man, as instrumentalities through which the school itself shall be made a genuine form of active community life, instead of a place set apart in which to learn lessons” (John Dewey, 1907a, p. 27) . In Dewey’s understanding, the Experimental School is where there is an element of common and productive activity. He argues that “there is something to do, some activity to be carried on, requiring natural divisions of labor, selection of leaders and followers, mutual cooperation and emulation” (John Dewey, 1907a, p. 28). Based on the provided material, we can conclude that the common component for Reggio Emilia’s and Dewey’s educational spaces is a community. Also, that it is “a spirit of free communication, of interchange of ideas, suggestions, and results, where both successes and failures of previous experiences, become the dominating note of the recitation” (Dewey, 1907a, p. 14). On the other hand, Ceppi and Zinni (2011a) describe the idea of the school in the following words: “The idea has been to do a school, and only rarely to give a school; that is, a place that has real meaning for a community and society” (Ceppi & Zinni, 2011, p. 115). Both theories focus on the child’s needs for free self-expression, and for flexible spaces that can be transformed together by their imagination. There is a need to design spaces alternatively, softer, less rigid, and more open to the indeterminateness of experience. Space, that is constructed, not by selecting and simplifying the elements, but through a fusion of distinct policies (inside and outside, formal, and flexible, mate rial and immaterial), which creates a rich and complex environment. As Dewey (1900) describes it, “The growth of imagination in flexibility, in scope, and in sympathy, till the life which the individual lives is informed with the life of nature and of society” (Dewey, 1900, p. 43). Additionally, we can discover that the overall softness of spaces is another key link for both theories. Specifically, Dewey’s multimodal teaching process, as presented in the Laboratory School, and the Reggio Emilia multimodal approach as presented in the Atelier are similar. According to Dewey’s Multiple Intelligence Theory, the core of the teaching process is the arrangement of environments within which the students can interact and study how to learn (Edwards & Gandini, 2018). Dewey (1907) describes the laboratory as “the place where the children bring the experiences, the problems, the questions, the particular facts which they have found, and discuss them so that new light may be thrown upon them, particularly new light from the experience of others, and the accumulated wisdom of the world symbolized in the library” (John Dewey, 1907b, p. 53).

## 1.8. The city of Reggio Emilia and its role in creating educational environment

Reggio Emilia is a city in Northern Italy, in the Emilia Romagna region, with a population of approximately 150,000. The historical traditions of the city are about social cohesion and the formation of the significance of the rights of individuals based on democratic values. In 1940, Loris Malaguzzi began teaching in elementary schools in the province of Reggio Emilia and in April 1945, he became a participant in an ambitious project involving people of a peasant and working origin. The goal of the project was to build a self-governing school in a small village near Reggio Emilia. This initiative had spurred the development of other schools in the suburbs and the poorest areas of the city, all self-governing (Holland, 2016). In 1963 the Municipality of Reggio Emilia began organizing a network of educational services which included the opening of the first kindergartens for children aged 3 to 6. This infant-toddler and pre-primary delivery system was grounded on the idea that all children, including very young children, have the right to an education and that residents should be directly responsible for the education of these children (Baucyh & Boszilkov, n.d.). As Cagliari and colleagues write, "Loris Malaguzzi was one of the most important figures in twentieth-century education. Devoting much of his life to early childhood education and the municipal schools for young children in the Northern Italian city of Reggio Emilia, he has gained an international reputation in this sector" (Cagliari et al., 2016, p. 12).

The female teachers in the municipal preschool and the municipal infant-toddler center in Reggio Emilia thought of themselves as agents of social change, and that this was connected to their memories of the Italian Resistance. The legacy of the Resistance, still alive in the women teachers in Reggio Emilia, can be more completely understood considering the historical meaning of that Resistance, and its importance in Italian history (Balfour, 2016). After the Second World War, organized women's movements proliferated in Italy, led mostly by former members of the Resistance. In Reggio Emilia, one of these movements, called the Italian Women's Union (UDI), campaigned for early childhood education. Women have contributed to the physical structure of schools and classrooms with a liability to early care and education, providing the cultural and social foundation integral to Reggio's educational philosophy. With the significant contribution and mobilization of the UDI, the local municipal government opened the first post-war municipal preschool in 1963. Soon after, these schools came under the leadership of Loris Malaguzzi and he became the first Director of the Reggio Emilia schools (Balfour, 2018).

Thus, women have contributed to the physical structure of schools and classrooms with a commitment to early education. They provided the cultural, social, and political foundation as an integral part of Reggio's educational philosophy (C. Edwards et al., 2011; Senent et al., 2021). Education, in fact, is the right of every child, an opportunity for the growth and development of the individual and the collective, and it is a social responsibility of the community (di Reggio Emilia, 2010; Senent et al., 2021).

Values and meanings of Reggio Emilia's educational practices inspired and influenced early childhood education out of Italy. The Reggio Emilia's approach gained an international success and effectively motivated scholars (Gardner & Jones, 2017). In the 1980s, Gardner began his relationship with preschools and with the city of Reggio Emilia. He promoted the research between Project Zero and Reggio Children on schools in Reggio Emilia. The results are described in the book "Making Learning Visible: Children as Individual and Group Learners" (Goebl-Parker, 2002). Elliott, in 2005 conducted a national study, where the early childhood education was reorganized and reconceptualized through the Reggio Emilia Approach. Gardner et al. (Gardner Jones, 2017), in their study explained the connection between the Reggio Approach and the MUSIC model with the key motivation principles. In the study of Wolfe et al. (2021) educators examined their experience with the documentation process, which was inspired by Reggio Emilia's approach. Dalgleish in his study (2018) investigated the role of the environment to cognitive development, and he described the influence of the Reggio Emilia approach to it.
How does this beautiful city in the North of Italy get international success? And how come its pedagogical practices are famous all over the world? A look at the theories behind the Reggio Emilia Approach can help in understanding its international success. The Reggio Emilia multimodal approach to learning bases its philosophy on the following theorists: Vygotsky, Bruner, and Dewey (Cagliari et al., 2016).

## 1.9.Conclusion

This part has analyzed the relationship between the Reggio Emilia Approach and Dewey's theories with a particular focus on educational spaces. The Reggio Emilia Approach and Dewey's theories were both discussed and linked with the educational environment. It also discussed how the same topics are represented and interpreted in both educational practices. In both, the child is the central figure, and the learning environment serves them and helps them to express their "100 languages". Dewey calls his educational spaces the Educational Space Laboratory. In Reggio Emilia, the same educational space is called the Atelier. The educational environment for both is like a neural network that goes through the whole body of education. The modern experiences of Reggio Children are a reference point for early childhood education even if, unfortunately, 'Reggio inspired' early education facilities are more common abroad than in Italy, probably due to the lack of consideration that the practical dimension has in the Italian cultural panorama and in our philosophical thinking, especially when applied to education. For the same reason, Dewey finds it hard to be recognized as a philosopher.

However, today, after at least twenty years in which Dewey's ideal presence seemed to be placed in the background of the pedagogical debate, (recognized, consolidated, but less operative than in the past) we are witnessing a rediscovery of the American thinker by pedagogists and also by philosophers attentive to the developments of the "first" pragmatism, of the Deweyan instrumentalism and of the neo-pragmatism of Rorty and Putnam.

# 2. CHAPTER - Creativity the skill of the 21 century

Empirical studies examining the creative abilities of children and adults have yielded inconclusive and inconsistent results regarding gender differences. Approximately half of the studies found no significant distinctions between males and females, while the other half presented mixed findings. On average, however, the studies suggested that females exhibited slightly higher levels of creative abilities (Abraham, 2016; Nakano et al., 2021). Gender differences in creativity are not primarily determined by biological factors, but rather by the influence of cultural and environmental aspects that shape the behaviors of individuals within each gender. It is important to consider that the impact of gender on creativity may vary depending on the specific type of creativity being evaluated, such as verbal, visual, or spatial abilities. Various theories have explored the study of gender differences in creativity, taking into account socio-cultural, environmental, and neuroscientific factors as significant factors in understanding these distinctions (Nakano et al., 2021). There is a scarcity of scientific research exploring the impact of group dynamics on individual creativity. Moreover, existing studies on creativity have primarily focused on individual cognitive processes, individual differences, and the influence of the external environment on individual creative output. In contrast, the examination of creative ideas generated collectively by groups, rather than solely from individual minds, has received relatively less attention and consideration in the existing body of research (Kurtzberg & Amabile, 2001).

Thus, the purpose of this study was to examine creativity within the context of group settings.

## 2.1. Aims of the Research

This research aims to contribute, based on relevant analysis, the promotion of creativity in projects for inclusive education in Multisensory Environments and to create a set of frameworks for developers and teachers. Primarily the thesis promotes specific properties and the evaluation of creative settings for activities to aid in education strategies for children's diversity (CD), to improve their creativity and social behaviors with peers and with society in general.

As children with ASD show difficulties in free exploration, we see that a Multisensory Environment presents an opportunity for children to practice free expression while engaging in a playful, creative experience with peers. Compared to the traditional creative experience, interactive environments can adapt and respond to changes in user behavior, adding consistency and challenges to keep the users motivated and reduce anxiety in a predictable environment. Although notable research has been done on the manifestations of creativity in different areas, there has yet to emerge a clear under- standing of children with ASD. As children with ASD typically demonstrate repetitive behavior, research into this field could provide an enjoyable insight into building new activities for these individuals. For our study searches in these fields, we used a recognized abstract and citation database 'Elsevier's Scopus'.

Other areas of research which will be discussed include activity structure, elements of encouraging co-construction and open-ended play. Encouraging co-construction is the practice of giving the option to collaborate, with added incentives, as opposed to playing alone. In real life a child with ASD is a part of society and needs to construct relationships with other people.

This interventional approach intends to encourage users' own volition while retaining the comfort of solitary creation, as opposed to enforced co-construction, where children cannot participate in the creative process without collaboration. For a deeper analysis of this issue, we conducted a focus group with experts in inclusive education. The evolution included qualitative methods, such as audio analysis. The goal was to form a protocol that could be used to determine perspectives about promoting creativity in children with ASD, in a Multisensory environment in Magic Room.

The study explores frameworks for designing interactive activities within the Magic Room, aiming to comprehend the diverse criteria that users adopt when engaging in goal-less play. In the absence of a specific objective, players have the freedom to shape their own narratives based on their creative instincts. However, this research lacks a quantitative evaluation to ascertain the instances when children with autism demonstrate higher levels of meaningful engagement. Considering that many interactive experiences for children with autism spectrum disorder (ASD) typically focus on fostering socialization, understanding the connection between open-ended activities and socialization levels could provide valuable insights for inclusive education teachers involved in autism intervention. The studies conducted not only aimed to enhance children's creativity but also sought to gain a deeper understanding of how and when they bring about changes in their experience while participating in an activity. This evolutionary process involved qualitative methods like video analysis. Ultimately, the objective is to establish guidelines that can be employed to determine the effectiveness of ASD interventions where users partake in open creative activities.

Finally, this research will aim to propose future activities in Multisensory Environments where children with autism practice creative construction and co-construction.

## 2.2. Research objectives

To conduct this research, an understanding of the current state of inclusive education in the educational environment was first developed. Specific focus was placed on tools that utilize multisensory environments for educational skills interventions in children with autism.

A research plan was formulated to better understand the impact of a multisensory environment on promoting creativity in children with autism. The plan includes the design, conduct, and analysis of focus groups. Criteria for creative activities within the multisensory environment will be extracted, and guidelines for developers and teachers will be developed based on the collected data.

I joined the Magic Room project, which consists of 19 types of activities and more than 100 tasks, all geared towards achieving specific goals. In the initial phase of the research, I explored perspectives on promoting creativity in children with autism spectrum disorder (ASD) within the Magic Room's multisensory environment. I proposed a focus group consisting of several sessions (Chapter 3). Using data from the focus group, I will identify criteria for guidelines on special activity requirements within the multisensory environment. The guidelines will be designed with variations in interaction design and open-ended scenarios. They aim to facilitate the creation of activities that encourage free exploration for children with autism, promoting the discovery of new things usable outside the Magic Room, and enhancing social interaction (collaboration) with neurotypical or other autistic children. Specific interaction design components, such as collaboration mechanics, open-ended play, proxemics, and contextual elements, will be explored (Chapter 5).

I will lead the ideation phase, design sprint sessions, oversee the development process, and conduct interactive prototype testing at Politecnico for this study. The thesis encompasses outcomes related to an empirical study investigating the promotion of creativity in children with autism, as well as the systems' potential for fostering free exploration in these children (Chapter 2). Finally, the author will apply the creative process guidelines to propose activities within the Magic Room.

The purpose of the research was to:

**Chapter 1** Analyze the role of the environment in education. Contribute an understanding of the role of creativity in education. Provide an understanding of the relationship between creativity and social interaction. Explain the different educational approaches applied to inclusive education. Consider the impact of the Scintillae Research Laboratory, within the Reggio Emilia Foundation, concerning the promotion of creativity. What Behaviors do children show while performing the creative task? How did they change their cooperation while they performed creative tasks?

**Chapter 2** Investigate whether a multisensory environment presents an opportunity for children to practice free expression while engaging in a playful creative experience with peers. How does gender influence group dynamics and creativity? In Magic Room What are the creative settings in Multisensory Environment? What happens if I apply creative settings in a Multisensory environment? Does the Multisensory Environment Fostering Creativity?

**Chapter 3** Explore the structural elements which encourage co-construction and open-ended play. Is there a difference in presented creative behaviors and social interaction observed between Scintillae and the Magic Room?

## 2.3. Research questions

To summarize a comprehensive understanding of current educational practices in developing and applying free exploration activities, this research aims to respond to the following questions:

1) How can we enhance a child's free exploration during the creative process with peers by designing activities for a multisensory environment and applying them in inclusive education?
2) How can we better comprehend the aspects of activity inside the multisensory environment that foster free exploration, creative thinking, creative expression, and engagement for children within the context of children's diversity?
3) How can evolutionary methods be effective for activities that promote creativity and co-construction for diverse children in a multisensory environment?
4) To meet the outcomes determined by experts, what criteria can aid designers and teachers in developing free exploration activities within a multisensory environment for inclusive education?

## 2.4. What is Creativity?

The creative process, defined as the series of thoughts and activities that lead to a novel, adaptable output, has been a significant focus of creativity research during the last century. Lubart, in his study, used the four stages model of the creative process and then examined how this model has fared during the past half-century (Lubart, 2001). In the following material, we will see the development history of this idea. But first, what is the 4-step model? The 4-step model is presented in the Guilford study

(Guilford 1950). Guilford concluded that the creative act consists of four steps: (a) preparation, (b) incubation, (c) illumination, (d) verification. But the 4-step approach does not fully illuminate psychological aspects such as sensitivity to problems, the capacity to produce many ideas (fluency), the ability to change one's mental set (flexibility), an ability to reorganize, and the ability to deal with complexity, and an ability to evaluate. Guilford proposes that those abilities are also integral to the creative process. Components of a 4-step model of creative thinking have been identified in the early stages. Wallas argued: "happy ideas come unexpectedly without effort, like an inspiration" (Wallas, 1926, page 80). Based on this kind of precision, he represents a four-sage module of the creative process. The first step is preparation. It is an initial analysis of the problem, defining and setting up the issue. The ability to think creatively is becoming the key to successful and satisfactory adaptation to the physical and social environment (Florida, 2002). A variety of models defines the creative process in traditional educational settings. However, these have little information about the creative process in experimental inclusive education settings.

In today's fast-paced society, individuals are increasingly expected to demonstrate adaptability and generate innovative solutions when confronted with unforeseen circumstances. Creativity refers to the "interaction between aptitude, process, and the environment by which an individual or group produces a perceptible product that is both novel and useful as defined within a social context" (Kaufman et al., 2008). It enables individuals to generate fresh and original ideas, devise innovative solutions, and express their unique perspectives and individuality (Abraham, 2016). The impact of group dynamics on individual creativity has been the subject of limited scientific investigation, with only a handful of studies delving into this relationship (Kurtzberg & Amabile, 2001). The research on creative thinking exhibits certain gaps, one of which pertains to the recognition that collaborative efforts often lead to the amplification of new information and knowledge. Consequently, it becomes crucial to assess creativity within social contexts and settings.

In HCI, using computer-based devices to foster social interaction in an in-presence setup is not new. Several technologies have been used with different results, with specific aims for fragile or typical people, and with different age groups, language, social contexts, and many other factors. We believe that children can exhibit the most natural cooperation with a creative objective if they share the same environment, not mediated by remote connection as seen during the last pandemic. We also believe that children express themselves more freely when using the most natural "controller" they have: their body. For this reason, interactive MultiSensory Environments (iMSEs) are the most suitable solutions. An iMSE is a physical shared space enhanced by invisible computer-controlled devices to immerse the users in playful activities. iMSEs can sense user movements, gestures, voice and generate gentle stimulation of multiple senses. Several examples of this approach have been used in the past years, from more artistic installations to therapeutic ones. Lind's Lines Lind (2020) and TeamLab's artistic installations Haslem (2020) represent examples of how to use iMSES to stimulate creativity in children in artistic setup. In the first case, users can compose music by selecting notes and tones by interacting with the room's walls. In the latter, the presence of the users can modify digitally generated graphics and even impact a second installations content, making the user the artists themselves.

A similar theme has been analyzed in Genplay Crowell et al. (2018) and in Sensory Paint Ringland et al. (2014b). Genplay used a similar generative art approach. Two children, one autistic and one neurotypical, were able to interfere with particles' flows to create artistic combinations of color streams. Children were observed playing freely in the environments without specific objectives or descriptions of the available interactions. Children then creatively tried to decipher the game rules and create the stream flow they liked most. In SensoryPaint, one or two children (one autistic and, optionally, one neurotypical) paint on a digital canvas by touching the projected surface or using smart objects like brushes. Despite the use of art simulation, its major aim was to stimulate the capability of children to communicate and socialize. There were interesting hints of the artistic development of users. However, not having further explored the artistic development of children, there is a need to explore further the use of iMSEs on children's creativity and artistic development.

## 2.5. Why is Creativity forgotten?

By using the term "creativity" the author means 'everyday creativity'. This is one of the most powerful capacities we have, bringing us alive in each moment, affecting our health and well-being, offering richness and alternatives in what we do, and helping us move further in our creative and personal development. Many people don't associate the term "creativity" with "everyday creativity." They believe that creativity is related to the arts, sciences, or at the very least, unique fields of study. It might also be about unique individuals, such as well-known scientists, authors, or painters. In this sense, creativity does not concern large groups of people. In this context the term is less interesting and is not our focus. Everyday creativity is about everything we do, throughout our lives and is fundamental to our survival. It's not only about what we do, but also how we do it. Through our daily creativity, we exhibit flexibility, improvisation, and a willingness to explore various options.

## 2.6. Importance of Creativity

Research on creativity has demonstrated that it is not an impulsive process but rather a convergence of an individual's creativity-related skills, domain-specific skills, and motivation. Among the various life stages, childhood is particularly conducive to acquiring these skills.

During childhood, children engage in extensive exploration of their surroundings. This period offers opportunities to discover the physical, social, and personal aspects of the world, laying the foundation for future learning and serving as a model for later exploratory behaviors, including investigating entirely new phenomena. Children who have sufficient capacity and opportunities to fully explore their environment accumulate a priceless "creativity capital" that they can tap into later in life. Conversely, children who are restricted from such exploratory activities face significantly diminished prospects for developing their creative abilities in the future.

In today's rapidly changing society, each new generation confronts issues that differ profoundly from those faced by previous generations. This poses a competitive challenge, particularly for children with autism, who are expected to integrate into the community. The responsibility primarily falls upon these children and their families as they strive to adapt to the demands of modern society. Social inclusion stands as a significant hurdle in the integration process for these children. Creative thinking is increasingly recognized as a crucial factor for successful and fulfilling integration into both the physical and social environment (Best et al., 2015; Florida, 2002; Gardner, 1973; Vartanian, 2009). M. Resnik wrote: "For today's children, nothing is more important than learning to think creatively – learning to come up with innovative solutions to unexpected situations that will continually arise in their lives" (Resnick, 2018). How ever, children with autism in school contexts, curricula, and classroom activities might still be separated from their peers. As digital media tools have been seen to appeal to children with autism (Bernard-Opitz et al., 2001; Moore Calvert, 2000) and engage them, we aim to explore this gap with multisensory technologies towards fostering creativity in children with autism.

## 2.7. Creativity and Children

Research on creativity has uncovered that creativity is not a spontaneous phenomenon but rather emerges at the intersection of various factors, including an individual's creativity relevant skills, domain-specific expertise, and motivation. It is the harmonious combination of these elements that gives rise to the creative process and facilitates the generation of innovative ideas and solutions (Amabile et al., 1996; Kurtzberg & Amabile, 2001). Childhood is widely recognized as the optimal phase for acquiring creativity related skills. During this period, all children embark on an extensive exploration of their surrounding environment. This exploration offers valuable opportunities to discover the intricacies of the physical, social, and personal worlds. It serves as a foundation for subsequent learning experiences and serves as a model for future exploratory behaviors, including venturing into completely new phenomena. Children who possess the necessary capacity and opportunities to fully engage in such explorations accumulate a priceless “capital of creativity,” which they can draw upon later in life. Conversely, children who are restricted from these discovery activities face a significantly diminished likelihood of developing their creative abilities in the future.

### 2.7.1. Creativity and social action

Two foundational elements ground our research: 1) creative ideas must be perceived as useful by others, and 2) group effort often results in an increased output of new information and knowledge. Under those two assumptions, analyzing creativity through social contexts is meaningful. However, group dynamics can affect the creative license of the individual. Individuals derive their identities from membership in a social group, whereas their social identity in the group can significantly affect their willingness to engage with others. The person’s relationship with a group influences their perceptions, which impacts responses to attempted innovations and, ultimately, to the potential of finished creations. For instance, “if a product is perceived to be associated with an ingroup or its creator is perceived to be an in-group member, it is more likely to be approached and regarded favorably than it is when it comes from an out-group.” In his book, Howard Gardner reinforces the importance of supportive group work whereby all members benefit from behaviors such as negotiation and dialogue, built around the values of respect, welcome, and listening. The lack of these skills narrows the magnitude of what one can creatively produce, leading to relatively conventional products. In contrast, the absence of an evaluation from peers seems to liberate creativity. Moreover, Gardner observed that creativity is connected to intrinsic motivation to engage in an activity rather than extrinsic motives. Following the same line, Malaguzzi supports this, saying that creativity is increased by interpersonal exchange, with the negotiation of conflicts and comparison of ideas. Nonetheless, it is crucial to keep in mind personal differences that may affect creative group activities. For instance, different problem-solving styles can either facilitate group creativity or make it more challenging. In conclusion, team interactions can hinder or enhance creativity.

The empirical research conducted on creative ability in both children and adults has yielded inconclusive and inconsistent findings regarding gender differences. Approximately half of the studies indicate no significant differences between males and females, while the other half present mixed results, with females tending to exhibit slightly higher creative abilities on average (Abraham, 2016; Nakano et al., 2021). However, it is important to note that these variations in creativity between genders are not attributed to biological factors but rather to the influence of cultural and environmental factors that shape gender-specific behaviors. Additionally, the impact of gender on creativity may vary depending on the specific type of creativity being assessed, such as verbal, visual, or spatial abilities. The examination of gender differences in creativity has predominantly focused on sociocultural, environmental, and neuro-scientific factors.

Furthermore, limited scientific studies have explored the influence of group dynamics on individual creativity. Most research on creativity has primarily centered around individual cognitive processes, individual differences, and the impact of the external environment on individual creativity. The creative ideas and outcomes generated by groups have received relatively less attention compared to the study of individual creative thinking.

As a result, the main objective of this study is to investigate creativity within group settings and examine the impact of gender on group dynamics and the creative process. The study aims to shed light on how the gender composition of a group influences the collaborative creative process and the dynamics that emerge within the group. By focusing on the interplay between gender and group creativity, this research aims to provide valuable insights into the role of gender in fostering collaborative creativity and offer a more comprehensive understanding of creative processes in group settings. While creativity is a personal skill, its manifestation depends on the world outside the individual. To reach its full potential, creative thinking must be shared, validated, and become part of others' lives. Thus, examining how other people's presence influences creative processes in group settings is essential.

Two foundational elements ground our research: 1) creative ideas must be perceived as useful by others, and 2) group effort often results in an increased output of new information and knowledge. Under those two assumptions, analyzing creativity through social contexts is meaningful. However, group dynamics can affect the creative license of the individual. An individual's social identity, derived from their membership in a specific social group, plays a crucial role in shaping their attitudes and behaviors towards others. The way individuals perceive their relationship with a group significantly influences their perceptions, responses to innovation, and ultimately, the potential for creating something meaningful.

For example, when a product is perceived to be associated with the individual's own social group or when the creator of the product is seen as a member of their in-group, it is more likely to be received and evaluated positively compared to if it originates from an out-group. This highlights the impact of social identity on the acceptance and favorability towards innovations or creations.

By recognizing the influence of social identity on individuals' perceptions and responses, we can gain a better understanding of how group dynamics and social relation- ships shape creativity and innovation processes. This understanding can be valuable in various contexts, such as product development, marketing, and fostering positive social interactions within groups (Clark, 1998b). In his book, Howard Gardner Plucker (1994) reinforces the importance of supportive group work whereby all members bene- fit from behaviors such as negotiation and dialogue, built around the values of respect, welcome, and listening. The lack of these skills narrows the magnitude of what one can creatively produce, leading to relatively conventional products. In contrast, the absence of an evaluation from peers seems to liberate creativity Plucker (1994). Moreover, Gardner observed that creativity is connected to intrinsic motivation to engage in an activity rather than extrinsic motives. Following the same line, Malaguzzi Edwards et al. (2012) supports this, saying that creativity is increased by interpersonal exchange, with the negotiation of conflicts and comparison of ideas. Nonetheless, it is crucial to keep in mind personal differences that may affect creative group activities. For instance, different problem-solving styles can either facilitate group creativity or make it more challenging. In conclusion, team interactions can hinder or enhance creativity (Kurtzberg & Amabile, 2001).

### 2.7.2. Children diversity. Autism Spectrum Disorder

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental disorder characterized by pronounced impairments across a broad range of social behaviors and patterns of repetitive actions and interests (Martin, 2014). This condition often presents challenges in engaging in reciprocal conversations and expressing oneself effectively through both verbal and non-verbal communication. Individuals with ASD may also face difficulties in forming and sustaining relationships with peers, as well as actively participating in imaginative and pretend play activities.

The essential characteristics of ASD encompass abnormalities in the development of various domains, as identified by Mills and Wing (2005). These areas include but are not limited to social interaction skills, communication abilities, and the capacity for engaging in flexible and imaginative thinking. It is within these domains that individuals with ASD may exhibit unique patterns and variations, resulting in distinctive profiles of strengths and challenges. By understanding these diverse areas of impairment, researchers and practitioners can work towards developing tailored interventions and support strategies to enhance the quality of life for individuals with ASD and promote their social integration and overall well-being.

1. Communication: Difficult or nonexistent verbal

communication. Difficulties in nonverbal communication.

2. Socialization: Severe difficulties in interpersonal relationships.
3. Imagination: There is a lack of imagination characters, unique uncommon, and repetitive gameplay.

The three main characteristics mentioned above make the child feel isolated and alien from the surrounding world. Nonetheless, one of the most challenging characteristics shown in ASD is a lack of the social abilities necessary for daily functioning with other people (Ploog et al., 2013). Although individuals with HFASD (high-functioning ASD and IQ meagre 70) show normative performances in social capacities in front of structured social tests (Geest et al., 2002), in more spontaneous, real-time social scenarios there are discrepancies in their performance when compared to neurotypical individuals with similar IQ and age (Klin et al., 2003).

Relationships with peers may suffer due to impairments in social communication abilities. People with ASD have difficulties in social engagement and may persist with long, egocentric discourse after the interlocutor has shown a loss of interest (Bauminger-Zviely et al., 2014). Studies on unstructured playground dynamics suggest that children with ASD may show a higher frequency of engaging in solitary, nonsocial play than their typically developed counterparts (Klin et al., 2003) (Bauminger et al., 2010). Even in the case that they want to become involved in activities with peers, they may not possess the communication skills necessary to create socially appropriate dialogue and integrate themselves.

### 2.7.3. Creativity and Autism

Engaging in creative activities provides children with the opportunity to connect and explore alongside their peers, fostering face-to-face interactions. However, these activities often fail to consider the unique needs and abilities of children with autism, who can also greatly benefit from social integration with their peers through tailored activities that align with their interests.

In today's rapidly evolving society, the challenges faced by new generations differ significantly from those encountered by previous ones. This presents a particularly competitive hurdle for the younger generation, especially children with autism. Society expects them to actively participate in the community, placing the responsibility primarily on the children and their families as they strive to navigate the demands of modern society. One of the main obstacles encountered in the process of integration is social inclusion for these children. Creative thinking emerges as a key factor for achieving successful and satisfying integration into both the physical and social environments. By fostering and promoting creative thinking, children with autism can overcome barriers and enhance their ability to thrive within their surroundings (Best et al., 2015; Florida, 2002; Gardner, 1973; Vartanian, 2009). M. Resnik wrote: “For today’s children, nothing is more important than learning to think creatively – learning to come up with innovative solutions to unexpected situations that will continually arise in their lives” (Resnick, 2018). Despite advancements in inclusive education, children with autism often face challenges in fully participating in school contexts, curricula, and classroom activities, which can lead to social separation from their peers. However, there is potential to address this issue by harnessing the power of digital media tools, which have been shown to capture the attention and engage children with autism effectively (Bernard-Opitz et al., 2001; Moore Calvert, 2000). In line with this, our aim is to investigate this gap further by exploring the use of multisensory technologies as a means to foster creativity specifically in children with autism. By incorporating these innovative tools, we aspire to bridge the divide and create inclusive opportunities for creative expression and engagement, empowering children with autism to thrive in educational settings.

## 2.8. Inclusive education

The thesis has emphasis on inclusion and reverse inclusion. Inclusive education is still widely seen as an approach to serving children with disabilities in general education settings (Mittler, 2005). However, it is becoming more widely seen as a reform to accommodate the diversity of all learners (Ainscow et al., 2013, Pijl & Meijer, 1991). The goal of inclusive school improvement is to eliminate exclusion formative processes resulting from attitudes and responses to racial and social diversity, class, ethnicity, religion, gender, and disability. Inclusion starts with believing that education is a basic human right and the foundation for a more just society. Reverse inclusion is the process in which typically developing children learn to respect, assist and integrate children with any form of disability into society by being placed in a space or through a specially designed device specifically to allow them to help their fragile friends (Vitello & Mithaug, 2013).

### 2.8.1. Approaches and materials in inclusive education

In middle childhood, healthy children experience fast social and emotional changes; they quickly develop cognitive skills, personality, motivation, and interpersonal relationships. The social skills learned through peer and family relationships and children’s increasing ability to participate in interpersonal communication provide a foundation for the future. All these things are essential for growing up. Children with ASD commonly have a social communication disorder. They find it extremely difficult to communicate with others in typical ways. They are hypersensitive and afraid of social communication (White et al., 2009). Many children with ASD are intensely aware of their social disconnectedness. A variety of their behaviors can include overstimulation, heavy dependency on schedules, self-injuring, an outburst of emotions, or becoming withdrawn (Attwood, 2000). Children with autism spectrum disorders are characterized by widespread abnormalities in social interactions and communication, as well as severely restricted interests and highly repetitive behavior (American Psychiatric Association 2013). Early behavior intervention programs can efficiently reduce these symptoms (Thill et al. 2012). Play is an effective solution in ASD intervention for helping children to reduce anxiety and move into the real, shared interaction. Through play, children can develop social and cognitive skills, mature emotionally, and gain the self-confidence required to engage in new experiences and environments (Kahn 1971). In general, children's play should be pleasant and enjoyable; it is spontaneous and voluntary; it involves the active engagement of the player; it involves an element of make-believe (Hirsh-Pasek, Golinkoff, and Eyer 2004). Properly used, learning through play can allow children with ASD to explore their feelings, environment, and relationships with parents, siblings, and peers. One of the basic principles of early childhood education is Play for children's learning and development. Playfulness can be seen through the theory and ideology of early childhood education programs in various ways (Saracho & Spodek, 2002; Wood & Attfield, 2005). Learning through play is a term used in education and psychology to describe how a child can understand the world around and interact with it. Through play, children can develop social and cognitive skills, mature emotionally, and gain the self-confidence required to engage in new experiences and environments (Birleson, 1981). Children's play is pleasant and enjoyable; it is spontaneous and voluntary; it involves the active engagement of the player; it consists of an element of make-believe (Hirsh-Pasek et al. 2004). In addition, play develops children's content knowledge. Play-based learning is based on a Vygotskian model of scaffolding where the teacher pays attention to specific elements of the play activates and provides encouragement and feedback on children's learning (Martlew et al. 2011, Vygotsky & Cole, 1978).

While there is substantial evidence on learning through play, there has been less evidence on teaching through play. The link between play and pedagogy has long been a subject of controversy, because of an ideological commitment to free play and free choice (Wood, 2008). However, contemporary theoretical and political changes have shifted focus to better understanding the different purposes and nature of play in educational settings; adult role in play planning and playfulness in child- or teacher-led projects activity (Wood, 2009).

One of the aims of this chapter is to examine the pedagogy of play and their instruments as the part of educational inclusive environment. Pedagogy of play is defined broadly as the ways in which early childhood professionals make provision for play and playful approaches to learning and teaching, how they design play/learning environments, and all the pedagogical decisions, techniques, and strategies they use to support or enhance learning and teaching through play. These results can also be extended to include the ways in which children act as playful pedagogues in their self-initiated activities. Properly used, learning through play can allow children with ASD to explore their feelings, environment, and relationships with parents, siblings, and peers.

Numerous studies have indicated that individuals with autism spectrum disorder (ASD) exhibit a strong preference for computer-based tasks (Chen and Bernard-Opitz, 1993). Researchers Brown and Murray (2001) delved into effective strategies for engaging children with autism spectrum disorder (ASD) and uncovered a significant attraction to information and communication technologies (ICT). The structured and predictable nature of computer-based technologies is thought to play a key role in fostering this preference. Acknowledging this affinity, there has been an increasing emphasis on researching and developing computer-based interventions to capture the attention of individuals with ASD.

In their work, Davis et al. (2010) emphasized the importance of designing ICT with features that would readily appeal to individuals with ASD in therapeutic settings. These features include task consistency, predictability, and the gradual introduction of novel elements. Such design considerations allow for easier regulation of change and ensure immediate and consistent feedback, as highlighted by Alcorn et al. (2011) and Moore and Calvert (2000) respectively.

Utilizing Virtual Environments (VE) specifically tailored for individuals with ASD can offer a promising avenue for practicing socialization skills. These environments have the potential to reduce anxiety while facilitating the development of desired behavioral patterns. By providing a controlled and customizable setting, VE-based interventions can create a safe space for individuals with ASD to engage in social interactions and acquire essential social skills.

### 2.8.2. Digital media tools fostering creativity in children with autism

Since early childhood, the current generation has had digital technology as part of their lives. According to Chen and Bernard-Opitz, children with ASD tend to enjoy computer-based tasks (Case-Smith et al., 2015). They show a great affinity for information and communication technologies (ICT). The utilization of new technologies has proven to be highly beneficial for individuals with autism spectrum disorder (ASD) by providing a convenient, predictable, and structured environment that supports continuous learning (Valencia et al., 2020). As a result, there has been an increasing focus on employing digital interventions to support and treat children with autism (Sandgreen et al., 2021). In a study conducted by Kientz et al., various interfaces such as personal computers and the internet, video and multimedia, mobile technologies, shared activity surfaces, virtual and augmented reality, sensor-based and wearable devices, robotics, and natural interfaces were identified as promising tools for ASD intervention (Kientz et al., 2013). The researchers justified their perspective based on historical research that explored technology-enabled interaction with autistic children. The concept of “Multisensory Environment” emerged in the 1970s, with the development of “Snoezelen” in the Netherlands—an innovative technique utilizing multisensory stimulation to provide a range of free-time activities for individuals with cognitive and behavioral impairments (Burns et al., 2000; Botts et al., 2008).

In the early 2000s, many MSEs projects appeared, such as MEDIATE, Lands of Fog, FUTUREGYM, and SensoryPaint. MEDIATE is an MSE that generates real-time stimuli (visual, aural, and vibrotactile) in which children with autism can express them- selves (Pare´s et al., 2006). In 2013 the first version of Lands of Fog project was created. The idea of the Lands of Fog was born from the project Bell del Fanalet (Mora-Guiard et al., 2016). The project destination was a multiplier virtual environment where a child with ASD could engage and collaborate (Crowell et al., 2019). In the study by Ringland et al. (2014), a multimodal system called SensoryPoint was introduced, enabling users to engage in painting activities on a large display using physical objects, body interaction, and interactive audio. The system aimed to provide a rich and immersive sensory experience.

Another research project, proposed by Takahashi et al. (2018), focused on the development of an interactive school gymnasium known as FUTUREGYM. The objective of this project was to enhance interpersonal interaction among students with interactive technology within the gymnasium environment.

In our laboratory, a multidisciplinary team has created and continually improved a technological environment known as the Magic Room. Originally an empty room, it has been transformed into a multisensory space through the integration of various technologies (Garzotto et al., 2020). The Magic Room offers a unique and immersive experience by incorporating multisensory elements that engage users in a captivating and interactive environment. Magic Room is a multisensory environment that provides gentle stimulation of different senses while offering relaxing, educational experiences (Arnone et al., 2020).

The Multisensory Environments listed above are widely used with autistic children to develop different learning skills. Still, there is limited research in this area, with little known about how these rooms can be used to promote creativity. Indeed, there are currently no evidence-based guidelines on using MSEs to promote the free exploration of autistic children. This study explores practitioners’ beliefs about MSE use for promoting creativity in autistic children, allowing learning from their perspectives.

## 2.9. Introduction of a classic approach

The only way in which adults consciously control the kind of education which the immature get is by controlling the environment in which they act, and hence think and feel. We never educate directly, but indirectly using the environment" (Dewey, 1916, p. 22). This quote is a good representation of this part. In this paragraph, the author observed the most demand in modern society's educational approaches. Firstly, it is important to emphasize the role of Dewey's theory in education. What is Dewey's theory? In Dewey's theory, learning is socially constructed and based on experiences. He also holds that learners collaborate with other learners and teachers to create their own understanding by solving problems they face in different situations. Therefore, educational processes should be organized in real-life experiences that give a context for the information. It is an experimental approach to pedagogy in a results-driven environment with the teacher presented as a co-collaborator. Play is a second effective approach in education. Through play, children can develop social and cognitive skills, mature emotionally, and gain the self-confidence required to engage in new experiences and environments (Kahn, 1971). In general, children's play should be pleasant and enjoyable; it is spontaneous and voluntary; it involves the active engagement of the player; it involves an element of make-believe (Hirsh-Pasek, Golinkoff, & Eyer, 2004). Properly used, learning through play can also allow fragile children to explore their feelings, their environment, and their relationships with parents, siblings, and peer.

## 2.10. Modern technology-enhanced approach

The current generation has had digital technology as a part of their lives since early childhood (Madden et al., 2005) and, according to Chen and Bernard-Opitz, typical and specialty fragile children tend to enjoy computer-based tasks (Chen Bernard-Opitz, 1993). They show a great affinity towards information and communication technologies (ICT) (Brown Murray, 2001) and for fragile people, new technologies offer a convenient, predictable, and structured environment that facilitates continuous learning (Valencia et al., 2020). This tendency fosters a growing number of studies that focus on the use of digital interventions for the support and education of mixed groups of children (Sandgreen et al., 2021). The study conducted by Kientz et al.

suggests that there is great promise for the use of the following interfaces in ASD intervention - personal computers and the internet, video and multimedia, mobile technologies, shared activities surface, virtual and augmented reality, sensor-based and wearables, robotics and natural interfaces (Kientz et al., 2013). Kientz and her colleagues justify their point of view based on historical research into technology-enabled interaction with autistic children. The earliest articles mentioned in the study that discuss the use of computers in the treatment of nonspeaking autistic children is that of Colby and colleagues.

The best educational properties were shown by interactive multisensory systems that have control and adaptation settings. In the study conducted by Cosentino et al. (Cosentino et al., 2019) and according to Garzotto et al. (Garzotto et al., 2020) findings, even a relative short experience in the Multisensory Environment might positively affect perceived well-being in the school integration environment, especially for atypical children.

## 2.11. Multisensory Environment: a modern technological solution to promote creativity

The author believes that children can exhibit the most natural cooperation with a creative objective if they share the same environment, not mediated by remote connection as seen during the recent pandemic. The author also believes that children express themselves more freely when using the most natural "controller" they have – which is their body. For this reason, interactive Multisensory Environments (iMSEs) are the most suitable solutions. The results of the studies show that children became more confident in the multisensory environment when with their partner and that they preferred to play together and share the experience rather than play alone. They also showed that children increase in social behaviors over the course of the sessions and that they respond positively with willful engagement during collaborative play. This study shows that the multisensory system has great prospects for further future development in helping children with Autistic Spectrum Disorder to achieve their potential.

## 2.12. Multisensory Environments

### 2.12.1. Historical Resume

The first mention of the "Multisensory environment" occurs in the 1970s. At this time in the Netherlands, a novel technique, "Snoezelen," was developed, based on multisensory stimulation, to provide free-time activities for people with cognitive and behavioral impairments. Cameron et al., in their scoping review analysis of the multisensory environments (MSEs), concluded that these spaces offer visual, auditory, tactile, olfactory, proprioceptive, and gustatory stimulation by using the following equipment: - projection equipment (floor and on the walls), sound (music) equipment, bubble, smart objects, smart light. In the early 2000s, many MSE projects appeared, such as MEDIATE, Lands of Fog, FUTUREGYM, and SensoryPaint. MEDIATE is an MSE that generates real-time stimuli (visual, aural, and vibrotactile) in which children with autism can express themselves (Pare´s et al., 2006). In 2013 the first version of the Lands of Fog project was created. The idea of the Lands of Fog was born from the project Bell del Fanalet (Mora-Guiard et al., 2016). The project destination was a multiplier virtual environment where a child with ASD could engage and collaborate (Crowell et al., 2019).

SensoryPoint is a multimodal system that allows users to paint on a large display using physical objects, body interaction, and interactive audio (Ringland et al., 2014). An interactive school gymnasium called FUTUREGYM was proposed to increase interpersonal interaction (Takahashi et al., 2018). A technological environment that the multidisciplinary team created and constantly improved in our Lab, is an empty room which has been adapted, through technology into a multisensory Magic Room (Garzotto et al., 2020). Magic Room is a multisensory environment that provides gentle stimulation of different senses while offering relaxing, educational experiences (Arnone et al., 2020).

### 2.12.2. Scoping review of Multisensory Environment

This part presents a review of studies between 2002 and 2021 on research into multi-sensory environments (MSEs) as an educational platform for fostering the improvement of various skills of children and adolescents diagnosed with autism spectrum disorder (ASD). Children with autism spectrum disorder often exhibit good results in the technology-based educational intervention. In current practice educational interventions apply different digital technologies and focus on different goals. Previous reviews examined the effects of digital technology without specific focus on the educational potential of MSEs in ASD intervention. This study is intended to review the learning potential of MSEs for children with autism. A systematic review of twenty-eight studies was conducted using six questions related to learning skills, participants, technology, data collection method, evaluation parameters and perspectives of future development. The set of learning skills which were concentrated on was social skills. Children with ASD were the primary subjects of all studies, the majority of which used MSEs technology. The pre-test and post-test research design method were predominant in this study which generally used observation as a data collection instrument. The study showed that individual learning was positively affected using MSEs. Future research into MSEs allowing each user to explore their favorite and most convenient form of learning is proposed to suggest the most commonly successful solutions for ASD profiles with similar challenges. In this research, the focus was on the analysis of the skills intended for learning in the selected articles as well as on the methods of measurement and the results achieved. A detailed analysis of the training properties of the multisensory system, possible scenarios for measuring results and prospects for development was carried out. In this part of our studies, we highlighted our main findings in the studies related to the research questions.

Nowadays human society experiences rapid growth in the number of children with ASD. The rate of ASD reported by the Centers for Disease Control (CDC) was 1 in 150 (2002). Since then there have been increases announced every 2 years: 1 in 125 (2006), 1 in 88 (2008), 1 in 68 (2010), 1 in 69 (2012) and 1 in 59 (2014) (Tureck et al., 2014).

Children with ASD are characterized by widespread abnormalities in social interactions and communication as well as exhibiting severely restricted interests and highly repetitive behaviors (American Psychiatric Association, 2013). These symptoms can be efficiently reduced through early behavior intervention programs (Thill et al., 2012a). The current generation have had digital technology as a part of their lives since early childhood Madden et al. (2005) and, according to Chen and Bernard-Opitz, children with ASD tend to enjoy computer-based tasks Chen and Bernard-Opitz (1993). They show a great affinity towards information and communication technologies (ICT) Brown and Murray (2001) and for people with ASD, new technologies offer a convenient, predictable, and structured environment that facilitates continuous learning Valencia et al. (2020). This tendency fosters a growing number of studies that focus on the use of digital interventions for the support and treatment of autistic children Sandgreen et al. (2020). The study conducted by Kientz et al. suggests that there is great promise for the use of the following interfaces in ASD intervention - personal computers and the internet, video and multimedia, mobile technologies, shared activities surfaces, virtual and augmented reality, sensor based and wearables, robotics and natural interfaces Kientz et al. (2013). Kientz and her colleagues justify their point of view based on historical research into technology-enabled interaction with autistic children. The earliest articles mentioned in the study that discuss the use of computers in the treatment of nonspeaking autistic children is that of Colby and colleagues (Colby, 1973; Colby and Smith, 1971).

This scoping review analyzes the multisensory properties of space of MSEs without giving a detailed analysis of the learning features of the systems. Reviews which mention the use of MSEs in ASD intervention technologies of providing a choice of free-time activities for people with cognitive and behavioral include: - Cameron et al. (2020), medical training Thompson (2011), sensory processing intervention Case-Smith et al. (2015). Reviews on ASD include social robotics (Barakova (2011); Saleh et al. (2020), use of VR and AR (Maggio et al. (2019); Khowaja et al. (2019b), Marto et al. (2019)) Interactive Technologies for Autism (Kientz et al. (2013), Odom et al. (2015).

Based on the material presented above, the literature provides scoping reviews of the technological and therapeutic properties of the Multisensory system. The educational properties are described in detail only in the literature review of the vertical reality and augmented realities. The focus of this systematic literature review is to provide state-of-art research regarding the studies utilizing MSEs to assist children with ASD to learn different skills. It is also to provide evaluation criteria and to make recommendations for future research.

The structure of this review is as follows. It commences with a discussion of the method used for identifying published papers included in this review and goes on to present the research findings and the recommendations for future studies. New paragraph: use this style when you need to begin a new paragraph.

### 2.12.3. Method for Systematic Scoping review

Arksey and O'Malley and Kitchenham have a similar definition for the Systematic Scoping Review process (Kitchenham, 2004), (Arksey & O'Malley, 2005) which formed the methodology of this study. Arksey and O'Malley identify four common reasons for scoping study. They highlight the following reasons: "to examine the extent, range, and nature of research activity; to determine the value of undertaking a full systematic review; to summarize and disseminate research findings; to identify research gaps in the existing literature" Arksey and O'Malley (2005). Both authors describe the type of scoping study aimed at identifying gaps in the existing research literature. Kitchman's methodological structure is defined in 3 sections and subsections. Arksey and O'Malley's structure consists of 5 sections. The content is the same, but the structure is different. The following are the stages of the methodological framework defined by Arksey and O'Malley which were used in this systematic scoping review:

1. Identifying the research question
2. Identifying relevant studies
3. Study selection
4. Charting the data
5. Collating, summarizing, and reporting the results

These stages are discussed in the following sections with the subsections in the activities at each stage.

### 2.12.4. Research questions

Clarify the focus of the scoping study and establish an effective search strategy total of eleven research questions and five sub-research questions were formulated. The research questions related to achieving these objectives are as follows:

(1) What demographic information is provided about the papers?
  - (i) When were the papers published?
  - (ii) Which countries have published the papers?
  - (iii) Which venues did the authors of the papers use to publish their work?
  - (iv) In which countries were the papers published?
  - (v) Which universities did the authors of the papers work for?
  - (vi) What subject areas are the papers about?
  - (vii) What type of format do the papers take?
  - (viii)

(2) What specific learning skills are addressed in the papers?

(3) Who are the intended users of the papers, and who are the secondary users?

(4) What specific features of MSE technology are highlighted in the papers?

(5) What types of research designs were used to evaluate the effectiveness of MSE?

(6) What methods were used to collect data on the participants' learning outcomes?

(7) What settings are the papers discussing as potential applications of MSE?

(8) What metrics were used to measure the effectiveness of MSE as a learning tool?

(9) What evidence is provided to support the effectiveness of MSE in improving learning outcomes?

### 2.12.5. Search Strategy

In this systematic review a PRISMA Statement was applied to reach an evidence-based minimum set of items. The articles were identified by searching on Elsevier's Scopus database. All the studies fulfilling our selected criteria and published between 2002 and 2021 were evaluated for possible inclusion. The database search was based on the following keywords in each category: "Multisensory environment" AND/OR "ASD intervention"; "Multisensory" AND/OR ASD "child"; "Multisensory environment" AND/OR "ASD"; "Multisensory" AND/OR "environment" AND/OR "ASD"; "multi- sensory" AND/OR "skills"; "Multisensory". Only texts in English were selected and any duplicates were removed. All articles were evaluated according to title, abstracts, and text.

### 2.12.6. Study Selection

This scoping study began by searching the electronic database for published articles related to MSE and ASD intervention. For our study searches we used a recognized abstract and citation database (Elsevier's Scopus) and refined our selection by using a series of filters – initially by the subject area "computer science" and then by using the keywords "multisensory environment" and finally by the papers published in the years from 2001 to 2020. This search resulted in 498 documents. As a further refinement we applied another selection filter by adding the word "child". This search reduced the number of initial documents to 116. On the by-year graph analysis, we found that the number of newly published papers on this topic started to increase from 2016. Because of this finding we decided to do another data search restricting it to the years from 2016 to 2020. This produced 57 documents. To produce the evidence-based minimum set of items we required from this data we added 2 keywords - "Human Computer Interaction" and "User Experience" and conducted another search which resulted in the articles we have used as a basis for this study. In addition to the database searches, we also included a search of the relevant current work being conducted by the Innovative Interactive Interfaces Laboratory (i3lab).

We used a systematic review method to choose studies that address our central re-search question regarding the effectiveness of utilizing MSEs to assist the learning of children with ASD. Systematic review methods using inclusion and exclusion criteria based on specific research questions were developed at the outset of the project to ensure consistency in decision-making. The inclusion criteria used in our scoping study related to the type of study, the type of technological solution and the focus group. We chose studies that appeared to represent a 'best fit' with the research question. If the relevance of a study was unclear from the abstract, we downloaded the full article. After reading 41 articles in full, 28 of these were selected for inclusion in the review.

The following Figure 3.1 displays the complete article selection process based on the inclusion criteria.

Due to time constraints, we included only those studies published between 2001 and 2020. The start date of 2002 was chosen because an informal play session of a group of ASD children within a full-body interaction artistic installation ("Lightpools") showed the potential of the installation to spark social interaction behaviors in children with autism Pare´s and Pare´s (2001). Only material in the English language was included because of the cost and time involved in translating material. We had to apply these limits for practical reasons so it is possible that potentially relevant papers may have been missed. The step-by-step flow of the entire search process and the selection of studies is depicted in the Figure 3.1.

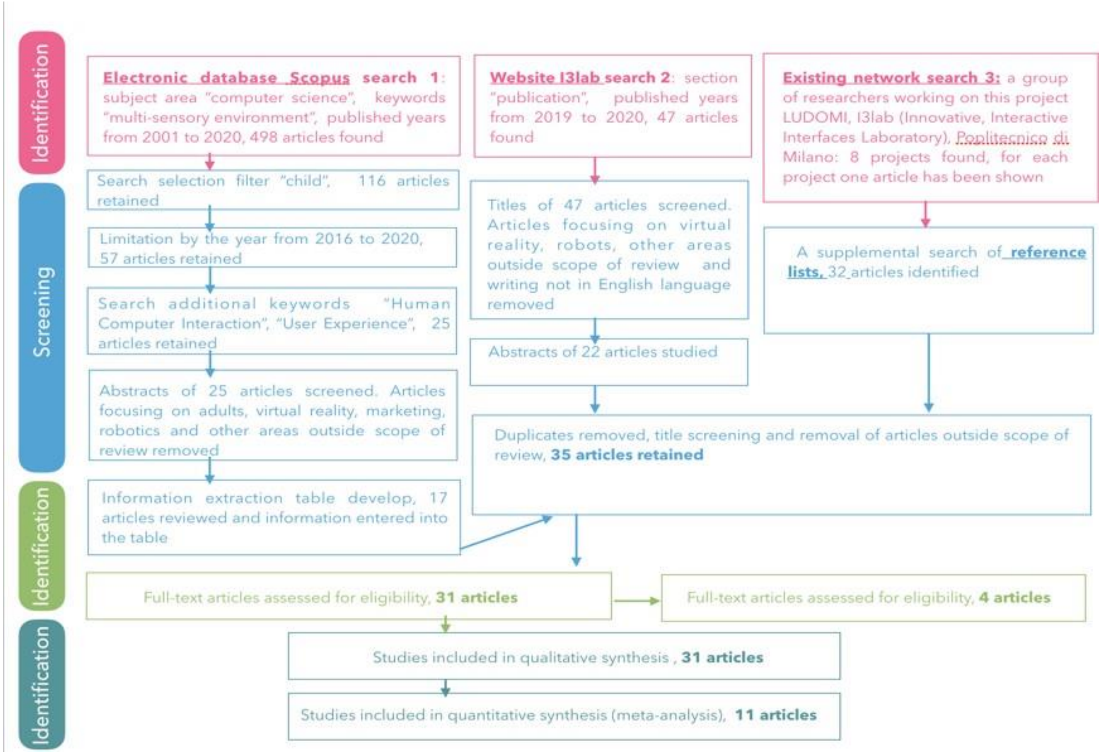



**Fig. 3.1** Article selection process.

## 2.12.7. Charting the data

The next stage of our work was to sort the key items of information obtained from the selected primary research reports. 'Charting' Spencer et al. (2003) describes a technique for synthesizing and interpreting qualitative data by sifting, charting and sorting mate- rial according to key issues and themes. This is a similar process to the one we adopted hence we have borrowed this term from the fourth step of Arksey and O'Malley's frame- work. We have used the "narrative review" approach, that takes a

broader view com- pared to the “data extraction” process. The attributes include author(s), year of publication, study location; type of multisensory technology; focus group; aims of the study; methodology; outcome measures and important results.
Based on these criteria we filtered our Scopus 28 papers and excluded some of them because the context of use was in psychotherapeutic intervention, an area outside our focus.

### 2.12.8. Results of the Systematic Scoping review

This stage of the scoping study involved collating, summarizing, and reporting the results. We used a data analytic framework and thematic structure to present a narrative account of relevant existing literature.

(i) When were the papers published?

The publishing trend of the 28 primary studies is shown in the Figure 3.2. The number of studies published in a scientific journal or presented at a conference are shown in the graph. Since 2016, there has been a growth in the use of MSEs in ASD intervention.

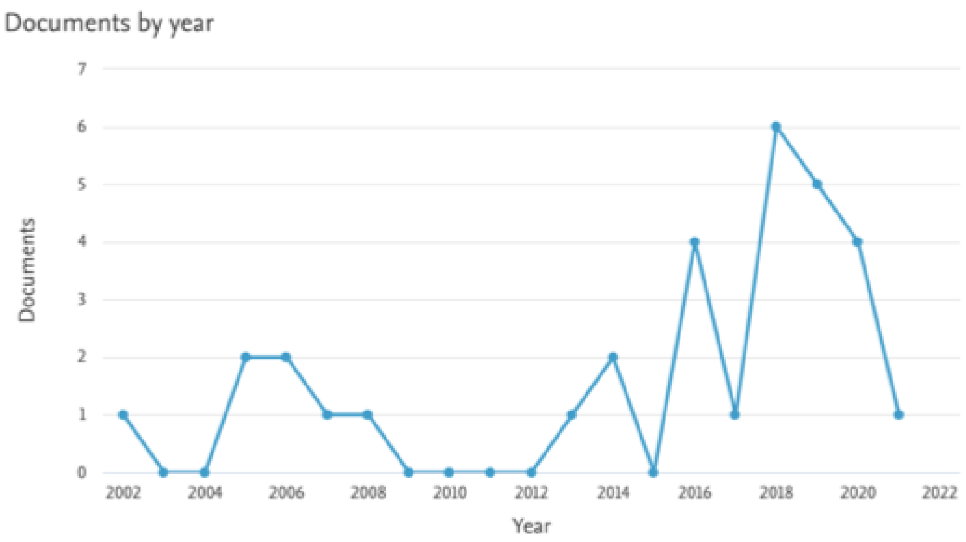



**Fig. 3.2** Documents selection by year.

(ii) In which countries were the papers published?

The Figure 3.4 shows the country origins of the authors of our selected papers. The analysis shows that eleven papers are from Italy, seven papers are from the US, and in both Spain and the UK produced six papers. Three of the selected papers originated in

Japan, Ireland, Mexico and the Netherlands each produced two papers and China and Germany generated one study each.

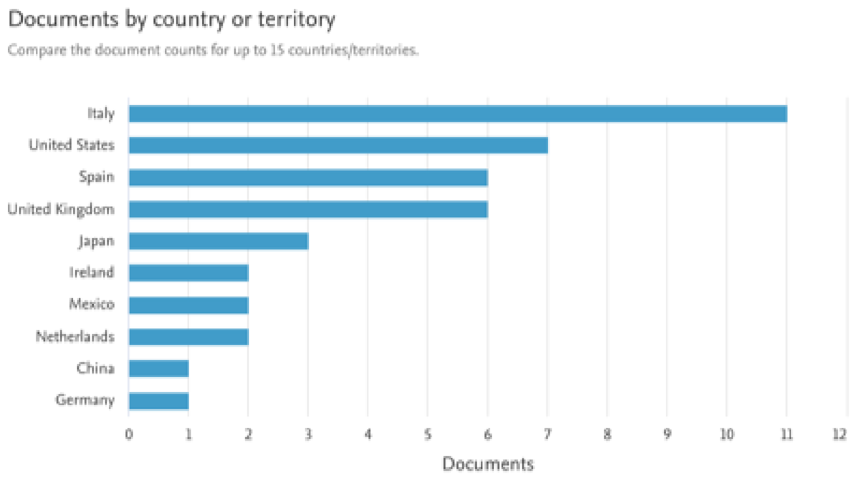



**Fig. 3.4** Documents selection by country or territory.

(iii)Which venues did the authors of the papers use to publish their work?

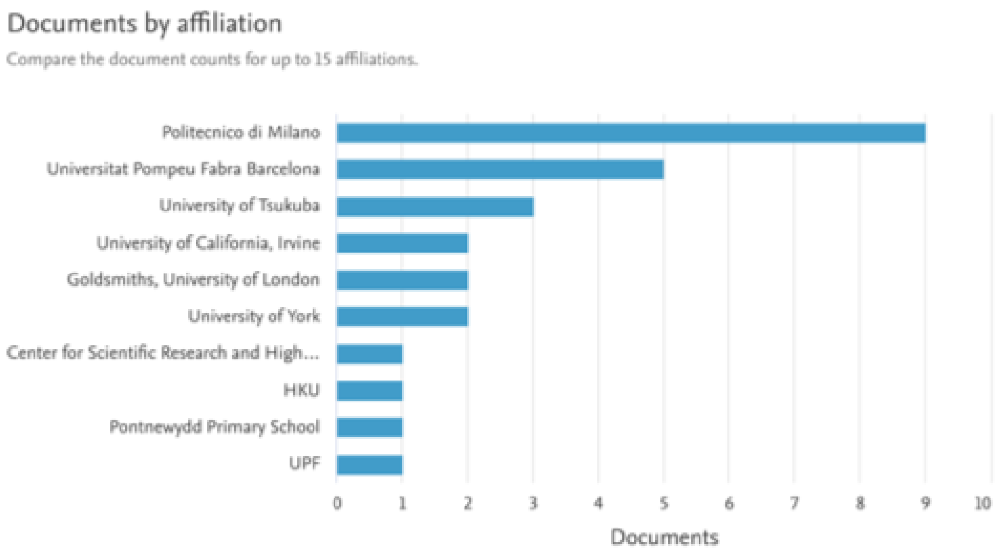
Figure 3.5 represents the publication sources of the selected papers on the Scopus research platform. This analysis includes a percentage review of articles by year; Cite Scopus publication by year; SCImago journal rank by year; source documents by year; source normalized impact per paper by year and source citation by year. The growth ofindices in all directions is apparent since 2016.


**Fig. 3.5** The publication sources of the selected papers on the Scopus research platform.

(iv) Which universities did the authors of the papers work for?

Figure 3.6 represents the top ten papers by affiliation Firstly, the literature was organized thematically according to different intervention types (educational/therapeutic). The analysis showed that the first university by affiliation with nine papers was Politecnico di Milano, while the Pompeu Fabra Barcelona University with five papers stood second, and the University of Tsukuba was in third place with three papers. The University of California, Irvine; the Goldsmith University of London and the University of York were each mentioned in two studies. Other universities have only one paper each.

**Fig. 3.6** Documents selection by affiliation.



(v) What subject areas are the papers about?

The Figure 3.7 shows that most of the selected papers (49,1 %), related to Computer sciences subjects. 8,8 percent of the papers occupied Psychology subject areas and 7,7 %of the papers related to the engineering subject areas.

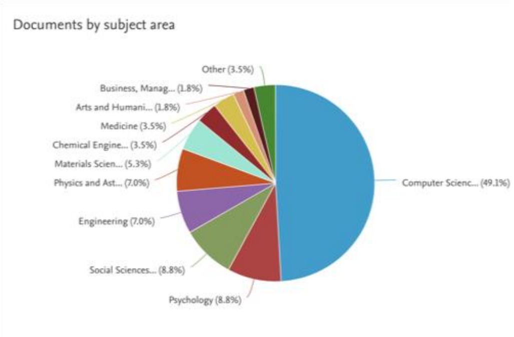



**Fig. 3.7** Documents selection by subject area.

(vii) What type of format do the papers take?

The Figure 3.8 shows the type of documents where a paper has been presented or published. 61,3 % of the papers were presented at a Conference 32,3 % were published articles and 3.2 % were Book Chapter and Review.

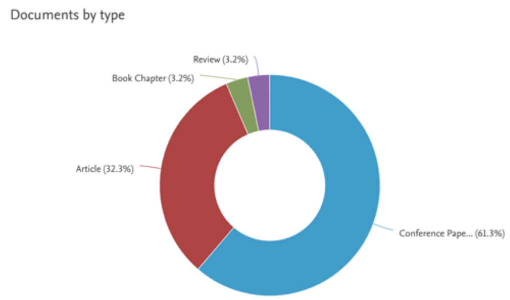



**Fig. 3.8** Documents selection by type.

### 2.12.9. What specific learning skills are addressed in the papers?

To avoid subjective decisions regarding data analysis we attempted to ensure a consistent approach to reporting our findings by developing a 'template' to be applied to each paper. The template began with a small table summarizing basic characteristics of all the studies included in that intervention group. This was followed by a commentary written under the following seven headings: Learning Skills; Primary user; Secondary user; Special features of MSE; Research design; Data collection method; Context of use.

The context of use in the studies, where the evaluation was conducted, refers to the environment. The studies were presented in either a classroom environment, a controlled research environment or special education centers.

In one or more of the current papers, a total of 22 skills were targeted. The primary studies focus on the following skills: Drawing skills, Cognition skills, Motor skills, Social skills, Learning performances, Attention, Adaptive behavior, Play skills, Memory skills, Visual processing, Cooperation skills, Life skills, Emotional skills, Relaxation, Selection, Classification, Identification, Association, Communication skills, Imagination skills, Creative skills, Cleaning skills. **Table 4** displays mentions of skills in the observed articles.

The Figure 3.10 shows the skills targeted in selected papers. The most frequently used were: social skills, these are used in 16 studies; cognition skills were used in 12 studies and motor skills were used in 11 studies. Communication skills are mentioned in selected studies 6 times, while attention is mentioned 5 times. Learning performances, Cooperation skills, Life skills, Emotional skills and Creative skills have been used 3 times in each of the selected papers. Memory skills, Relaxation and Imagination were mentioned in 2 of the studies and the remaining skills were each used in 1 study.

The Figure 3.10 shows that in selected studies 3 authors used more than 6 skills. The most frequent result was two target skills and ten of the studies had this result. Selected papers have been organized based on the target skills. A brief description of the study is listed below in alphabetical order of the target skills.

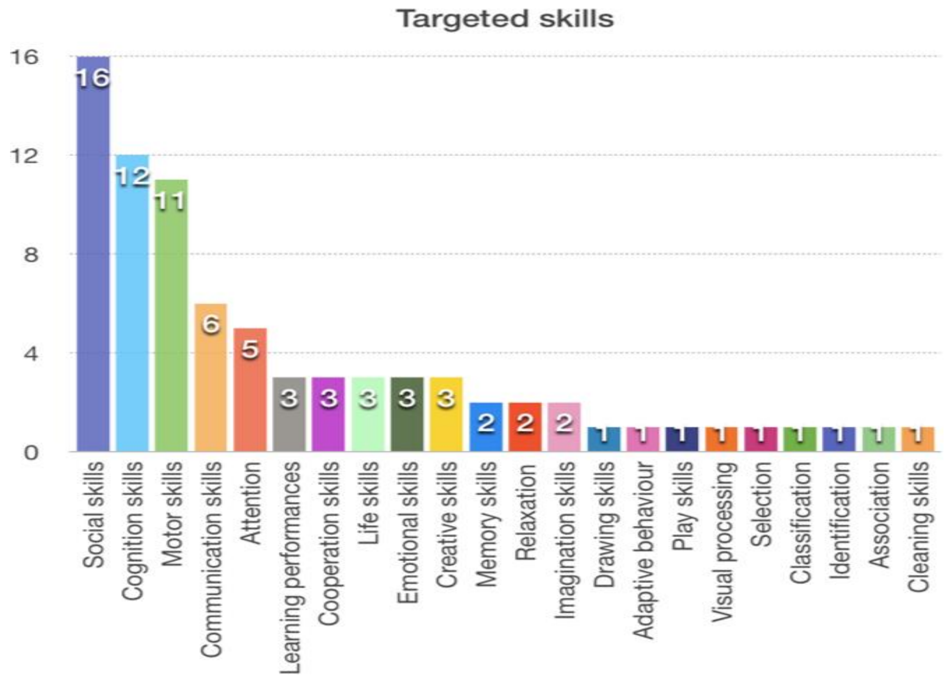



**Fig. 3.10** Number of the skills targeted in one paper.

1. Adaptive behavior: According to De Luca et al. (2021), virtual reality (VR), in combination with cognitive-behavior therapy, has the potential to enhance adaptive behavior.

2. Attention: The study conducted by De Luca et al. De Luca et al. (2021) used an interactive series of eight exercises involving cognitive rehabilitation related to the attention process. The tool was a movement-based system providing patients with interactive VR scenarios to interact with. The patient performed motor and cognitive tasks or activities, such as identifying/finding objects, counting, describing, chasing, or moving objects in conjunction with VR scenarios. According to Garzotto et al. Garzotto et al. (2020a) the Virtual Wardrobe activity available in Magic Room is designed to improve attention. Hayes and Ringland et al Ringland et al. (2014c) proposed to help children by turning their attention towards their bodies. Sensory stimulation may improve the efficacy of the traditional therapies. The study conducted by Takahashi et al. Takahashi, Oki, Bourreau, Kitahara and Suzuki (2018a) presented an empathic design approach for technology-assisted teaching in a special needs school setting. This was realized by FUTUREGYM which is a school gymnasium with interactive floor projections which aims to keep the children’s attention

focused on the content provided, fostering learning by visual aids using colors, patterns, or animations.

3. Autonomy: Garzotto et al.Garzotto et al. (2020a) conducted activities Virtual Wardrobe and Grocery Game, in MSE Magic room with task instructions designed to improve autonomy.

4. Cleaning skills: In this research Takashi et al. Takahashi, Oki, Bourreau and Suzuki (2018) focus on immersive Visual Support (VS) activities called FUTUREGYM designed for children with neurodiversity. It consists of two interactive VS activities (Mop Game and Mop Guide) for vocational cleaning training, created in collaboration with teachers with the aim of inspiring students to clean and assisting them in acquiring basic cleaning skills.

5. Cognition skills: According to De Luca at al. De Luca et al. (2021), the use of VR in addition to cognitive behavior therapy could be a useful and promising tool to improve cognitive function in individuals severely affected by ASD. Garzotto et al. Garzotto and Gelsomini (2018a) have designed a multisensory multimodal interactive environment called "Magic Room". The idea behind Magic Room is based on embodied cognition Graf et al. (2019) and sensory integration Garzotto et al. (2019) hypotheses. The former stresses the formative role of embodiment in the development of cognitive ability. Embodied interactions facilitate cognitive functions associated with the regulation of sensorimotor contingencies and enhance higher cognitive capacities such as mental imagery, working and implicit memory, According to Garzotto et al. Garzotto et al. (2020a) the seven kinds of activities in the existing Magic Room which are available are: Classification game, Association Game, Battleship game, Memory Game, Virtual Wardrobe, Grocery Game, Immersive game and Storytelling. Each of these can be customized to engage children in about 100 different activities in multiple ways. Garzotto et al. Gelsomini et al. (2020) conducted a study to explore the potential of immersive embodied interaction for learning. This approach is grounded on theories that recognize the relationship between physical activity and cognitive processes. The author planned and developed an instructional didactic experience called IMAGINE which aimed to promote the acquisition of "factual knowledge" on a curricular topic based on the premise that embodiment would improve

the learning process. In the study conducted by Hotz et al. Hotz et al. (2006) the sensory control strategy is focused on information processing and manipulation of sensory information reactions, with a focus on maximizing selective attention through environmental regulation rather than high levels of stimulus. The Snoezelen environment is believed to help relaxing, offering a pleasurable feeling, and discouraging behavioral changes. Navarra et al. Kanellos et al. (2018) developed a disruptive and creative gamified monitoring and rehabilitation software program to help children control and resolve Attention Deficit and Hyperactivity Disorder (ADHD) symptoms.

6. Communication skills: One of the main ideas behind the design of Pares et al. Pare´s et al. (2006), Pares, Masri, van Wolferen and Creed (2005a) MEDIATE was to provide simple interaction dialogues that would give children with severe autism a sense of control of the environment because children with ASD have no sense of agency; i.e. they have no sense of connection between them and the surrounding world. Takahashi et al. Takahashi, Oki, Bourreau, Kitahara and Suzuki (2018a) assumed that Spatial Augmented Reality (SAR) would help children with ASD to gain a deeper understanding of successful communication and to assist them in their everyday activities.

7. Collaboration skills: In the study conducted by Marwecki Marwecki et al. (2013) a hybrid therapy game allowed face-to-face communication and a possibility for social interaction within a comfortable and controllable digital setting. The strategy of the game involved the players in collaborative actions and provoked social interaction. Mora-Guiard et al.Mora-Guiard et al. (2017a) presented “Lands of Fog “a full-body interaction system designed for children with ASD to play with a typically developing peer. The game requires children to collaborate by working together to discover all the creatures that inhabit the virtual world in the game. For the design of the interactive system the authors adopted a Participatory De- sign (PD) approach.

8. Creative skills: Pares et al. Pare´s, Carreras, Durany, Ferrer, Freixa, Go´mez, Kruglanski, Pare´s, Ribas, Soler and Sanjurjo (2005) presented MEDIATE an interactive environment that provides real-time visual, aural, and vibrotactile stimuli for PAS children. The primary aim of MEDIATE is for children to have the possibility to experiment, and

be creative in a predictable, controllable, and healthy environment. In the study of Pares et al.Pare´s et al. (2006) the main aim is quite similar, to give the chance to children to be creative and to explore themselves. Williams et al. Williams (2008) designed an audiovisual immersive interactive environment to encourage creative interaction and expression from the participants.

9. Drawing skills: Anderson et al.Anderson, Panneer, Shi, Marshall and others (2018) conducted a second study to examine whether the use of a projected augmented reality (AR) character has potential for “learning through teaching”. The author demonstrated that children readily engaged with Oscar, the AR character, across multiple input modalities and were motivated to attend learning activities.

10. Learning skills: Anderson et al.Anderson, Panneer, Shi, Marshall and others (2018) conducted a first study to investigate if the usage of the projected character engaged children during a math exercise.
    Motor skills: .Garzotto et al. (2019) conducted a study to investigate the performance, behaviors, and attitudes of children with NDD using multisensory environments with an IoT (Internet of Things) empowered physical space (“Magic Room”). Graf et al. Graf et al. (2019) proposed using projected augmented reality (AR) in the form of an interactive floor system to facilitate co- located physical play experiences for people with mobility disabilities and their non-disabled peers. The key contribution of this was “iGYM,” a wheelchair accessible projected AR that allows people with all levels of ability and accessibility to manipulate virtual goals realistically on an immersive floor.

11. Play skills: Dow et al Dow et al. (2007) investigated the impact of immersion (and hopefully presence) on a rich narrative experience. Facade is the first fully produced real-time interactive drama combining autonomous characters, artificial intelligence (AI)-based story management, and natural language processing to place the player in a dramatic world. Through conversation, movement and emotive gestures, the player interacts with the characters Trip and Grace, and quickly finds herself entangled in the dynamics of their troubled marriage.

12. Relaxation: In the study conducted to Gal.Garzotto et al. (2016a) the scene portrays a situation in which the primary objective is relaxing, with the child being immersed in a relaxing atmosphere with soft

lighting and calming music.

13. Real-life skills: The study conducted by Johnston et al. Johnston et al. (2019) tested the auditory spatial attention and sound localization capacity of children and adolescents with ASDs in a multi-modal virtual reality game world.

14. Reduce anxiety: Johnston et al.Johnston et al. (2020) presented SoundFields, an immersive virtual reality game that addresses this issue by incorporating exposure- based therapy approaches into game mechanics and providing target auditory stimuli to the player using binaural-based spatial audio. SoundFields is a method for reducing anxiety levels in response to identified problematic sounds.

15. Social skills: Garzotto at al. Arnone et al. (2020) combined the use of virtual and physical world stimuli in the MSE through different activities for children. The authors found that this approach led to an improvement of social and practical skills in low-medium functioning children with ASD. Garzotto at al. Gelsomini (2018a) conducted a study aimed at uncovering the Magic Room’s potential to promote skills in specific areas, and involved all children who participated in the design process. An activity “Pass the light” was developed. This activity aimed at practicing social skills and was inspired by the classic Circle Game. The goal of these kinds of activities in the study conducted by Garzotto et al. (2019) is to teach children respect for others and appropriate social behavior, e.g., waiting while others are playing and the turn taking need in social interaction. Mora-Guiard et al. Mora-Guiard et al. (2016) designed a full- body immersive environment in which children with HFASD could learn social interaction behaviors and the advantages of teamwork while playing, experimenting, and becoming creative with a typically developed partner. This research in ASD intervention consists of finding mechanisms for social initiation (making demands, joint attention, non-verbal communication, etc.) to help the children to realize that to collaborate with others is better than to work on their own. One of the hypotheses of the research says: “full body interactive experience would increase the propensity of each child to engage with other people”. Ringland et al. Ring- land et al. (2014a) examined how natural user interfaces (NUI) with whole-body movement-based and concrete gestures can assist sensory integration therapists. Takahashi et al.Takahashi, Oki, Bourreau, Kitahara and Suzuki (2018b) describes

development of the FUTUREGYM system which aimed to provide children with ND the opportunity to learn from their peers how to build social relationships, and build self-esteem in order to realize successful inclusive education. Learning performances: In the study conducted by Cosentino et al. Cosentino et al. (2019), demonstrated how personalized and multisensory learning improves children's performances and teachers' work. Children have different abilities, inclinations and problems, and each learning process takes a different time and uses different learning strategies. Garzotto et al. (2020a) investigated how MSEs can be used to provide supportive environments for community interactions in- volving primary school children with different abilities. According to Garzotto et al. (2020a), even a relative short experience in the Magic Room might positively affect perceived well-being in the school integration environment, especially for atypical children . In the study conducted by Garzotto et al. (2019) activities were designed to train children to build associations between objects or shapes, and colors. Another study conducted by Garzotto et al. Gelsomini et al. (2020) investigated whether IMAGINE can facilitate children's learning. The research was focused on a comparison of the learning process in a traditional classroom and the one in IMAGINE with the goal of determining the effect on children's learning outcomes.

### 2.12.10. Who are the intended users of the papers, and who are the secondary users?

Each study includes two types of participants: primary user and secondary user. In most of the papers primary users are children with ASD. In studies with inclusive education, primary users include both children with and without neurodevelopmental disorder.

The Figure 3.11 represents 3 groups of primary users in selected studies. The graph shows that the primary user group with only atypical children is the most prevalent with 19 of the primary users being atypical children. 5 of the studies included inclusive education users and 4 studies included only neurotypical primary users. The secondary users are teachers and caregivers. **Table 4** shows primary and secondary user for each article.

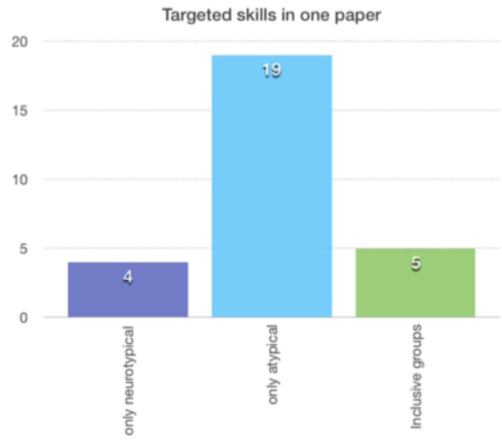



**Fig. 3.11** Primary users groups in the study.

### 2.12.11. What specific features of MSE technology are highlighted in the papers?

Researchers in the study have used different types of Interactive Smart Spaces (ISS) technology. Based on the research conducted by Garzotto et al. ISS technology is divided into two types depending on interaction, intensity and content. These are; Automated Interactive Smart Spaces (having low interaction intensity and low content intensity) and Multisensory Smart Spaces (having high interaction intensity and high content intensity) Garzotto et al. (2020b).

Automated Interactive Smart Spaces are digitally enhanced physical spaces in which IoT devices orchestration and optimized computing resources have been largely finalized to automate certain activities or ambient features.

Multisensory smart spaces are defined by the ability to produce a broad range of digital media contents and sensory effects that activate all senses, as well as various modes for the user to communicate with devices, digital contents embedded in physical spaces and smart objects. Special features of MSE are shown in the **Table 5.**

### 2.12.12. What types of research designs were used to evaluate the effectiveness of MSE?

Trochim et al. illustrate the different types of research-based design (Trochim and Donnelly, 2001). These research designs are mostly used for evaluations in educational contexts. The first design is a posttest-only randomized experiment. The second design is a pre-post nonequivalent groups experiment. It's not a randomized experiment because random assignment wasn't used. The last one is posttest-only nonexperimental design.

Among the primary studies, the pre-test and post-test design was the most used design within 12 of the studies, Similarly, the second most used research design was post-test which was used in 8 primary studies. Pre-test and post-test control groups were used in five studies and lastly, the post-test control group design was used in 3 studies.

### 2.12.13. What settings are the papers discussing as potential applications of MSE?

Selected studies include the following context of use: therapeutic center (9), classroom environment (9), controlled research environment (8) and the gymnasium in the schools (2). The study using the post-test and post-test control group was within a classroom and controlled research environment Gelsomini et al. (2020).

### 2.12.14. What metrics were used to measure the effectiveness of MSE as a learning tool?

In the Khowaja et al study, the evaluation parameters have been categorized and presented in two types: machine-assisted and human-assisted (Khowaja et al. 2019). The machine data collection methods use a programming code to automatically monitor the behavior of the participants and measure their results (programmatically) (Ojeda- Castelo et al. 2018). Human-assisted evolution parameters are included in the criteria manually marked by a person to obtain views on topics, attitudes, or behaviors (inter- view, questionnaire, focus group, and observations are all human-assisted). We provide a table, where all the evolution parameters are indicated. Based on the information in this table we conducted an analysis which is shown below (Table 6).

Machine-assisted evaluations include using a set of multimodal multisensory activities which support interaction with 'smart' objects designed to stimulate neural systems. The program tracks the body position and the reactions of the child, their emotions, gestures, pose or facial expressions in the 3 axes of motion. Each movement has its own meaning in deciphering the behavior of the child. These settings vary across studies. Also, the movement of the child in the room space in relation to other participants is delayed thus allowing the measuring of cooperative, collaborative and social skills. A human-assisted evaluation is used when watching a live session, or one recorded to show user interaction with the app, to calculate and to fully analyze the human body responses.

Human-assisted evaluation (HAE): In the study conducted by Dow et al. Dow et al. (2007) each participant played the Facadee video game three times. Between each episode the authors did open-ended interviews. Garzotto et al.[6] used the mixed evaluation approach where observations were annotated manually by the observer to record the relevant phenomena in children's behavior. In the studies conducted by Garzotto et al. Garzotto et al. (2020a), Garzotto and Gelsomini (2018a) the researchers did observation reports, analysed video recordings and carried out a final interview with the entire therapeutic team. Gelsomini et al. Gelsomini et al. (2020) based their data analysis on school tests results. Graf et al. Graf et al. (2019) analyzed interviews with caregivers. Mora-Guiard et al. Mora-Guiard et al. (2016), Mora-Guiard et al. (2017a) focused their research on the evolution of user engagement. Studies Pare´s et al. (2006), Pares, Masri, van Wolferen and Creed (2005a), Ringland et al. (2014a), Ringland et al. (2014c), Takahashi, Oki, Bourreau, Kitahara and Suzuki (2018a) use qualitative evaluation by psychologists.

Programming-assisted evaluation (PAE): In the study by Anderson et al. Ander- son, Panneer, Shi, Marshall and others (2018) gestures, pose, facial expressions and the distance of the child from the AR character Oscar were used as evaluation parameters. Cosentino et al. Cosentino et al. (2019) used spoken language, body position, different gestures and movements in analysis and evaluation. In the study undertaken by De Luca et al.De Luca et al. (2021) a camera was used to record children's movements. At the end of each session a full list of all the exercises performed was analyzed and scored. Dow et al.Dow et al. (2007) used the mixed evaluation approach - HAE and PAE in their study. The authors also collected quantitative data such as player and character dialog, body/head position and rotation and AI processing logs. In the study by Garzotto et al.Garzotto et al. (2020a) final feedback was collected from children using a four values Smiley-ometer. In the study presented by Garzotto et al. Garzotto et al. (2019), Garzotto et al. (2016a) data generated by brain-computer interface, (EEG monitoring technology), has been used by Kanellos et al. Kanellos et al. (2018). Hotz et al.Hotz et al. (2006) evaluated heart rate, blood pressure and muscle tone. In the study conducted by Johnston et al. Johnston et al. (2019) two-way mixed ANOVA (analysis of variance) was used to evaluate participants. In the study Johnston et al. (2020) Johnston et al. used an interaction tracker and the Smiley-face assessment scale. The research of Takahashi et al. Takahashi, Oki, Bourreau, Kitahara and Suzuki (2018b), Takahashi, Oki, Bourreau and Suzuki (2018) analyzed the position of each child during running. Williams et al. Williams (2008) captured children's gestures through a digital camera and mapped these to computer vision algorithms to create a ‘moving painting’.

The Figure 3.12 shows that of the selected studies: 12 use Human-assisted evaluation, 14 use Programming-assisted evaluation and only two studies use mixed evaluation.

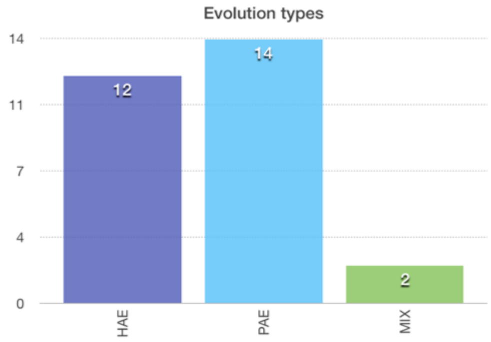



**Fig. 3.12** Evaluation parameters in performance analyze.

### 2.12.15. What evidence is provided to support the effectiveness of MSE in improving learning outcomes?

The results of the primary studies are presented based on the groups used and the skills targeted in the studies. The results of each study are briefly described below:

1. Learning Skills: The Qualitative indicators from the first study by Anderson et al.Anderson, Panneer, Shi, Marshall and others (2018) showed that children engaged with the AR character Oscar in many ways.
2. Drawing skills: In the second study by Anderson et al.Anderson, Panneer, Shi, Marshall and others (2018), based on qualitative observations, the author noted that one indicator of engagement was body positioning – specifically how closely children approach the animated agent.

Social Skills: The authors in the study Arnone et al. (2020) demonstrated the flexibility of the Multisensory environment The interactive MSE ‘Magika’ allowed researchers to easily integrate a new tangible interface according to the needs of children and therapists. In the study conducted by Garzotto Garzotto and Gelsomini (2018a) comparing the first and the last sessions showed an increment of 28 % in the relational area and 64 % in communication. The latter was mainly associated with improved verbal skills and intentional communication. Collected data from the study of Garzotto et al.Garzotto et al. (2019) indicated that the Magic Room has a strong potential as a learning environment for children with NDD. The encounters in the Magic Room have elicited functional performances, social interactions, and emotional reactions that either do not occur with conventional MSEs or take much more time to be done. According to the results of the study by Mora-Guiard et al. Mora-Guiard et al. (2016) the children increase in social behaviors over the course of the sessions and children respond positively with willful engagement in collaborative play. According to the findings of Ringland et al. Ringland et al. (2014a), Natural User Interfaces (NUI) such as SensoryPaint could specifically promote social engagement by including aspects of a multiplayer game with common goals relating to target practice and drawing, as well as the use of short, goal-oriented narratives. According to Ringland and Hayes et al. Ringland et al. (2014c) during their deployment study, participants collaboratively used the system often. Parents and therapists noted that children improved their language and social skills while using the system.

Learning performances: In the study conducted by Cosentino et al. Cosentino et al. (2019), according to Garzotto et al.Garzotto et al. (2020a) findings, even a relative short experience in the Magic Room might positively affect perceived well-being in the school integration environment, especially for atypical children. In the study conducted by Garzotto et al. Gelsomini et al. (2020) children's ac- quired notions were gathered through the senses and relayed to short-term memory where, through repetition and rehearsal, they were committed to the semantic (long-term) memory. These results also confirmed that each child memorized al- most double notions per turn when performing in IMAGINE, compared to when exercising in the classroom.

Cognitions skills: In the study conducted by De Luca et al. De Luca et al. (2021) the combined approach provided an improvement in spatial cognition skills with a significant reduction of ideomotor stereotypes. Collected data from the study by Garzotto et al. Garzotto and Gelsomini (2018a) show the strongest improvements in this area. The values in the last session are almost double those in the original session. In the study conducted by Garzotto et al. Gelsomini et al. (2020) it showed that the improved result may be linked to the wide range of different interaction styles and the multiple senses involved which makes it easier to find the learning modality that best suited the subjects'natural inclinations. Collected data from the study by Hotz et al. Hotz et al. (2006) show some beneficial effect on decreasing the level of agitation, with considerable variation between individual subjects.

Attention process: In the study conducted by De Luca et al. De Luca et al. (2021) the combined approach resulted in an improvement in the attention process. The analysis of the results in De Luca et al. (2021) show a significant enhancement in the other cognitive domains. After the use of the combined approach (CBT in a VR environment), there was a significant increase in the attention processes, as shown by the improvement of MTCM. The findings of Ringland and Hayes et al. Ringland et al. (2014c) showed how a multimodal large display, augmented by whole body interaction, tangible interactions and immersive audio input helps children balance their attention between their own bodies and sensory stimuli. The result from the study of Takahashi Takahashi, Oki, Bourreau, Kitahara and Suzuki (2018a) showed that the children succeeded in completing the game task, so the game has the potential to help them focus their attention on learning by implementing an element of fun.

Adaptive behavior: Collected data from the study by De Luca et al. De Luca et al. (2021) supports the idea that the combined rehabilitative treatment using CBT with VR may be a promising tool in improving cognition with regard to attention and visuo-spatial skills, supporting a better adaptive behavior in neurodevelopment disorders such as ASD.

Play skills: The qualitative data of the results Dow et al. (2007) shows that an increased sense of presence in Facade does not necessarily lead to a more engaging play experience, contrary to the assumptions in the literature of presence. Immersion and the sense of presence were thrilling and new for some players, but the experience seemed to cross a comfort barrier for others, where they no longer felt like they could play freely.

Autonomy: Collected data from the study by Garzotto et al.Garzotto et al. (2020a) confirmed these results, highlighting a higher degree of children's engagement in the Grocery game.

Motor skills: Collected data from the study by Garzotto et al.Garzotto and Gelsomini (2018a) show the improvements observed here were smaller than in other areas. Even so, most children showed a much stronger attitude to movement than in daily tasks, according to caregivers. According to the results of the study by Garzotto et al.Garzotto et al. (2019) it was found that some changes in motor skills in each infant don't take into consideration the individual variations in intellectual functioning and adaptive behavior. According to therapists, these changes can be ascribed to the richness of experiences and sensory stimulation provided by the various smart elements, the capability of bridging the real and the virtual environments. The authors in the study Graf et al. (2019) showed that the system was accessible to people using wheelchairs.

Relaxation: According to Garzotto Garzotto et al. (2016a) the collection and interpretation of brain signals during ID children's activities, as well as in relation to controlled stimuli in smart spaces, allows for the creation of a body of therapeutic data that can expand current scientific knowledge and practices in the ID field.

Real-life skills: Collected data from the study of Johnston Johnston et al. (2019) show that, considering autism-related impairments in processing ITD and ILD binaural signals Garzotto et al. (2020a), spatial audio was capable of accurately attracting participants to areas of the virtual world relevant to the position of the auditory stimulus.

Reduce anxiety: According to Johnston Johnston et al. (2020), a comparison of pre- and post-study anxiety related to target auditory stimuli showed a significant reduction in anxiety.

Collaboration Skills: The results from the study of Mora-Guiard et al.Mora-Guiard et al. (2017a) shows that the children became more confident in the virtual environment with their partner, and they preferred to play together and share the experience rather than play alone.

Creative skills: Collected data from the study of Pares [20] showed excellent results in the expressivity of the children. The results from the study of Williams et al.Williams (2008) showed increased environmental engagement, atypical communicative responses in the case of the ASD boy, highly articulated gestural ex- pressions, and increased vocal utterances.

Communication skills:  The results of the study 21 Pare´s et al. (2006) showed that the children found in MEDIATE at least one of the proposed interactions and successfully played with it. According to Pares et al. Pares, Masri, van Wolferen and Creed (2005a) children, who need very rigid daily routines and who do not cope well with unknown places, have actually become curious enough to enter MEDIATE by their own will and start playing.

Cooperation skills: The results of the study Takahashi, Oki, Bourreau, Kitahara and Suzuki (2018b) showed that each student increased their cooperative running behavior in contrast to the other members of the school . It emphasizes the opportunity for behavior modification brought by practice with visual instruction.

Cleaning skills: According to Takashi et al. Takahashi, Oki, Bourreau and Suzuki (2018) all the children completed the game without giving up and they showed positive emotional expression. The Mop Game has the potential to help students focus on cleaning behaviors when having fun, as well as encouraging social activities such as collaboration and cooperation.

### 2.12.16. What are the results of using MSE in papers?

The Figure 3.13 shows future work indicated in selected papers.

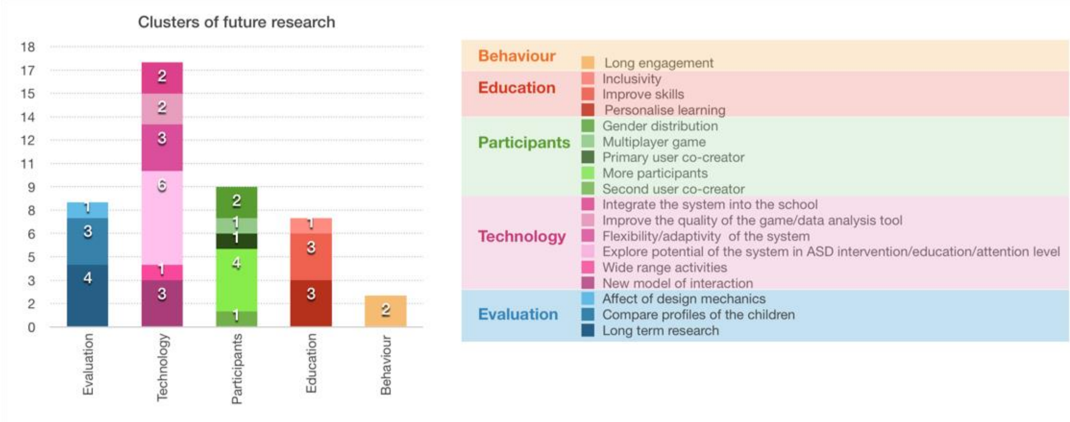



**Fig. 3.13** Clusters of future research.

Future works themes shown in the color column include evaluation, technology, participants, education, behavior. Each rectangle represents a sub-theme, and the value of N inside the rectangle is the frequency of the selected paper in which the sub-theme was discussed. The table on the right shows a detailed description of the sub-theme in each category. Keep your font size consistent.

We can see on the graph that the prevailing number of selected papers indicates that technology is the largest area for future work and is the most popular sub-theme for exploring the potential of the system, new model integration and wide-ranging activities. Some of the authors conduct two or more sub-theme plans. For example, Anderson et al. Anderson, Panneer, Shi, Marshall and others (2018) plan to develop a creation-themed application and provide a new interaction model with characters from movies and television.

### 2.12.17. Conclusion of the Systematic Scoping review

In this research, the author focused on the analysis of the skills intended for learning in the selected articles as well as on the methods of measurement and the results achieved. A detailed analysis of the training properties of the multisensory system, possible methods for measuring results and prospects for development was carried out. In this part of r studies, it is highlighted the main findings in the studies related to the research questions. Garzotto and Gelsomini have more studies regarding interacting children with ASD within a Multisensory environment. Italy is currently leading the research in this field. The US, Spain and the UK also have achieved good results in this field. The selected papers are prevalently related to the computer science subject area and psychology. Most of the chosen papers present several learning skills in one study. Most of the activities described in these papers are focused on the development of social skills, cognition skills, and motor skills. Other skills such as creative and emotional skills are paid less attention. Due to the study criteria all the study as the primary user includes children with ASD. The secondary user appears to be the caregiver or teacher, depending on the context of use. Secondary users were often co-designers of deductive material, they participated in the creation of the evaluation system and took part in observing children during the execution of the assignment. In Human-Assisted evaluation caregivers did the job of analyzing the children's performance and behavior. According to the paper selection criteria, all the papers describe the Interactive Smart Spaces technology. The best educational properties were shown by interactive multisensory systems that have control and adaptation settings. The Multisensory project without active interaction, like the Snoezelen project Hotz et al. (2006), shows a good result in relaxation. The two most frequently used research designs included both pre-test and post test.

The influence of the educational program on the child is shown more clearly in pre-test and post-test research design. Two data collection methods noted in the selected studies were human-assisted evaluation and machine-assisted evaluation. Preferable, but less used in the selected research, is the combination of these two data collection methodologies to foster the robustness of the Multisensory system and evaluation.

The results of the studies show that children became more confident in the multi-sensory environment when with their partner and that they preferred to play together and share the experience rather than play alone. They also showed that children increase in social behaviors over the course of the sessions and that they respond positively with willful engagement during collaborative play.

This study shows that the multisensory system has great prospects for further future development in helping children with Autistic spectrum Disorder to achieve their potential.

## 2.13. Does the Multisensory environment foster creativity?

### 2.13.1. A multisensory Environment shows promising results

In the analysis of the literature presented in the previous paragraph, we could see that significant results in multisensory rooms were achieved in the development of physical action, engagement, and social behavior. The author showed many studies conducted by Garzotto et al. in the multisensory room Magic Room. Let's focus on Garzotto's et al. recent research in Magic Room. What promising results does Magic Room show?

An MSE, generally, refers to a dedicated indoor physical spaceequipped with physical materials and devices that provide stimulation for multiple senses. Only a few scientific studies have examined the multisensory environments influence on group and individual creativity. There exist some gaps in the research on creative thinking, such as the fact that collaborative effort frequently results in the enhanced production of new information and knowledge. Therefore, it is critical to evaluate creativity via social settings in Smart Spaces and in traditional educational spaces.

Only some studies with creative settings are known. Stimulating spontaneous natural social interaction in the presence using a human-computer interface is one of the most challenging design objectives. There are several reasons for this, but the main one is that designers must let users start autonomously or spark a social interaction while using shared or distinguished devices. For this reason, iMSEs are one of the most suitable solutions to perform such research: they present a shared space that hides the computer-controlled devices, in which the children are immersed in a general playful activity.

Several examples of this approach have been used in the past years, from more artistic installations to therapeutic ones. For example, Lind's Lines Lind (2020), and TeamLab's artistic installations Haslem (2020) represent examples of how to use iMSES to stimulate creativity in children. In the first case, users can compose music by selecting notes and tones by interacting with the room's walls. In the second case, among the several possible interactions available in their installations, generated graphics are distorted by the presence of the users and can even impact the environment of a second installation, making the user the artists themselves.

A similar theme had been analyzed in Gunplay Crowell et al. (2018), and in Sensory Paint Ringland et al. (2014b). In the first case, a similar generative art approach was used: two children (one autistic and one typically developed) can interfere with flows of particles to create streams as artistic setups.

First, children were observed playing freely with the environment without knowing the rules. Children then creatively tried to decipher the game rules and create the stream flow they liked most. In the latter, two children (one autistic and one typically developed) were asked to paint on a digital canvas by touching the projected surface or using smart objects like brushes. The primary aim of SensoryPaint was to stimulate the capability of children to communicate and socialize. Even if it was not the main focus of the research, there were also exciting hints at the artistic development of users. However, having yet to explore the artistic development of children further, there is a need to explore further the use of iMSEs on children's creativity and artistic

development.
In Lands of Fog Mora-Guiard et al. (2017b), instead, two children, one with ASD and one typically developed, are required to discover the hidden elements of the game. To do so, they must cooperate and move in proximity to the target to interact with it. In this case, the social skills involved are more communication-oriented than creativity-oriented, which is more connected to discovery. However, given that children are not explained the discovery mechanism, nor the objective they have to reach, it is arguable that a certain degree of creativity is still required to complete the experience. Also, complex social interactions (e.g., agreeing or compromising with the other player to achieve specific desired results) can be considered fundamental in a shared collaborative creation process.

Pares et al. (2005) presented MEDIATE, an interactive environment that provides real-time visual, aural, and vibrotactile stimuli for PAS children. The primary aim of MEDIATE was for children to have the possibility to experiment and be creative in a predictable, controllable, and healthy environment. Williams et al. designed an audiovisual immersive interactive environment to encourage creative interaction and expression from the participants.

The known results in Smart Spaces with creative settings are promising. Collected data from the study of Pares showed excellent results in the expressivity of the children. The results from the study of Williams showed increased environmental engagement, atypical communicative responses in the case of an ASD boy, highly articulated gestural expressions, and increased vocal utterances. These promising results inspired the author to conduct a further experimental study.

# 3. CHAPTER – Methodology

Different methodologies were considered to achieve the research goal. The first methodological approach included outcomes related to empirical studies investigating the promotion of creativity in children's diversity and systems' propensity for fostering free exploration of children with special needs. Empirical research included designing, conducting, and analyzing focus groups, extracting criteria for creative activity inside the multisensory environment and guidelines for developers and teachers. The experience gained in the previously described projects and based on the state-of-art analysis, was used together with the results obtained by focus groups to build guidelines for developers and teachers. The second methodology included the ideation phase, design sprint sessions, overseeing the development session and running interactive prototype testing in a "Magic Room". As a result, a generative game was developed and empirically evaluated by teachers. Practical exercises comprised the third methodology. Due to the COVID-19 outbreak, experimentation in the Magic Room and the Scintillae Research Laboratory had to be limited to reduce health risks. Nevertheless, both places were able to be used to perform creative activities and to conduct experimentation with children and young adults. In the Magic Room the generative game was tested through experimentation with children. This study included 8 participants whose ages ranged from 8 to 12. The findings revealed a link between social interactions, creative actions, creative thinking, and creativity. In the Scintillae laboratory thirty participants (young adults), in groups of 3, carried out a LEGO mosaic-related creative task. In the other practical study in the Scintillae laboratory, the research team observed children's creative process in groups. The children, aged from 6 to 12 years old, were placed in groups of 3-4 and asked to construct their ideas of an "educative community" using mosaic LEGO dots.

The experimental part takes place in two practical educational spaces: Creative Space Scintillae and the technological space Magic Room. The main aims of the Experimental feature were to investigate the following: In Scintillae.

## 3.1. Research questions of the phases and hypotheses

**First phase. Scintillae**

1. What creative and social interaction behavior do children express while performing creative tasks?
2. What is the relationship between social interaction and creativity?

**Second Phase. Data capture methodology**

1. How do multiple observers agree on the observational focus during the creative process experiment?

2. How synchronized is the operation of the multiple observers?

3. Does the observation technique of the multiple observers change during the experiment session, and how does it change?

4. What tools can be used to enhance inter-observer agreement and reliability?

Hypotheses:

5. H1: Synchronization of participants increases in direct proportion to the time spent together.

6. H2: The number of fixed behavioral variables observed by multiple observers increases with each new day of the experiment and increases with each new session.

**Third phase. Study 1**

1. What elements can be appreciated from the child, and which can be seen as boring?

   (a) How long can the experience last before the child gets bored?

2. Do we really stimulate explorative behavior in the child?

   (a) Are there any distractions that prevent the child from trying to reach the goal?

3. Is this game actually collaborative, that is, are the kids motivated to collaborate and socialize?

**Third phase. Study 2**

4. What are some difficulties that an atypical child can encounter by playing the

game?

5. What can be improved in the future?

**Fourth phase.**

1. Does a correlation between social interaction and creativity exist?
2. Does a correlation between creative thinking and creative action exist?
3. Does a correlation between creativity and engagement exist?

## 3.2. First phase. Scintillae. A case of experimentation with children

Scintillae is a space dedicated to exploration and research on play and learning in the digital age, open to children, and adults of all ages including teachers, educators, and researchers. This space was realized through a partnership between Fondazione Reggio Children – Centro Loris Malaguzzi and The LEGO Foundation. Fondazione is located in Reggio Emilia a city in Northern Italy, in the Emilia Romagna region and with a population of approximately 150,000. The historical traditions of the city are about social cohesion and the formation of the significance of the rights of individuals based on democratic values. In 1940, Loris Malaguzzi began teaching in elementary schools in the province of Reggio Emilia and in April 1945, he became a participant in an ambitious project involving people of a peasant and working origin. The project's goal was to build a self-governing school in a small village near Reggio Emilia. In 1963 the Municipality of Reggio Emilia began organizing a network of educational services which included the opening of the first kindergarten for children aged 3-6 years (Baucyh & Boszilkov, n.d.). The schools came under the leadership of Loris Malaguzzi and he became the first Director of the Reggio Emilia schools (Balfour, 2018). Cagliari and colleagues write, "Loris Malaguzzi was one of the most important figures in twentieth- century education. Devoting much of his life to early childhood education and the municipal schools for young children in the Northern Italian city of Reggio Emilia, he has gained an international reputation in this sector" (Moss, 2016, 12). To preserve and share the ideas and accomplishments of Loris Malaguzzi, the center naming him was established (Rinaldi, 2021).

In 2021 the Loris Malaguzzi Center turned ten years, and they invited the city to participate in the workshop and to create a collective installation with the support of the LEGO Foundation. The material for installation was a LEGO Dots kit, which contained the base, a bag of dots, and the card. It was created by Ricardo Zangelmi, a designer of LEGO Foundation and originally from Reggio Emilia. In Reggio Emilia, infant-toddler and pre-primary systems are grounded on the idea that all children, including very young children, have the right to an education, and the residents should be directly responsible for the education of the children. Thus, the workshop theme was "A community of living beings" (Baucyh & Boszilkov, n.d.; Carla Rinaldi and Fondazione Reggio Children - Centro Loris Malaguzzi, 2020). Furthermore, children and their parents were asked to "Represent the idea of living beings".

The current study's researchers participated in one day of the project that lasted one week. All the workshops were conducted in three phases: Introduction of the "Atelierista" a creative, collaborative process with LEGO dots of the child and the parent, naming the result. The “Atelierista” is an individual with a background in education and creative arts. He or she works directly with classroom teachers and simultaneously with teachers and students, devising and facilitating learning experiences that complement classroom curricular learning (Vecchi 2010). In the first part of the workshop, the “Atelierista” told the child that the Loris Malaguzzi Center is celebrating its 10th year, so that they would build a giant statue with LEGO pieces. Next, the children were asked to represent their idea of “A community of living beings.” When the children had doubts, the “Atelierista” asked support questions such as “What is the difference between living beings and inanimate?” and “What is a community for the child?”. Support questions gave the ideas to children before the creative process started.

### 3.2.1. Motivation of the study

The analysis of creativity within social contexts is crucial for several reasons. Firstly, it aligns with the requirement that a creative idea must be recognized and valued by others. The perception of value is often influenced by social factors, such as group dynamics and shared norms. Additionally, collaborative efforts in groups frequently lead to a higher production of novel information and knowledge. The collective input and diverse perspectives within a group can foster creativity and enhance the quality and quantity of creative output.

Furthermore, an individual’s social identity and sense of belonging to specific social groups play a significant role in their willingness to engage with others. The dynamics of their relationship with the group shape their perceptions and responses to both existing creations and attempts at innovation. It has been observed that individuals tend to approach and favorably regard products or ideas that are associated with their in-group or created by fellow in-group members. This highlights the impact of social identity on the reception and evaluation of creative endeavors.

Creativity itself is not a spontaneous occurrence but rather a result of various factors, including an individual’s creativity-relevant skills, domain-relevant skills, and motivation. By studying creativity within group settings, we gain valuable insights into how these factors interact and influence the creative process. Examining the presence of others and the dynamics of group interactions allows us to better understand how collaborative environments shape and enhance creative ideas.

In summary, investigating creativity in social contexts helps us grasp the social dynamics, value perceptions, and collaborative aspects that contribute to the generation and evaluation of creative ideas. By exploring the interplay between individual and group factors, we gain a more comprehensive understanding of the complexities of creativity and its social underpinnings.

### 3.2.2. Aims and Objectives of the study

The study explored the relationship between a playful, creative experience and in-presence group interaction. We aimed to investigate how children cooperate when asked to execute a creative task with LEGO, how they instigated social interactions, and how these influenced the children's creative process.
Our focus was on identifying repetitive behaviors and defining them into variables. Such behaviors were operationalized into two sets of categories. The first included variables relating to social dynamics. The second included variables relating to the creative task. The research questions focused on: (1) the identification of children's behavior variables; (2) dividing children's variables into two categories; (2) studying the correlation between variables.

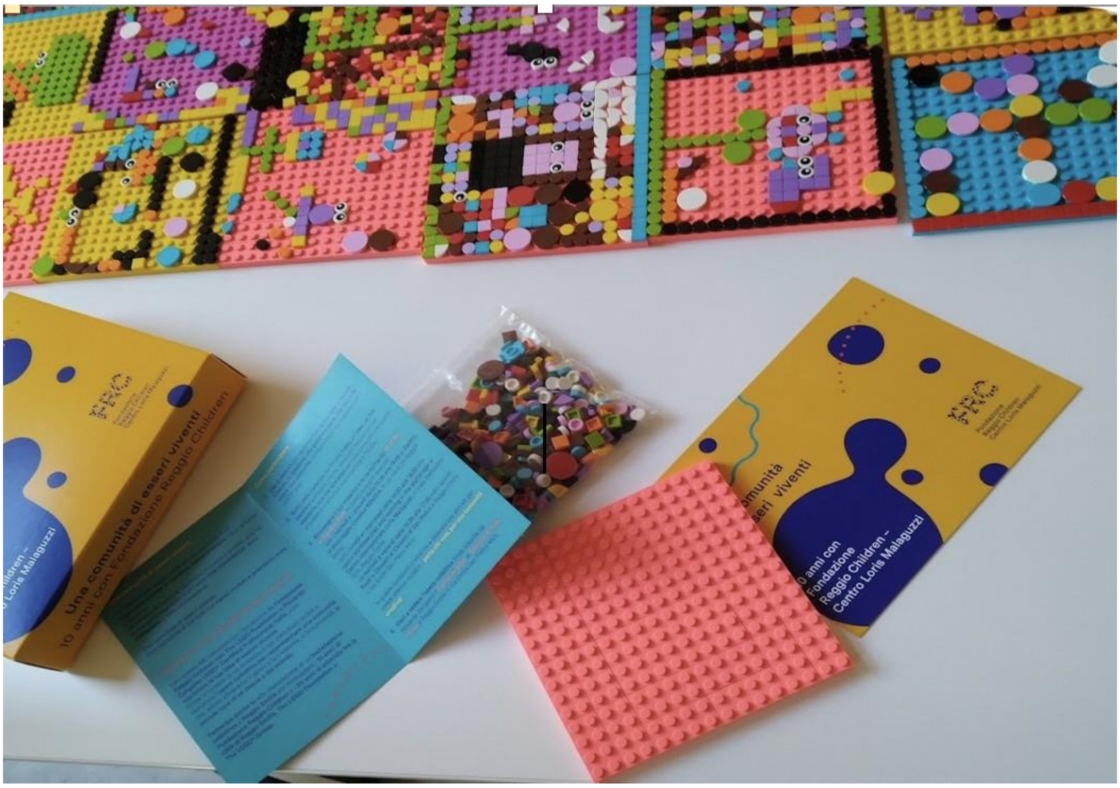
### 3.2.3. Problem statement and sub-problems

By using the term "creativity" author means 'everyday creativity. This is one of our most powerful capacities, bringing us alive in each moment, affecting our health and well-being, offering richness and alternatives in what we do, and helping us move further in our creative and personal development. Many people do not associate "creativity" with "everyday creativity." They believe creativity is related to the arts, sciences, or at the very least, unique fields of study. It might also be about unique indiviOduals, such as well-known scientists, authors, or painters. In this sense, creativity does not concern large groups of people. In this context, the term is less exciting and is not our focus. In this study author is interested in "Everyday creativity", it is about everything we do throughout our lives and is fundamental to our survival. It is not so much about what we do as how we do it. We are part of society, and our approach to realizing things depends on others. For this reason, it is essential to look at our everyday creativity in the context of social group interaction. With our everyday creativity, we adapt flexibly, improvise, and try different options in the context of social group interaction (Runco & Richards 1997, Richards 2007).

### 3.2.4. Description of Experiment

The study utilized an exploratory sequential mixed-methods design to investigate the group dynamics and creativity of the participants during the creative task (Berman,

**Fig. 4.1** Examples of LEGO created by children.




2017). This design involved initially collecting qualitative data, which was then followed by a statistical analysis of the observations made by the researchers (Wolfe, 2000). The qualitative component of the study involved carefully observing the participants during the LEGO experiment and documenting their behaviors. These observations provided valuable insights into the dynamics of the group and their creative processes. Additionally, detailed discussions among the researchers were conducted to gain deeper insights into the behavioral signals exhibited by the participants (Parlitz et al., 1996). By combining qualitative observations and statistical analysis, the study aimed to gain a comprehensive understanding of the group dynamics and creativity displayed by the participants. The experiment took place in the research laboratory Scintillae in Loris Malaguzzi International Center, Reggio Children Foundation. The participants constructed their ideas by using mosaic LEGO dots. While they created, they expressed different types of behaviors, such as social, collaborative behaviors. The duration of the creative process was a minimum of 21 minutes and a maximum of 45 minutes. In the end, the children named the mosaic and left their work as a part of the installation.

The research team observed the creative process of the 8 children aged 6 to 12 years old. They were in groups of 4, all accompanied by the parent.

The experimental study consisted of two sessions that took place on the same day. Each session was facilitated by a moderator who observed one group at a time. The duration of the experiments varied between 21 to 45 minutes, with the specific timeframe dependent on the creative task assigned to the participants. On average, a group session included a brief 5-minute introduction, followed by a 30-minute period dedicated engaging in the creative activity using LEGO Dots. Finally, the participants were given to 5 minutes to collectively name the results of their LEGO creations. The tasks involved collaborating in groups of four individuals and using LEGO Dots to represent their conceptualization of a community of living beings. All instructions and interactions during the experiment were conducted in Italian, and the process of translation was undertaken by one of the observers during the subsequent analysis phase.

## 3.3. Second Phase. Data capture methodology

The most used methodology is observational when it comes to analyzing behavior and identifying behavioral patterns. In this study, observation methodologies of 2 types, traditional and technological, were applied.

### 3.3.1. Critical view on State-of-Art

Observation is what we constantly do in our daily lives. We observe physical and social phenomena, as well as other people, and based on these observations, we try to understand and make sense of the world around us (Pare´s et al., 2004). Our daily observations form our folk theories. Bruner argued that folk theories provide us with a system of interconnected assumptions and beliefs that form the source of our knowledge about the world that we use to organize and make sense of new experiences (Bruner, 1990). Dewey comments that observation is a purposeful and intentional learning tool. Observation is used as a tool to offer concrete experiences to learn about the educational process or skill development (Dewey, 1910). For example, observation was a key tool for Piaget in understanding children's language and the cognitive processes involved in children's learning (Piaget, 1926).

Observation is a learning tool that can be used, such as learning about something or learning how we learn to understand our learning process. Therefore, we focus on observation as a tool to understand the learning process.

### 3.3.2. Objectives of the research

This part of the thesis investigates how multiple observer observations change throughout the experiment and for each session. Also, our research aims to identify the most suitable instruments for observation.

Firstly, our task was to agree between multiple observers on the type of observation. Observation has been described as a fundamental foundation of all research methods in the social and behavioral sciences. This is because diverse data collection methodologies use observation to enrich the collected data and lend meaning to the interviewees' words. Furthermore, social scientists observe human activities and the physical spaces where behaviors occur (Angrosino, 2007). Observations rely on a continuum such as structured to unstructured, responsive to pre-ordinate. Unstructured observation needs to be clearer on what it is looking for, while structured and semi-structured observations are evident on the issues to be observed. This part will focus on the structured observations, primarily conducted in artificial settings, and entirely structured by the researchers (Bryman, 2012; Cohen et al., 2007).

Second, an essential task for multiple observers was to conclude the observation grid. Structured observations are very systematic and generate numerical data. Numerical data allow comparisons between settings and situations and the noting or calculating frequencies, patterns, and trends. The observer is passive and nonintrusive, noting the occurrence of the studied factors (Cohen et al., 2007). Different epistemological perspectives make it difficult to find a definition of observation that encompasses both quantitative and qualitative approaches. For instance, behavioral observation focuses on the a priori identification and accurate coding of the presence and extent of specific behaviors. Qualitative observation focuses on processes and interactions described inductively and post hoc (Katz-Buonincontro Anderson, 2020). However, it is essential to identify activities, behaviors, and interactions to observe during the observation process.

### 3.3.3. Problem Statement

Since the results of experiments are formed on the results of behaviors variable, the method of determining behavior variables over time becomes dominant for author.  A method of observation have been chosen. Observation is a type of empirical research that uses first-hand accounts of real events in the real world to learn their distinguishing features and how they change over time (Katz-Buonincontro Anderson,

2020). Through observations, researchers can recognize behavior patterns as they unfold and note the most pertinent details and features (Cohen et al., 2007).
Usually, more than one observer participates in the observation process. All participants in the experiment must come to a co-centum to agree among themselves on what is included in their scope of review and what is less critical and can be excluded. Also, their work must be sufficiently synchronous. It is essential to check the interaction process of observers during all sessions of the experiment to confirm the reliability of the result.

### 3.3.4. Procedure of Experiment

Using the observational experiment with children as an example, author researched interaction and agreements between multiple observers. Three observers participated in the study. The study occurred in the Scintillae research laboratory at Loris Malaguzzi International Center, Reggio Children Foundation. A structured observation method was used to investigate the multiple observer dynamics throughout the experiment. Within this framework, an initial preliminary study formed the basis for the follow-up design of the agreement. Each observer recognized behavior patterns as they unfolded and made notes about the most pertinent details and features. More detailed discussions between the observers were conducted to gain in-depth insights into the behavior signals of participants in the LEGO experiment (Parlitz et al., 1996). As a result of the preliminary study, determining inter-observer agreement is crucial for developing and implementing observational measures. The observation grid was concluded in the pilot phase between the observers. Then the observation form was prepared in digital and traditional forms. The example of the digital grid can be seen in Figure 4.3.
All sessions were carried out in 3 days. The three observers observed one group at a time. The experiments lasted between 37-56 minutes, with the variation in time reflecting the creative task participants had to share. In addition, the observers observed one participant from the group in the presence (the participant's candidacy was agreed upon in advance between the participants) using the application and, if necessary, leaving comments. The remaining 2 participants were observed by observers by video recording separately after the experiment.

### 3.3.5. Third Phase. Study 1. Participatory design

This thesis chapter aims to contribute a set of guidelines and theoretical foundations which will be useful for designing and developing activities for promoting creativity in children with autism, based on a rigorous qualitative and quantitative analysis of a series of sessions of focus-group with teachers and observation of the child inside of the Multisensory Environment.

The first step of the participatory design we had implemented to analyze pack of activities and equipment realized in The Magic Room. These activities have been studied in such a way as to cover the widest possible set of requirements of experts in the field of social interaction and creative environment for children with autism.

### 3.3.6. Focus Group

In the current study, an exploratory sequential mixed-methods design was used to investigate the beliefs and experiences of practitioners who worked as support teachers and promoted creativity. Within this framework, an initial qualitative investigation formed the basis for the follow-on design of the game/activity. The qualitative study is built on the grounded theory methodology. More detailed focus group discussions were conducted to gain in-depth insight into the beliefs and experiences of educational practitioners about the educational environment that supported the creative expression of autistic children.

Our objectives were:

1. Profile of the child
2. Identify the most promising areas of creativity
3. Identify materials, contents, and tasks that can help to develop creativity in the Magic Room.
4. Identify opportunities to transfer such activities to contexts outside the Magic Room (e.g., classroom, home)

### 3.3.7. Participants

Fourteen female practitioners from 31 to 60 years old took part in the Focus Group. Practitioners were teachers from Italian Kindergarten, Primary and Middle schools, and

the majority had a work experience from 11 to 40 years. The selection criteria for participants in the focus group encompassed two key aspects: having experience as a support teacher and being located either in the town of Reggio Emilia or the wider region of Reggio Emilia. The determination of the sample size followed guidelines established by Miles and Huberman (1984), Zuckermann and Glaser (1968), and Hillman and Radel (2018). It is important to note that all participants willingly provided informed written consent to take part in the study.

### 3.3.8. Material and procedure

The focus group schedule was refined using a framework outline based on the research questions (Strauss Corbin, 1990). The focus group was repeated twice. The focus group was performed online using Microsoft Teams. The presentation of the Magic Room took approximately 20 minutes of presentation time and 60 minutes of discussion time. First, there was the description of the Magic Room using slides and videos, and then a discussion was held. The Focus group discussion was in Italian, and then the final results were translated into English. Focus group sessions were recorded through Microsoft Teams and then stored in the principal investigator's OneDrive (linked to the institutional account of the university). Slides, a video presentation of the Magic Room, and informed consent were the materials used in a focus group.

The focus groups lasted between 86-102 minutes, with the variation in time reflecting the amounts that participants had to share. The discussion was divided into thematic groups of questions. Questions were based on the objectives of the study. The focus group discussion began with the child profile questions, followed by questions about creative expression in a traditional environment and then about the Magic Room. The focus group then explored the possible effect of the equipment in the MSE, in terms of stimulating creativity, for typical and atypical development in children. The last group of questions investigated opportunities to transfer creative thinking to contexts outside the Magic Room (e.g., classroom, home). The focus group questions were structured and did not provide further follow-up questions. Each participant answered all questions, and the focus group sessions were audio-recorded for later transcription.

### 3.3.9. Data Analysis methodology

The qualitative analysis of each focus group session was conducted, and subsequent comparisons were made between the results of all sessions. The analytical framework employed in this study follows the Grounded Theory approach and comprises two primary phases: semantic analysis and contextual analysis (Long et al., 1993; Schilling, 2006; Scott Glaser, 1971). These phases provide a systematic and comprehensive method for analyzing the data obtained from the focus group sessions.

### 3.3.10. Semantic Analysis

Semantic analysis of the focus group started from the audio transcription. It was made in Microsoft Word and transcribed in a OneDrive institutional account. We worked with original Italian language audio and transformed it into an Italian language text file. We identified speakers and excluded phrases belonging to the mediator for reliable analysis. Author automated semantic analysis and divided it into two stages. The first stage included screening the transcription and preparing it for data processing. It was done automatically by the algorithm in which we applied the Natural Language Toolkit (NLTK) (Bird et al., 2009). This algorithm deleted stop words and punctuation, and then by using the replace function, it standardized the words. For the second stage of the semantic analysis, we developed a Machine Learning algorithm to facilitate the semantic data processing of the Focus group. The algorithm was tested on the data of the two focus group sessions. The main objective was to examine the data for patterns or repeated ideas that emerged. We implemented it by measuring the frequency of the words in a document and finding the most relevant word combinations. We utilized Scikit-learn machine learning library as well as Numpy, Pandas, and Regular Expression to realize this operation. We applied a CountVectorizer method to convert a text document to a matrix and token counts (Mohapatra et al., 2022; Zhel, 2020).

The result represents the repeated ideas and their weight in the text. We programmed in the setting of the algorithm to represent 30 repeated ideas. We identified the repeated ideas by using the Tfidf Transformers method. In the algorithm setting, we limited our search area by phrase, including from 2 to 2 words. The order of ideas in the tables depends on their weight in the text (from largest to smallest). We excluded repeated ideas from the next step of the analysis which represent general information. After filtering the result, we got 17 repetitive ideas in first session of the Focus Group and 18 repetitive ideas in the second session of the Focus Group. We assigned a code to each chosen repeated idea to decrease the weight of the text. In Table1, F1-F17 are assigned codes, and in Table 2, F1-F18 are assigned codes.

### 3.3.11. Contextual Analysis

Author arranged a set of codes which we applied to categorize our data based on the semantic analysis results. At this stage of our analysis, we returned to the original text of the focus group and looked at the context of the sentences where our codes appeared. To make this stage of the work accurate and fast, we created an appropriate algorithm. This algorithm found the sentences where those codes were mentioned. By using this algorithm, we extracted all sentences with our codes. This stage presented the extracted sentences and the number of codes in each sentence.

In extracted sentences, we identified anchors (patterns) that allowed the key points of the data to be gathered. We got a set of codes that we applied to categorize our data based on our initial ideas and the semantic analysis results. We assigned codes to the data in the sentences. In this part of our analysis, we used the open coding technique of the Grounding Theory (Lotto, 1986). Similar patterns from the sentences were grouped into higher-order categories. We did categorization in sentences by combining patterns into subcategories and then subcategories into higher-order categories. We looked for new subcategories (patterns) and refined old patterns in the chosen text. We sorted all sentences with repeated codes by pattern and presented them in the form of an excel table. The results of our work were two tables with identified patterns. Tab. 1 represented the first session of the Focus Group and included 48 patterns. We assigned codes C1-C48 to the patterns. Tab. 2 represented the second session and included 33 patterns. On this table, C1-C33 are the patterns. In the spreadsheet, we marked the repeating patterns into subcategories.

We used the actual coding technic of Grounding Theory. The categories and subcategories are assembled into causal relationships that tentatively explain the phenomenon of interest (Schilling, 2006). We started by identifying recurring ideas in the patterns and marked them in our table to reach this objective. On Tab.1 and Tab.2, Matches were marked with the symbol “X”. After we checked all possible coincidences of repeated ideas in the patterns, we moved to the next step. We observed the relationship between the patterns. To exclude less significant and less meaningful relations between the patterns, we considered only the relation between two patterns that had two or more coincidences of repeated ideas. We identified all possible relations between the pattern that meet above requirements. Our work showed 157 detected relations in Focus Group session one and 167 detected relations in Focus Group session two. Then we used statistical methodology to calculate the number of relations of each pattern and the number of mentions of repeated ideas. Thus, we can calculate the weight of the significance of an individual pattern relative to the total number of detected relations of the patterns. Significance was determined by correlation between the total number of patterns relation and specified pattern relations. We considered pattern relations that have two or more repeated concepts.

As a result, we can see a hierarchy of patterns, depending on how many ideas are mentioned in the code and how many links with other codes it has. Tab. 3 (A) shows the result of the analysis of the first session, and Tab. 3 (B) shows the result of the analysis of the second session.

We have built charts for a visual demonstration of the most significant patterns. Charts represented correlation between two points of data: the pattern and percent of patterns relation. In Fig. 1, we can see a representation of the most significant patterns from the first session, those with a major number of relations. First twelve are: (1) independent strategies (this pattern has13,59% relations from the total number of relations) ; (2) guided activities (this pattern has 12,1% relations); (3) multiple responses (11,48%); (4) evaluation (9,55%); (5) a small group of companions (5,095 %); (6) supports the compromise (4,458%); (7) synergistic work (4,458%); (8) social environment (3,8%); (9) disorientated (3,8%); (10) teacher supports (3,8%); (11) construction (3,8%); (12) social inclusion (3,184%).

In Fig. 2, we can see a representation of the most significant patterns from the second session, those with a major number of relations. First twelve are: (1) sensory experience (12,575%); (2) different movements (11, 377%); (3) different materials (10,778%); (4) different sounds (9,58%); (5) different children (7,784 %); (6) easy guided interaction (7,186%); (7) achievement of goals (5,389%); (8) without a guide they are random (4,848%); (9) express yourself (4,848%); (10) construction research (4,848%); (11) relation (4,192%); (12) micro learning (3,593%).

## 3.4. Third Phase. Study 2

### 3.4.1. Procedure of the Preliminary Evaluation

Preliminary evaluation was conducted in a form of Focus Group. The group consisted of 4 teachers from Reggio Emilia; all of them work, or have worked at some point, as special education teachers, thus having had the possibility to know the needs and behaviors of children with special needs, as well as to support them.

The focus group has been conducted as an online meeting with the teachers via Microsoft Teams; the teachers connected via remote, while 3 out of the 4 of our group were inside of the Magic Room, since at least 2 people were needed for the demo part that took place in a later stage. The meeting had been recorded using Microsoft Teams,
which then stored the recording safely in OneDrive under the domain of Università di Modena e Reggio Emilia (unimore); the link was later shared with the institutional

account of the co-mediator, in order to revise the notes taken. The meeting, including presentation, demo, and QA, was held entirely in Italian. The mediator had the role of introducing and presenting our project to the focus group and took care of asking the questions we had prepared for them; in other words, the mediator was the interface to the group of teachers, the one who held the discussions “in person”. The co-mediator is primarily an annotator, who acted as a “listener” behind the scenes, similarly to the “witness”, but also took notes of the answers and feedback collected from the focus group. The role as co-mediator was given to control that the meeting was proceeding according to the schedule, and that we were collecting the data we needed. The Lab Assistant was the co-protagonist of the demo part, as the game required two players, the other of which was still the mediator. They both had to show the actual capabilities of the game, including all the possible interactions and events. The meeting started with the mediator introducing our group, the context in which we have been working, the problem we want to address and the solution we propose. This first phase lasted approximately 10 minutes. The second phase was the demo itself and lasted 10 more minutes. It was initially the time we had planned to spend for this part before the meeting, and it turned out to be the perfect time to perform all the gestures and to explain all the events and dynamics to the teachers. The third and last part, which was the longest, was the actual discussion, where we would hear the teachers’ voices and collect their critical opinions and feedback on our presented work. It took 1 hour to present them the 5 questions listed above, and make a discussion for each, so that every teacher - or the majority - could advance their opinion, or at least say if they agreed or not on the others’ statements.

## 3.5. Phase 4

### 3.5.1. Objectives of the study

The author, with colleagues, conducted an exploratory study using the generative game “ Explora!”. The study explored the relationship between a playful, creative, explorative experience and in-presence social interaction. Investigators aimed to explore how children cooperate when placed in an unknown environment for the first time, how they instigate social interactions, and how these influence the creative process of the children. We also would like to understand if time significantly affects those effects.

### 3.5.2. Problem statement

To the best of our knowledge, no scientific studies have examined group dynamics' on individuals' creativity in a MultiSensory environment. Furthermore, research on creativity has rested squarely on the individual's cognitive processing, individual differences, and the effects of the external environment on the individual. Relatively little consideration has been given to the creative ideas generated by the groups instead of a single mind Kurtzberg and Amabile (2001). The study focuses on filling this research gap.

In the study, author started from an existing experimental interactive MultiSensory Environment, in which it was included a playful activity called "Explora!". The game lets two children explore a digital replica of forest, in which they can interact with different environment elements, causing different effects. After a tutorial on the interactions, we let the children freely interact without any previous knowledge of the effects of their actions, and we observed and classified their behaviors following Table 1.

**Table 1** Behaviors classification 1.

| **Variables** | **Behavioral signal** |
|---|---|
| **Engagement** | Face expression<br>Body expression |
| **Bored/tired** | Negative emotions<br>Over stimulation<br>Loss of attention<br>Loss of interest |
| **Creative action** | Crouch<br>Jump<br>Raise a hand<br>Grab a hand |
| **Creative thinking** | Proposal on how to do it, what the idea is<br>Talk about the idea<br>Talk about solutions |
| **Social communication** (group process) | Verbal<br><br>Non-verbal |
| **Need for intervention** | Adult verbal intervention<br>Adult physical intervention<br>Adult technical intervention<br>Verbal expression of incomprehension, confusion |

### 3.5.3. Experiment Design

An exploratory sequential mixed-methods design was selected to explore the social interaction and creativity of the participants during the generative game “Explora!” Berman (2017). The experiment occurred in the experimental MSE installed in a laboratory setup to guarantee a more secure and aseptic environment. All sessions were video, and audio recorded. The researchers used behavior signals focused on social interaction, dynamic engagement, and changing the sequence of social actions between individuals or pairs in a multisensory environment Zhou et al. (2020) following the behavior macro-categories reported in Table 1. Children may present those behaviors through verbal communication, body interaction, body gestures, and peer-to-peer communication.

### 3.5.4. Participants and configuration of the experimental group

All study participants’ parents were previously notified about the study, including details about the study procedures, goals, and data treatment, and recruited on a voluntary basis. Dedicated documentation and flyers reported all information for the parents’ consultation. Informed consent was collected from all parents prior to the beginning of the study. Furthermore, participants’ parents were informed that their children could leave the study at any time and that they could request the deletion of any sensitive data. The study was conducted in compliance with the Helsinki Declaration of 1975 (as revised in 2008) and received ethical approval from the Ethical Committee of the university. The study was conducted among 8 participants between 9 and 12 (M = 10,75, SD = 0,09). Evaluators and Parents formed the children’s pairings in advance.

### 3.5.5. Material and procedures

Each couple of children played with “Explora!” once, over a total of 4 sessions. One evaluator and two parents observed one group at a time. The average group session included a 2-minute introduction, a 5-minute tutorial, and 30 minutes of the generative game. During each session, the evaluator and the two parents collected the occurrences of behaviors, by completing a predefined observation grid. All observers were required to complete their grids independently and without interference. A technician was in charge of controlling the functioning of the Magic Room while the application acted entirely autonomously.

# 4. CHAPTER - Results

In the first phase of research, the author investigated perspectives about promoting creativity in children with ASD (autism spectrum disorder) in a multisensory environment called the Magic Room. The author proposed a focus group consisting of multiple sessions. Using data from the focus group, the author presented finding criteria for guidelines for special activity requirements within the multisensory environment. The guidelines, with variations in the interaction design and open-ended scenarios, were designed to help in building activities for improving the free exploration of children with autism, providing an approach to discovering new things that can be used outside of the Magic Room, and improving social interaction (collaboration) with neurotypical children or other autistic children. The author attempted to incorporate specific interaction design components such as collaboration mechanics, open-ended play, proxemics, and contextual elements.

This thesis includes outcomes related to empirical study investigations about promoting creativity in children with autism, the propensity of systems to foster free exploration in children with autism, and the application of the creative process guidelines to propose an activity for the Magic Room. The results will be presented in the upcoming section.

## 4.1. Results Phase 1

The experiment sessions were subjected to an in-depth qualitative analysis, and subsequently, the results obtained from all participants were compared. The analysis followed a structured approach consisting of two main phases, which aimed to address the primary research questions as outlined in the study conducted by Popescu (2014). During the initial phase, behavior categories relevant to young adults were established. This was followed by a meticulous classification of all observed behavior signals, which were then assigned to respective variables for further quantitative data analysis. The process of identifying these variables involved carefully interpreting the meaning of each behavior signal and determining appropriate grouping criteria. Notably, specific repetitive behaviors exhibited by the children were identified and classified, as presented in the corresponding Table **2.**

In the second phase, the qualitative data were transformed into quantitative data using the Observational Coding System (Hawes et al., 2013). The percent of represented behavior signals was calculated for each participant.

The result is presented in Figure 4.2.

We can see the high overage result in creative thinking, which is equal to 31,94 percent, despite the same category of creative thinking, which is relatively low and equal to only 5,56 percent. Also, the results in the other category, the social dynamics, are high. For example, the value of Group Work is 18,06 percent, and Group conversation is 30,56 percent.

**Table 2** Behaviors classification 2.

| **Behavioral signal** | **Variables** |
|---|---|
| A child Stacks LEGO dots on the base<br>A child Unstacks the Lego Dots | Creative action |
| A child Chooses the color of mosaic<br>A child Looks design of the other children | Creative Thinking |
| A child searches for the dot on the floor | Distracting action |
| Peers help to put the mosaic on the base<br>A mother helps to put dots on the base | Group Work |
| A child talks with the mother<br>A child talks with peers<br>A child Talks With 'Atelierista' | Group Conversati on |
| Actions and behaviors aimed at playing with created work or efforts to play with the LegoDots | Play |

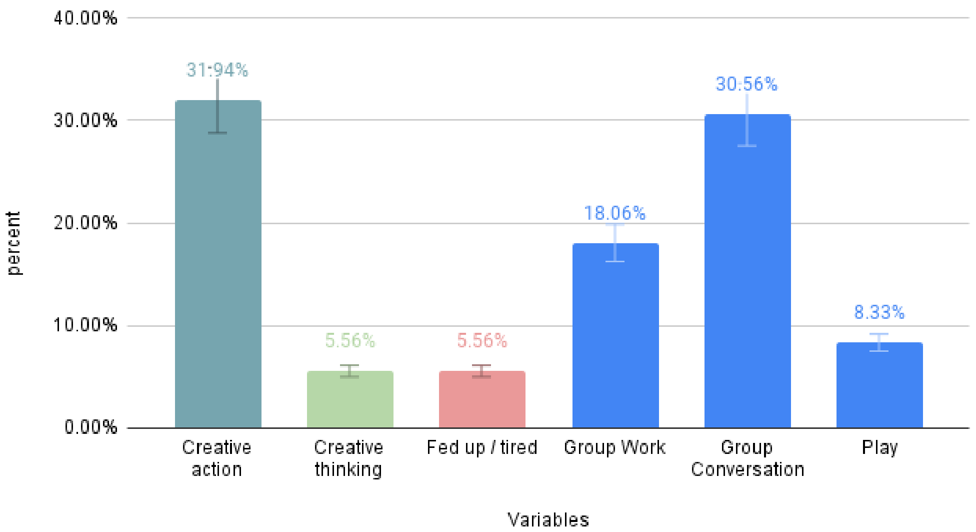


**Fig. 4.2** Categorical variables with percentage.

## 4.2. Results Phase 2

Technological solution for observation

The observation application is made by using the JavaScript platform. It is a web application that can be opened from various devices. The app is very simple and easy to use:

1. The interface shows the number of participants in the session and introduces behavioral variables identified by the observer through the preliminary phase.
2. While the experiment is ongoing, the observer can click on the behavior corresponding to the participants in the desired period.
3. The participant selects the button to save the result and receives a text file with the behaviors associated with the participants, indicating the time of their expression.


**Fig. 4.3** Observation App Interface.

Since the environment affects the observations, we divided the results of the observation into two groups. The first is those we observed in the presence, and the second is those we observed at a distance. Below are the results of the first type of observation in the presence.

Figure 4.4 shows the median number of behaviors observed by the three observers in the three days and eight sessions. It can be seen that the median number of observed behaviors in three days is growing.

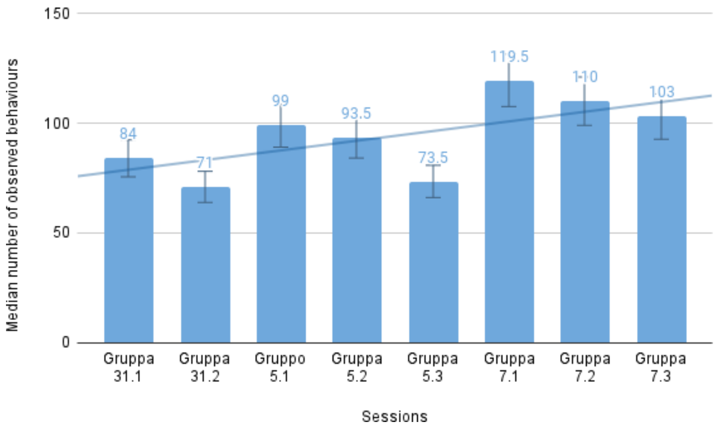



**Fig. 4.4** Median number of observed behavior in each session.

For example, the first session's first result is 84 recognized behaviors. At the same time, the last experiment day's first session shows 119,5 recognized behaviors. At the same time, the number of recorded behaviors in sessions conducted on the same day decreases from the first to the last. For example, on the first day, the first session shows 85 recognized behaviors, and the last session ofthe same day is 71.

Other Figure **4.5** shows the percent of the median difference between the number of registered behaviors observed by all observers in the three days. The percent difference between the median number of behaviors observed by all observers between the first and last session of the same day decreases. For example, the difference in median of observed behaviors of one participant on the first session on the first day is equal to 6,7%, and in the last session on the same day, it is 3,8%.

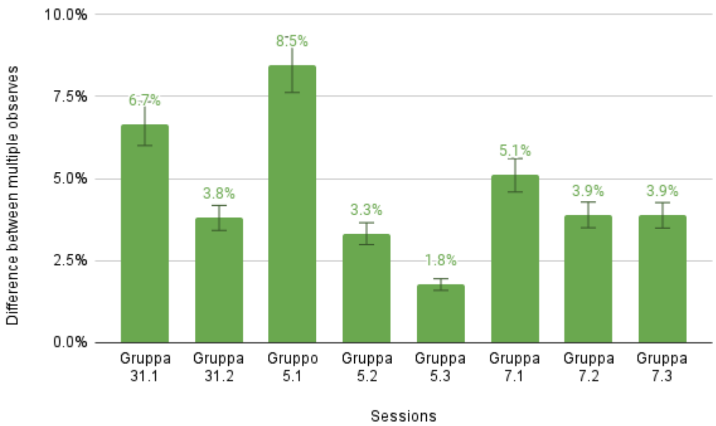



**Fig. 4.5** Difference between observed behaviors in each session.

## 4.3. Results. Phase 3. Study 1 Guidelines

The guidelines listed below were found by using concepts from the semantic analysis. Almost all guidelines include the following concepts: room generates, creative sphere, interaction with space, and real learning.

**Guideline 1. Child-centered approach**

- The child finds the independent strategies in the guided activities. The child is free to find their way to reach the game's objectives with consistent support.
- A multisensory response in the strategies is made by the child. Since we work with children's diversity, the system is alerted to offer the children different types of materials and stimuli.
- Evaluation of the strategies found by the child. Since the child is searching for their way of expression and has the right to make a mistake, the game doesn't have a strict path to follow. One of the main measurements is the engagement of the child.
- The child accepts compromise approaching individual strategies. A child learns to work in a group and find solutions that fit his peers' ideas.
- A child has an individual strategy in a social environment. The child feels responsible for his part of the work.

**Guideline 2. Social interaction**

- A child finds the strategies in close contact with peers. Children learn to be a part of a group. The game gives positive feedback after collaboration with peers.
- Personal discovery in synergistic work. Game requirements include social interaction with peers. The game should be designed for 2-4 children who play simultaneously.
- A child finds the answer with the teacher. The teacher supports the child's progress.
- An abstraction that gradually leads several children to work together. The objective fosters children to make progress in group work.
- Synergistic work in an educational game. Children achieve more significant results together.
- Synergistic work with multiple responses. While the children achieve their joint

results, each child has personal stimulation.

- Social area assessment. The game offers personal, consistent assistance in interaction with partners.
- Multiple Choice evaluation. Prepare an environment where the child has multiple materials and instruments to construct their project.
- Social environment as a small group of companions. Children arrange themselves together to retrieve information or images from the projection by moving in space.
- Work in a small group of classmates and teacher. Teachers construct together with children.
- An abstraction that gradually brings the small group of companions forward. The context activates the individuality of each child and helps to progress all groups.
- Synergistic work in the small group of companions. When each child has a vested interest, it is much easier to achieve group goals and learn together.

**Guideline 3. Guided activity**

- A child has a multiple-choice in a guided activity evaluation.
- Instructive game with a small group of companions. The Children need instructions given before starting a creative process. It may be realized as a trial game or an instruction from the teacher.
- Game Instructed by the teacher. The teacher controls the game, she/he has the option to stop the game and to instigate a discussion with the children.
- Instructive joint game guides peers forward. The game has a support option such as a message, light, or sounds that support the children to explore themselves and the game.

**Guideline 4. Sensory aspect**

- The sensory aspect in a small group of companions. The system has personalized feedback.
- An alternative in the sensory aspect. We can consider different ways to activate the creativity and in order to provide alternatives that can be taken from the different contexts.

**Guideline 5. Suggested types of evaluation**

- Teacher evaluation. Observation made by the teacher aimed to find significant behaviors.
- Evaluation among a small group of companions. The Child is supposed to stays in a rhythm with others; i.e. they stay in the sequence of activities intertwined with others.
- Evaluation of an abstraction. Children express themselves freely - the teacher learns with them by observing their way of learning. The learning is valid for children and for the adults. This informs teacher evaluation.
- Evaluation of the synergistic work. Children in the group work on the same project. Each member of the group has to find a solution which makes a meaningful contribution to the whole project.
- Multiple choice evaluation.

**Guideline 6. Role of the teacher**

- The teacher supports the compromise. The teacher has an objective for the task. However, they must be perceived by the child and then translated in a certain way to support creative thinking.
- Teachers work synergistically with different children. First, teachers must make many proposals to get to know children well and start working on their own needs to provide engaging, stimulating contexts rich in materials. Then the teacher begins to grasp the nodal points (objectives of the child) where children stop to take sides, play and reflect.
- An abstraction that gradually brings teachers forward (that advance the teacher's knowledge). The creative ideas of the child advance the teacher's capacity. The role of the teacher is to provide support, to overcome the gap of difficulty that the children face to allow them to proceed to move forward both in the activity and in their thought process in their creative process.

## 4.4. Results Phase3. Study 2 UX Design

To investigate the interplay of creative and social behaviors', we created a novel interactive, multisensory experience in which two children could interact together, coordinate, and explore an idyllic digital world to discover its secrets. The content that will enrich the digital space is run-time generated according to a set of cause-effect rules depending on the previous and current interactions performed by the players. Children are clueless about this mechanism and are invited to discover as much as possible during the session. The immersiveness of the smart space, the tone of the graphical content, and the use of full-body interaction enhances the players' involvement and creates a unique experience that allows us to study the children's reactions more ecologically. To power and deploy our experience, we used the powerful support tools offered by the environment of the Magic Room Garzotto et al. (2020*c*). This was also necessary to use the current installations of the system to conduct our experimental study.

### 4.4.1. Game Concept

The world of "Explora!" is placed in an idyllic, magical forest. It contains some defining elements: a) trees; b) bushes; c) a small pond; d) a campfire; and e) an area covered in tall grass. (Letter reference in Figure 5.1)

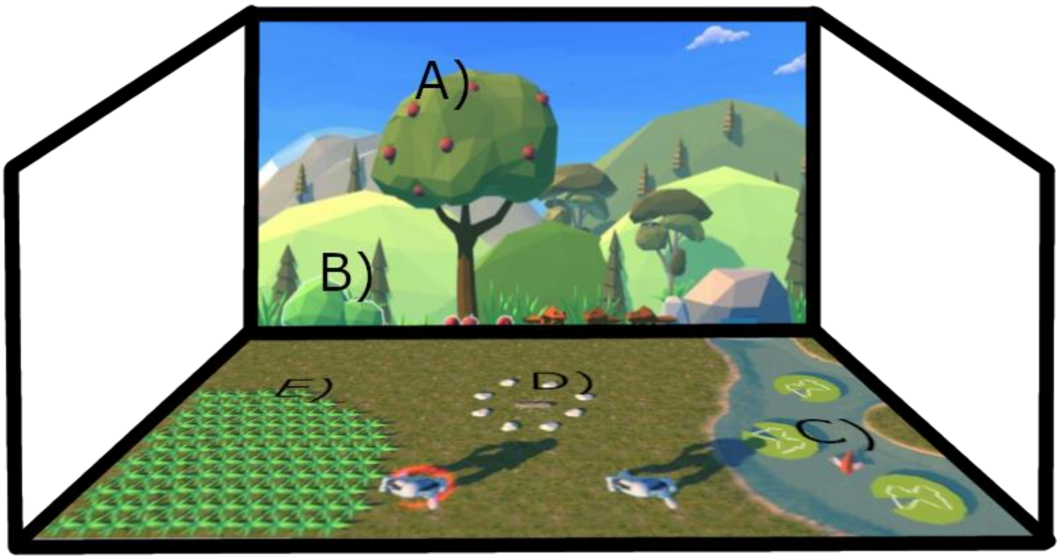



**Fig. 5.1** Perspective view of the front and floor screen during the activity.

This environment has been designed to mimic a familiar natural reserve close to our city. In the evolution of the prototype, the resulting environment is sufficiently generic to represent a generic natural area in the countryside areas which surround a city. The design around the experience in "Explora!" is that of an open game; this means that while each action the user performs has specific effects and preconditions

to be met (e.g.; having at some point of the experience performed another action), the experience is not imposing a set of actions required to achieve a goal, as in narrative games. Nor does it tell the player which interaction should be done where or what precondition exist on that task. Instead, the player can explore possible actions and follow the path that they find finds interesting. Let us make an example to explain this concept better. When the child gets close to a frog near the pond, it will jump further from the children from one lily pad to another. However, if the children collect a butterfly by walking in the grass, the frog eats the butterfly. Such a chain of events is never explained to the children. It will happen every time the conditions are met, but then it is up to the children to understand what changes the frog's behavior.
This unknown ruleset to be discovered makes "Explora!" an immersive experience that seeks to enhance the children's explorative and adaptive behavior and develop their social competencies via collaborative two-player interactions. The game seeks to activate the children physically and mentally as they walk around in the Magic Room and think of possible interactions. Given that the game does not impose a time window for the player, it is also a powerful tool for educators who can fit this activity into each child's schedule.

**Fig. 5.2** Pictures taken of "Explora!" in the testing space

Our project "Explora!" is a highly interactive and immersive experience for the Magic Room, catered toward atypical and typical children - aged 6-12 years old - to develop their explorative, collaborative, and communication skills. This is a game for two players set in the woods, next to a river. It consists of exploring an idyllic landscape to discover its hidden secrets by interacting with the elements present in the surrounding environment. All the interactions are full body, tracked by a Kinect sensor, and can result in a change on the floor or front projections of the room; the children are challenged to understand the causes and effects of each gesture performed to find a way of progressing through the game. The children are also motivated to collaborate and socialize with each other, thanks to a few collaborative tasks that are needed to progress; also, they are encouraged to teamwork in discovering new things in an environment that is unknown “a priori” to them, and full of surprises. “Explora” is a 2-player game played inside the Magic Room, which features the possibility of full-body interaction, which means that the player must use their entire body in order to play the game. With the help of projectors, light, and sound the magic room offers the possibility to immersethe player in another world.

The world of “Explora” is placed inside a forest, featuring trees, bushes, a campfire, a small pond, and a patch of tall grass. This setting was initially inspired by the natural reserves surrounding the village of Cornaredo, right outside Milan, where a middle school has already deployed a fully working Magic Room; in the early phases, we were thinking of this location as our probable site of launch, that’s why we decided to bring a landscape familiar to their inhabitants.

“Explora” is an open game in the sense that every interaction with an object hasan effect, but the game itself does not tell the player which interaction should be done on which object. Instead, the player should explore the possible actions and follow the path that the player finds interesting. The paths and rules of the game are unknown a priori to the player but known by the teacher. This makes “Explora” an explorative experience that seeks to enhance both the children’s explorative and adaptive behavior and develop their social competencies via collaborative two-player interactions. The game seeks to activate the children both physically and mentally as they walk around in the Magic Room and think of possible interactions.

“Explora” features an implicit goal, which is met when all animals in the game have been discovered. It is important to emphasize the possibility of not telling the children about the final goal if the teacher thinks the kids will have a better experience without knowing it. For example, if the children know that they need to reach a final goal, they could get frustrated, angry, or annoyed if they don’t progress in the experience; or maybe the teacher can’t have a session in magic room long enough for the kids to reach the goal. Therefore, we wanted to make it possible for the teacher to bring the students for the duration that seems fit, without the children feeling the pressure of needing to complete the game. Also, we have focused on making the game appear friendly and playful, we chose assets that make the game feel and look like an adventure to entice the kids to explore, like an adventurous soundtrack. Using these cartoon-like assets also makes the environment more familiar to the children and prevents any unpleasant surprises or scary moments in the game.

### 4.4.2. Interactions

Interacting with immersive spaces is always very challenging. The Magic Room offers the possibility to use either smart objects as controllers or full-body interactions. We decided to opt for the full-body interaction, as it allows the children to perform various actions directly in the flow of physical exploration of the space, on the two projected screens. Each child keeps a portable smart light in both hands that provides a localized, punctual source of feedback (changing its intensity) for the interaction and identifies the player (blue or red).

While we let the users discover the environment, at the beginning of the experience, we decided to explain the four gestures provided to them. The tutorial is interactive, as it prompts both players to follow the gestures indicated at each step. Couching has also a special effect: when used by both player on a lit campfire, it switches the setting of the scene between day and night. It is also used to interact with the campfire at the center, key interaction that switches the setting of the scene between day and night. Jumping activates special events in the game (e.g.; jumping on the grass/flowers to awaken butterflies, fireflies, or bees). Based on the drag and drop mechanism, the players can also use their hands to grasp an object on the front screen. Lastly, we have included a special gesture: raising the portable lamp with both hands, designed to provide in-game support for the user, through a hint system described in the next paragraph. Figure 5.6 presents these interactions.

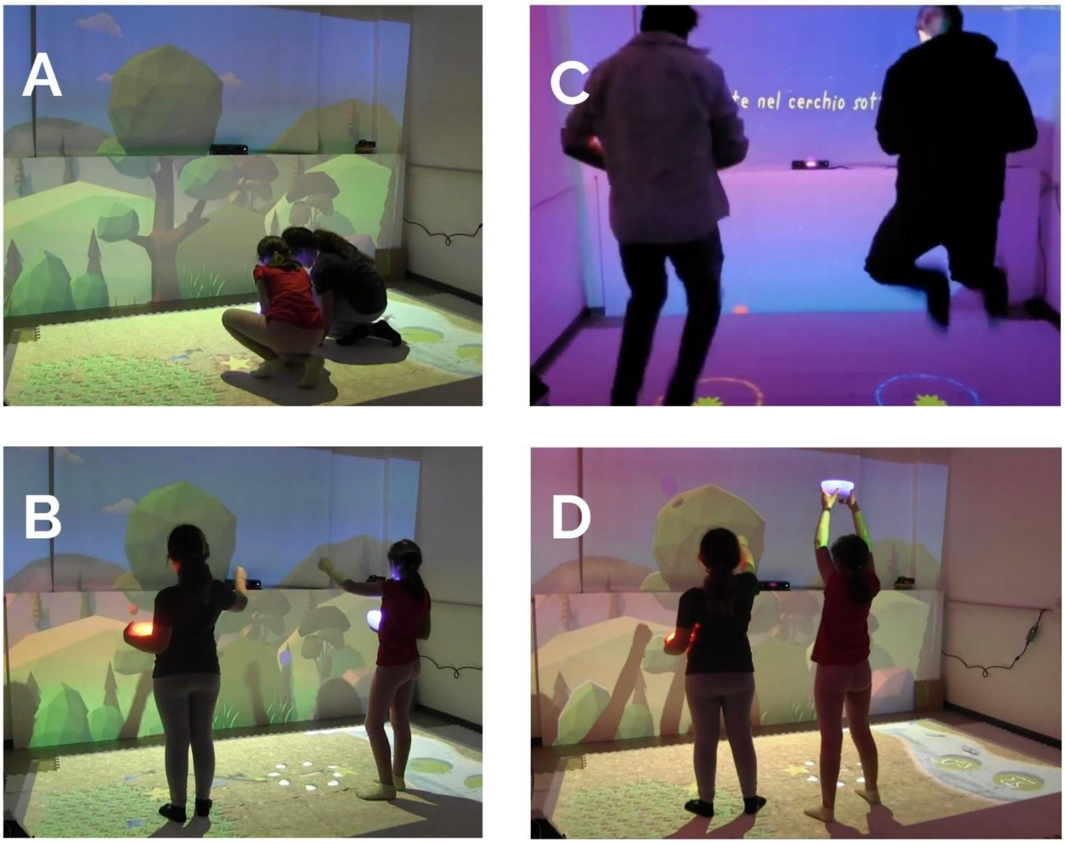



**Fig. 5.3** Interaction with immersive space: (A) Crouch; (B) Grasping Hand; (C) Jump; (D) Raise Hands.

When starting the game, the players must complete a short tutorial level, to learn the possible interactions and get familiar with the game. The tutorial is interactive, as it prompts both players to follow the gestures indicated at each step.

As our game adopts a full-body interaction paradigm, our game features different interactions to perform different actions. The game has four types of interactions, which trigger actions. If the player crouches on an element in the game, it will be picked up, and if the player crouches again, it will be put down. The interaction jump is an action used to activate things in the game. If the player raises a hand, the hint system is activated. The last interaction is the grasping hand used to control objects on the front screen and works as a drag and drop mechanism.

### 4.4.3. Hint system

To help the players in the game, we have designed two types of help. The first one is implemented in the game, and we call it a hint system. The hint system is activated when a player raises his/her hands or portable light (in fact, both players can carry a portable light that acts like a feedback indicator, which becomes brighter on activation of the help system).

When the hint system is activated, it highlights for a short period of time, with an outline effect, the elements that can be interacted with at that specific point of the game to progress. An example is shown in Fig.3 and Fig.4.

To prevent excessive use of the system, we implemented a cooldown (lasting indicatively half a minute), which is shown in the form of particles around the player of the same color of their lamps; these particles fade out over time, and when they completely vanish, the help system can be activated again.

To prevent the children from getting stuck during the session, we have designed a hint system as an additional form of help. When the hint system is activated, it high- lights for a short period, with an outline effect, the elements that can be interacted withat that specific point of the game to progress (the white profiles shown in Figure 5.1).

To avoid the excessive use of the system so that the children are encouraged to explore, we implemented a cooldown of 30 seconds. After players have asked for a hint, a colored halo of dancing particles surrounds her/him until the cooldown ends, signaling that the player can ask for a new hint.

### 4.4.4. Role of the teacher

As a secondary source of help, we recommend that the accompanying adult take active participation in helping the child. First, the adult must prepare the children mentally by anticipating (without spoiling the surprises) how the game will be and what the child must follow (starting from the tutorial); this prevents especially the atypical children from coming across unwanted surprises that might be found puzzling, to the point of negative reactions.

Secondarily, the adult can choose to give suggestions to the players, in case the hint system does not help, but must intervene as soon as a child shows signs of frustration. Conversely, if the child is not reaching the goal but still shows to enjoy the game, an intervention is not required unless the adult wants to suggest the kid try something else in the game.

### 4.4.5. Technology

As stated above, “Explora!” is powered through the Magic Room System. The Magic Room Garzotto and Gelsomini (2018c), Garzotto et al. (2020c) is a technological solution that creates a virtualized layer for the hardware setup, allowing the developers to focus only on the definition of the experience. The controlling software for the game acts automatically on this virtualized space. The Magic Room engine then applies those changes in the real environment.
The Magic Room is equipped with floor and wall projections, Kinect motion sensors, smart lights, aroma emitters, a 5.1 Dolby audio system, a bubble machine, and smart objects (e.g., digitally enhanced toys). Among the smart appliances, great importance is given to portable smart lights, which are the primary feedback source for the users. Instead, the fixed smart lights offer a much more immersive environment, differentiating between the day and night conditions. The bubble machine, finally, is used at the end of the game as a celebration, independently from the children’s results.
The software of “Explora!” has been developed using Unity as a game engine. Low-poly 3D models defined the graphical design: the choice was made to give more of a feeling of an open environment, but at the same time, the low-poly was a compromise between the choice of a cartoonish setting and the realism and immersiveness of the resulting environment.

### 4.4.6. Hardware

The game presented makes use of a Magic Room, which is an Interactive Multisensory Environment: a space that offers a variety of sensory experiences, ranging from colors, projections, to sounds and aromas, in response to the interactions with the users (the children), or with who controls it from an outside perspective (for instance, the caregivers that take care of the children).
We used the portable lights, as feedback indicators for the children, mostly related to the help system activation and cooldown. In addition, the bubble machine is being used at the end of the game, i.e., when the children have discovered all the “secrets” of the magic room (which counts as a win in our scope). Lastly, the necessary elements for

the experience to work are the Kinect Sensor - which tracks the players moving around and interacting with the environment -, the two projections on Floor and Front, and the Audio System - for background, as well as for sound feedback (Fig. 5 and Fig. 6).

### 4.4.7. Software

The software of Explora has been developed using Unity as game engine, and C as programming language. From the aspect of design, the game was built using low-poly 3D models: the choice was made to give more a feeling of an open environment, but at the same time the low-poly was a compromise between the choice of a cartoonish setting, and an easier way to find assets for the scope of our project. The models, animations and music were mostly downloaded from external sources, such as the Unity Asset Store and a few others. Still, in some cases, to better adapt them for our purposes, a few refinements have been made using the Unity built-in tools, as well as Blender, and an image editor for minor texture modifications. Spending a word on shaders, the Universal Render Pipeline has been used, as well as a custom shader for vertex coloring on a few models.

## 4.5. Phase 4

After the experimental sessions, we analyzed the recorded videos and the observation grids completed by observers. Grids reported the time and type of behavior detected. We used ELAN Coding Software to transcribe the observation grids and visualize audio and video recorded material. After performing an agreement analysis on the different grids based on the videos, we used the Observation Coding System Hawes et al. (2013) to assign to the code the signals into macro-category labels for quantitative analysis. As a result, each session produced two separately timed sequences, each reporting occurrences of one of the six behavior categories: involvement, bored/tired, creative action, creative thinking, social communication, and need for intervention.
To analyze the time sequences, we divided each session into three segments of 10 minutes each. We decided to call the first the “discovery phase”, the second the “familiarization phase,” and the last the ”learning phase.” Data were then aggregated by summing up all category occurrences in the time segment, obtaining 18 measures for each subject. To better visualize results, in Figure 5.4; we reported, for each session, the percentage of behaviors pertaining to each category in each time segment, over the number of behaviors recorded during that time segment. In the figure, blue bars refer to the first children in each session and green bars for the second; bar

saturation represents the different time segments, from the first (the brightest) to the third (the pastel).

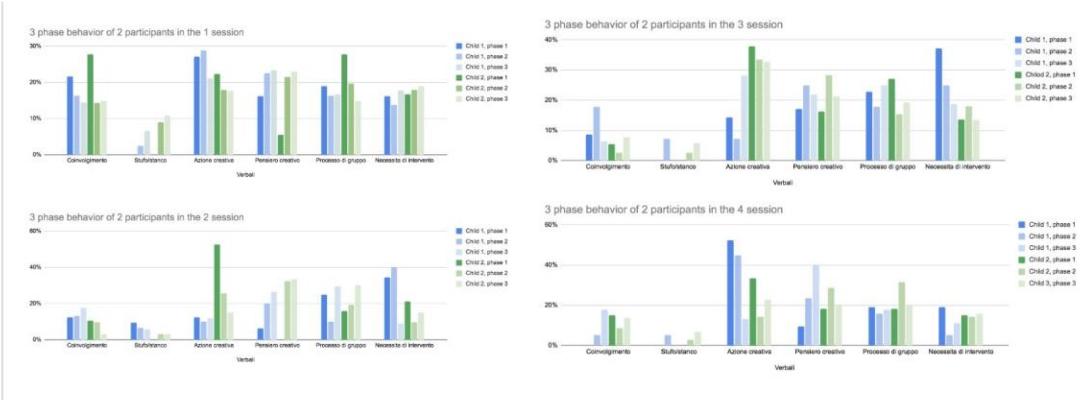



**Fig. 5.4** The median of the six variables for each participant in 3 phase time. Once converted into an Excel file, we analyzed the time sequences to measure correlations between actions expressing creativity and the other behaviors. We also performed an analysis to discover the effect of the three-time segments on the behaviors. To verify the possibility of applying Pearson correlation, we applied a Shapiro-Wilk normality test.

Shapiro-Wilk normality test was done by Mattia Gianotti. Those results are essentially significant for this thesis, for this reason they are presented here. For the numerously of the population of users (n = 8 users), the p-value is 0.818.

Results are reported in Table 3.1, reporting all distributions to be considered normal.

| | Engagement | Group Process | Creative Thinking | Creative Actions |
|---|---|---|---|---|
| Phase 1 | 0,992901 | 0,942957 | 0,907609 | 0,936657 |
| Phase 2 | 0,976825 | 0,867161 | 0,977407 | 0,978682 |
| Phase 3 | 0,914429 | 0,923593 | 0,818243 | 0,962467 |

**Table 3.1** Results of Shapiro-Wilk normality test

Following those results, we investigated the correlations between the different behaviors. We have applied Pearson Correlation to identify a correlation coefficient be- tween the different conditions. In particular, we have evaluated a statistically significant correlation between the Creative Actions and Creative Thinking is r(22) = -0,465 p = 0,022. Correlation between the Engagement and the group process instead is not statistically significant r(22) = 0,257 p = 0,226.

As a second analysis, we decided to aggregate the behaviors between Social Interactions (comprehending all interactions unrelated to creative processes), Creative Actions, Creative Thinking, and Creativity (the sum of Creative Actions and Creative Thinking). In this case, the results are much more relevant. The correlation between Social interactions and Creative Actions has a strong negative correlation statistically significant r(22) = -0,668 p = 0,0003.

The correlation between Social interactions and Creative Thinking a small negative correlation non statistically significant r(22) = -0,348 p = 0,096. The relationship between Social Interaction and Creativity, instead, is a perfect negative correlation statistically significant: r(22) = -1 p = 2,23E-170. Finally, there is a last statistically significant correlation: between Creative Actions and Creative Thinking where there exists a negative mild correlation r(22) = -0,465088705839019 p = 0,0220. Also, Mattia Gianotti computed these behaviors' using Pearson correlation, differentiating the three phases.

Results can be found in Table 3.2.

| | Social Interaction - Creative Action | Social Interaction - Creative Thinking | Creative Action - Creative Thinking | Social Interaction - Creativity |
|---|---|---|---|---|
| Phase 1 | r(6) = -0,856 p = 0,0067 | r(6) = -0,213 p = 0,614 | r(6) = -0,3249 p = 0,433 | r(6) = -1 p = 2,5E-24 |
| Phase 2 | r(6) = -0,677 p = 0,065 | r(6) = -0,243 p = 0,562 | r(6) = -0,5492 p = 0,158 | r(6) = -0,464 p = 0,247 |
| Phase 3 | r(6) = -0,718 p = 0,045 | r(6) = -0,483 p = 0,225 | r(6) = -0,262 p = 0,531 | r(6) = -1 p = 2,5E-24 |

**Table 3.2** Pearson correlation R during the separated phases of the experience

Finally, we are interested in understanding the relationship between engagement and creativity. Results are shown in Table 3.3.

| | Creativity | Creative Thinking | Creative Action |
|---|---|---|---|
| Phase 1 | r(6) = -0,61 p = 0,107 | r(6) = -0,261 p = 0,533 | r(6) = -0,454 p = 0,258 |
| Phase 2 | r(6) = -0,2992 p = 0,472 | r(6) = 0,004 p = 0,992 | r(6) = -0,260 p = 0,533 |
| Phase 3 | r(6) = -0,1369 p = 0,748 | r(6) = 0,372 p = 0,364 | r(6) = -0,446 p = 0,268 |
| Overall | r(22) = -0,338 p = 0,106 | r(22) = -0,177 p = 0,407 | r(22) = -0,360 p = 0,084 |

**Table 3.3** Pearson correlation R for the Engagement of children and creativity

## 4.6. Phase 4 Results comparison between Multisensory Environment Magic Room and Scintillae

Two experiments were conducted, one in Multisensory Environment called Magic Room and the other in a research laboratory with traditional material Scintillae. Both experiments aimed to investigate children's creativity in social interaction settings. In both experiments participated, eight children participated. The Magic Room held four sessions of the same experiment with children aged 9 to 12 years old. In the Scintillae was conducted two sessions with children from 6 to 12 years old.

We applied the same approach to analyze both data collected in the experiments. After the experimental sessions, we analyzed the recorded videos and the observation grids completed by observers. Grids reported the time and type of behavior detected. We used ELAN Coding Software to transcribe the observation grids and visualize audio and video recorded material.

The structure of both analyses was based on two main phases, responding to the research questions: (1) how children cooperate when asked to execute a creative task and exploitative task; (2) how they instigated social interactions; (3) and how these influenced the creative process of the children (Popescu 2014). In the first phase, the behavior categories of the children were defined. Then, a classification of all observed behavior signals and allocated them into variables for quantitative data analysis was done. In both cases, the behavioral variables groups were divided into social dynamics and creativity. Since multisensory play requires the accompaniment of a technical assistant to whom the child can turn, the identified behaviors of the social interaction category are different. However, the creativity category remained the same for both experiments and included two variables creative thinking and creative action. The social interaction category in Magic Room includes Engagement, Fed up/tired, Group process, and Needs Intervention. In Scintillae, the same category includes variables such as Group Conversation, Group Work, Play, and Fed up/tired.

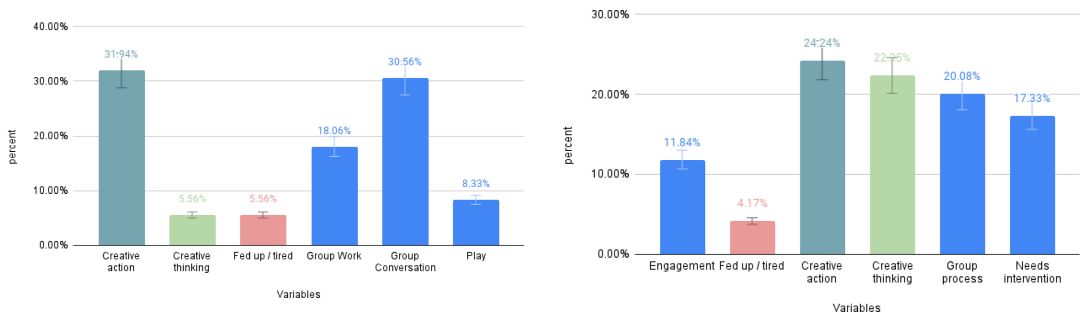



**Fig. 5.5** Percent of behavioral variable reproduced by children. (Left) Experiment in Magic Room; (Right) Experiment in Scintillae

In the second phase, the qualitative data were transformed into quantitative data using the Observational Coding System Hawes et al. (2013). Finally, the percentages of represented behavior signals were calculated for each participant.

Figure 5.5 shows the percent of each behavioral variable reproduced by the children during both experiments. The bar on the right shows the result of the investigation in the Magic room, and the chart on the left shows the investigation in Scintillae. We can see that the behavior variable creative action in both experiments shows the highest result; in Magic Room, it is equal to 31,94 %, and in Scintillae, it is equal to 24,24 %. Also, the destruction in both cases is relatively low in Magic Room, it is equal to 4,17%, and in Scintillae, it is equal to 5,56%.

In the next step, we compared the two categories of behaviors. Creativity for us was the sum of creative action and creative thinking. For us, social dynamics was the sum of other behaviors linked to interpersonal interaction or destruction. It can be seenfrom Figure 5.6 that creativity prevails in Multisensory Environment Magic Room and equals 46,59 %; thus, in Scintillae, it is equal to 62,50%.

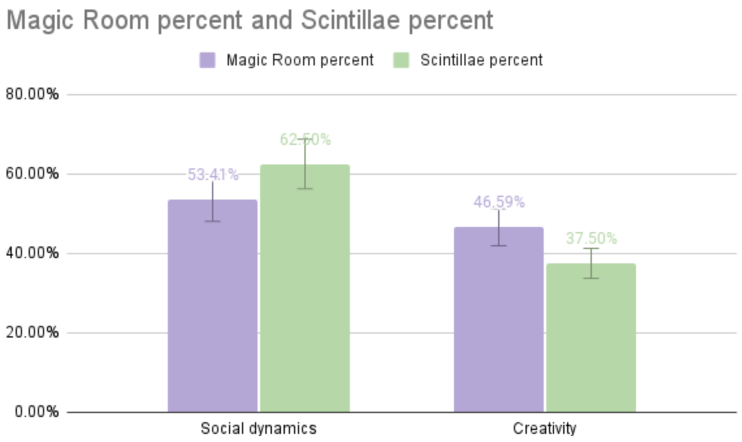



**Fig. 5.6** Comparison between two categories: creativity and social interaction.

Since we focus on inclusive learning, we must include fragile children in experiments and see how their social interaction changes in creative settings.

# 5. CHAPTER - Discussion

Since the objectives of the first and second studies were focused on presenting the guidelines and behaviors necessary to be observed in the experimental Multisensory Room, this chapter initiates a discussion of the third and fourth studies. These studies demonstrate how creative settings influence creative behavior in group dynamics.

## 5.1. Discussion. Phase 3. Study 1

1. Do we really stimulate explorative behavior in the child?
   (a) Are there any distractions that prevent the child from trying to reach the goal?
2. Is this game actually collaborative, that is, are the kids motivated to collaborate and socialize?

3. What are some difficulties that an atypical child can encounter by playing the game?

To evaluate the result of following our guidelines we used Mitchel Reznik's "kindergarten approach to learning" – characterized by a spiralling cycle of Imagine, Create, Play, Share, Reflect, and back to Imagine (Resnick, 2018). We organized presentation and then discussion of the game 'Explora' with 4 participants who have been involved in Focus Group and they evaluated our game. The objective of our discussionwas to understand if we interpreted their guidelines in the right way.
The teachers evaluated the game as an enjoyable one that can help children exploreby themselves through well-designed sounds and animation, which gives a more immersive feeling and makes the environment feel alive. The game covered the needs of children's diversity. It can be adapted for the children's needs, but it is important teachers support in some cases; the typically developed child will play this type of activity and figuring out the interaction might be rewarding and exiting for them. Whereas for an atypically developed child they will need instruction from the teachers to move them forward. If the children succeed the in game, they love it! In future developments we will introduce a higher level of personalization regarding the difficulty which will helpreduce the teacher's workload.

Our game has wide target age selection. There is a huge gap in terms of children behavior, learning curve and interests. Therefore, it was recommended to select same age participants in one session of the game. The age of third grade was the most suggestedone to consider.

To define the role of the teacher, two solutions were proposed. The first solution was adding storytelling with a narrative voice that acts like a guide. The alternative wasto accompany the game directly by the teacher and present the stimuli progressively. Children could have more and more possibilities only after progressing instead of having them all from the beginning. That's aimed at improving the experience, especially for atypically developed children.

Finally, we were advised to choose our future work between the following two alternatives, in case of future development:

## 5.2. Discussion. Phase 3. Study 2

**What elements can be appreciated from the child, and which can be seen as boring?**

1. Keep the realistic setting with stimuli that can be learned from and repeated in the reality. For example, make treasure of an interaction like giving the apple to the beavers, which can be predicted more easily, because of the knowledge of reality; on the opposite side, the effect of having a butterfly following you after jumping on the grass, is something that does not happen in reality. Serendipitous events like this last one, can be appreciated by some, but can be found as confusing by others.

2. Do the opposite and use a surreal setting - like the bottom of the ocean - to let the child understand the line between reality and game. This option will not be addressed here, as the majority preferred the first one to achieve our goals.

Ford defines that "creative action represents competing behavioral options that may be simultaneously influenced by multiple domains of social action (Ford, 1996)". Creative actions facilitate development and learning. It provides variations necessary for organizations to enact shifting aspects of the environment or test previously untested aspects of a relatively stable environment effectively (Ford, 1996).

Equally high results of creative activity correspond to the child's age and enhanced ability to master the world through movements. Antle at el. conducted in his study that movement helps children to think. Antele at. el. suggests fostering the learning process with abstract concepts by appliance mental simulations based on concrete motor- perceptual experiences (Antle, 2013). Both of our experiments support this

idea.
Creative thinking is the generation of new concepts, ideas, and ways of thinking about existing information (Guilford, 1967). The multisensory environment provides a wide range of interactions for conveying information to children, depending on their abilities and preferences in the sensorimotor field. Because of the fragile children that could use the environment, the developers thought it would be essential to adapt the system to each child's needs and potential (Pare´s et al., 2004). It can result in a higher value of design thinking in Multisensory Environment Magic Room. It is a confirmation of results previously measured in the Magic Room (Garzotto et al. 2020c) that poses even more attention to the power of iMSE to engage the users and open new possibilities for research in terms of the application field for this technology.

**What can be improved in the future?**

Due to Covid-19 restrictions, we have a small selection of children in both experimental cases. However, the preliminary experiment result is encouraging. We planned to experiment on a large sample of children based on the promising result. Preliminary results also show that the Magic room contributes more to developing creative thinking than the Scintillae. Therefore, in the future, it would be essential to conduct a similar experiment in Magic's room and place the control group in the Scintillae laboratory.

Since we focus on inclusive learning, we must include fragile children in experiments and see how their social interaction changes in creative settings.

## 5.3. Phase 4

Our study has some limitations. First, the sample size is too limited. Given the uniqueness of each child and the chemistry of each pair of children, our results are only preliminary. We will continue to recruit new subjects to increase the sample size. Unfortunately, COVID-19 restrictions and disinfection procedures have hampered our research plans. Another important aspect is that we cannot determine whether the results also depend on different responses to the novelty effect of children in iMSE. Although our participants had never seen a uniform state of iMSE, adaptation to novelty is a unique property that could play an important role given the small sample size.

Another limitation is that the child can see the observer taking notes during the process. Future experiments should consider using fake mirrors or streaming cameras to observe from a distance.

For all the above reasons, our findings are still very preliminary and insufficient to make any definitive statements. Nevertheless, we hope to provide insight into the topic by addressing research questions.

**Does a correlation between social interaction and creativity exist?**

Our data seem to support this claim. We found a statistically perfect negative correlation between social interactions and creativity in general. Even if preliminary, data seems to state that social interactions are a “limiter” to creativity. Mathematically, such a strong negative relation means that at the increase of one, the other must decrease almost as much. However, analyzing the data in depth, this result takes a more complex meaning. We can first observe that results change when considering the two aspects that form our concept of creativity. When confronted with creative actions only, the correlation is strongly negative (= -0.668). However, when confronted with creative thinking, there is a very feeble negative correlation (= -0.348). This means that social interactions greatly influence only the “active” component of creation, while the mental processes connected are not so much impaired. There can be more reasons for this effect: one can be connected to the physical motion that, in the case of collaborative spaces, need to be negotiated between the two players or that cooperative actions simultaneously require more time to be coordinated. Instead, the communication of creative ideas can flow unaltered. However, more data are required to perform a certain claim.

There is an even more exciting observation we could make considering how those elements cooperate with the time segment, even if, due to the sample size, most measurements do not present statistical significance.

In the discovery phase, the first 10 minutes, the novelty effect is the primary phenomenon. Children try, explore, and experiment without knowing the space and the activity. In this case, we see that there is a perfect negative correlation between social interactions and creativity. The most prominent component of creativity is the creative action part ($r = -0.855$), where creative thinking is negligible ($r = -0.212$). We speculate, also considering the sheer amount of interactions and the videos, that in this phase, the two children play autonomously and share what they discover. Creativity is personal creativity, but it is also shared in the group to enhance the knowledge of the system. Moreover, in this phase, the children present more creative behaviors but fail to create in the game because they still need to master the interactions. In the familiarization phase, the central 10 minutes, the correlation between creativity and social interaction is again centered on the creative thinking component ($r = -0.677$). We speculate this is because children mastered the basic interaction and started discussing how to perform more challenging and cooperative tasks, understanding the cause-effect relationship be- tween their interaction and the environment, and testing various combinations. In the final learning phase with the correlation there is a more important contribution from the creative thinking part (r = -0.483), where textit creative action is still very important (r = -0.718). We assume that it depends on the children's ability that, having learned the tricks of the experience, they need less communication to understand what to do to achieve their common goal.

Our results show a medium negative correlation between the two main components of creativity (r = -0,465). This means the higher the level of creative thinking, the lower the creative action. A high level of creative thinking means that individuals spend more time coming up with ideas or solutions for accomplishing the task, thus reducing the productivity of creative action. To support this claim, we can also see a medium correlation only in the familiarization phase (r = -0,549), where the children discuss discovering creative strategies. Creative thinking is one of the major processes of the creative process. It is an essential competency that helps individuals make decisions Fitrianawati et al. (2020), Glaveanu et al. (2013). These findings correspond to previous studies that found the same negative relationship. For instance, Scibinetti et al. Scibinetti et al. (2011) argue that there is domain-specificity concerning the role played by inhibitory functions in the production of original solutions during creative action. Additionally, creative action may influence creative thinking by limiting divergent thinking due to self-perception, where group members self-sensor and do not share their thoughts in their pairs Makel et al. (2022).

**Does a correlation between creativity and engagement exist?**

Concerning this research question, the results are surprising. An essential premise is that engagement is high during all the experiments, with a slight physiological reduction at the end due to tiredness. Considering this condition, we expected that creativity and engagement were positively or negatively correlated. In the first case, a positive correlation may signal that the possibility for the children to express themselves would have been the core of the engagement we recorded. In the latter scenario, we could explain it considering the difficulties of the reasoning have tired the children and thus reduced their engagement. Results instead show substantial neutrality between Creativity and Engagement. Apart from the discovery phase, where children have struggled to understand the actions (that is physiological), all other correlations are feeble or non-existent. Even if these data are particularly non-statistically significant due to the sample size, it is a hint that the children's activity has been enjoyed independently of the content. Even if these data could be affected by the novelty effect, it is a confirmation of results previously measured in the Magic Room Garzotto et al. (2020c) that pose even more attention to the power of iMSE to engage the users and open new possibilities for research in terms of application field for this technology.

The literature considers the various social influences that support or hinder creative behavior. There is evidence that personal attributes interact with situational variables to affect group creativity (Amabile, 1996; Slayton et al., 2019; Tromp, 2022; Zhou, 2021). Ford states, “Creative action represents competing behavioral options that may be simultaneously influenced by multiple domains of social action” (Cameron Ford, 1995). Thus, our experiment confirms the positive correlation between creative action, group work, and group conversation.

However, group members must be able to connect and coordinate to effectively work as a team (Slayton et al., 2019). Therefore, high levels of group work and group conversation, justified by the experimental situation of not knowing each other and having “to build a group” in the here and now, may increase the time taken to perform the given task within the allocated time, reducing the productivity of the creative task. We observed such a situation in our experiment, resulting in a low number of creative thinking.

## 5.4. Theses contributions

Creating a game that stimulates creativity is a personalized and contextual task that requires the involvement of a team of creators with professional experience in education, computer science, and design. Thus, the group must have at least 3 participants, a representative from each direction. It is also suitable to involve the parents of the children, especially if they are in the fragile category. In the literature, there are recommendationsfor creating a gaming Multisensory environment. However, many of them specialize in the development of creative abilities in children. The contribution of these theses is thecreation of recommendations for groups that set themselves the task of creating a gamethat enhances creativity in a Multisensory environment.

The recommendations presented in this chapter are intended to help game development groups. Of course, the recommendations are not conclusive. They should be adaptive depending on the requirement and context. Recommendations are the result of the theoretical and practical work of the author. Following the author’s advice will help to avoid mistakes and difficulties that the author has encountered. These instructions are advisory but recommended reading.

Since the idea of this thesis was to consider the influence of creative settings in the environment on social interaction between participants, the recommendations pay much attention to the interactive mood. The other part deals with the role of the teacher in the game and the parameters that can increase the adaptability and flexibility of the system.

## 5.5. Interaction Mood

The interaction mood is how users interface with the system and with each other. We divide the interaction modes into various sections: embodied, tangible, visual interaction, vocal interaction, and textual interaction and engagement. However, there are two fundamental typologies of interaction: Explorative Interaction and Focused Interaction. Exploratory interaction occurs when users explore an object's incarnation and its interactable parts, trying to see what happens when one or more of these interaction points are activated. Reconnaissance should not be conducted with the control devices, whose use must be immediately and well-defined. Exploring is the first action a user should take on a new object. Then, users can become familiar with objects, find where they are, and react to their actions. Guidance may be needed during the exploration phase due to the complexity of the object.

Focused interaction is a deliberate action to elicit a particular behavior from an object. In this case, the user's intent is clear and self-describing.

## 5.6. Embodied Interaction

Embodiment is a fundamental concept for HCI (Dourish, 2001). Embodied Interaction is interaction with a computer system in this environment. Our surroundings include both physical and social reality, which exploit the way we that the interaction occurs. Embodied Interaction is the way the everyday world works or the ways we experience the everyday world (Dourish, 2001). Embodiment denotes a form of participative status. Embodiment is about how things are embedded in the world and how their reality depends on being embedded.

Embodied interactions have unique properties compared to other media paradigms. This is because direct physical manipulation of virtual content allows users to participate in activities with other users.

This concept of embodied interaction also covers the direct manipulation of virtual environments by collaborative user groups. Moreover, since emotions are believed to be related to the perception and understanding of information, full-body interactive environments based on embodied interactions and user states are helpful for concept learning.

Embodied interaction is usually closely connected with another concept, such as embodied cognition. Embodiment means how the nature of a living entity's cognition is shaped by the form of its physical manifestation in the world (Antle, 2013). Embodied cognition is a perspective based on the concept that psychological processes depend on and are shaped by aspects of the body such as its shape, sensorimotor system, and interaction with the world around it (Barsalou, 2010). Andy Clark does a good overview of embodied cognition in his book "Being There: Putting Brain, Body, and World Together Again" (Clark, 1998a).

Antle at el. conducted a study about how movement helps children to think, and he has developed two areas of theory in this field. The first area relates to the idea of learning through imitation. The second area is connected to human-computer interaction and explains how abstract thought is enabled through movement (Antle, 2013; Dillenbourg, 2002). Antele at. el. suggests fostering the learning process with abstract concepts by applying mental simulation based on concrete motor-perceptual experiences (Antle, 2013). For example, it can be used in a repeating physical pattern, such as closing the fingers with the corresponding image schema "grab an object" next to it. Physical motions can be divided into main groupings, gross body motion, such as whole-body interaction and fine motion such as grasping.

Full-body interaction.

Full-body interactive environments are digital media that allow interaction through the natural actions and gestures we use to communicate in our daily lives. We express ourselves through body movements. We are actively participating in our interaction with the space around us. These technologies represent a unique stance on the interactive technology paradigm, which puts the body at the center of interaction. Thus, the child becomes not only the center in the learning environment but also the center in the settings of the system. For us, he is the main actor. Antle et al. conducted their study that motion of the body while viewing images and imbalance in social justice issues were more deeply affected by the work (Antle, 2013).

Full-body interaction technology enables a wide range of sensorimotor activities and creates an interaction between the user and the virtual environment. Additionally, full-body experiences allow users to collaborate face-to-face with others during interactive experiences without the need for an intermediate physical interface. These systems can mediate this face-to-face interaction between users.

The game must provide a set of prescribed bodily interactions for users to interact with the multistory environment. The author suggests limiting the number of body interactions by 4-6. Then, it could help the children to quickly memorize and regenerate those interactions.

The movements must be natural, and each must be used in its own context. For example, to activate moving birds or butterflies, you need to jump to get a piece of fruit from a tree, or an object from a cabinet by raising your hand.

The movements should be simple and easy to remember so that children of all learning abilities and frailties can participate in the game.
Hand gesture.

The gesture is a part of full-body interaction. Gestures can provide support for spoken information and they can provide insight into speakers' thoughts (Goldin-Meadow 2011).
Cook et al. report that encouraging children to make gestures while learning resulted in better retention of knowledge (Cook et al., 2008). The most effective technique used to achieve hand gestures is depth camera mapping by having the player very close to arecognizer object or embedding sensors inside gloves.

The author recommends limited use of this technology. Fine motor reading requires accurate reading of the date, and this is quite difficult in the context of a game. Therefore, a possible solution for hand gestures might be opening and closing the entire palm.

Settings for Embodied Interaction:

1. Keep the setting as realistic as possible - with stimuli that can be learned from and repeated in reality. An example would be making a treasure of interaction like giving the apple to the beavers, which is something that you can predict more easily because of your knowledge of reality; on the opposite side, the effect of having a butterfly following you after jumping on the grass is something that does not happen. Some can appreciate serendipitous events like this last one but simultaneously be found confusing by others.

2. Does the opposite and uses a surreal setting - such as using the bottom of the ocean to let the child understand the line between reality and game. This option will not be addressed here, as the first one was preferred by the majority to achieve our goals.

3. All the sounds and animations give a more immersive feeling and makes the environment feel alive.

4. Interaction is intimately connected with the settings in which it occurs.

5. Consider work activities and artifacts in concrete terms rather than in abstract ones.

6. Use tools which investigate social action and practice.

7. Social and tangible computing are related to each other and provide a model for Human-Computer Interaction.

## 5.7. Tangible Interaction

The philosophical underpinnings of embodied interactions are widely accepted. More-over, since embodied interactions move from the purely psychological interaction domain to the physical interaction spaces, it is closely related to the area of tangible interaction Hornecker (2011).

The tangible interaction is sensing-based, it gives physical form to digital information. Ulmer et al. defined it, “The approach has two basic components. First, physical objects are used as representations of digital information and computational operations. Second, physical manipulations of these objects are used to interactively engage with computational systems” Ullmer et al. (2005). Tangible interaction is less focused on the actual interaction with the physical world and more on the recreation of digital world interaction. Tangible interaction provides better support for active collaboration. It aims to bridge the gap between the physical and digital worlds. This kind of interaction might be advantageous for informal science education. The term tangible interaction describes Human-Computer Interaction user interfaces and interaction approaches that emphasize: (1) the tangibility and materiality of the interface, (2) the physical embodiment of data, (3) whole-body interaction, and (4) the embedding of the interface, and (5) the user interaction in real spaces and contexts Hornecker and Buur (2006). Hornecher et. al. allocated separate concepts that are related in the structure but offer different views on materials interaction. A series of concepts elaborates on each topic and provides more specific content processes to understand their implications.

Tangible Manipulation. Tangible Manipulation is a bodily interaction with physical objects. These objects are determined by computational resources, allowing users to control their computation.

Tangible Manipulation involves directly manipulating objects that represent the objects of interest. A good example is a SensoryPoint that presents interacting with the environment through the ball, which is a smart object Ringland et al. (2014b). The technology behind this interaction are two controllers that aim to let the children assume a natural interaction with the environment.

In general, manipulation is based on GPS technology, Bluetooth beacon localization, a set of accelerometers, gyro-scopes, and magnetometers.

It is necessary to be attentive to the intervention of physical objects in the digital game in a Multisensory environment and follow the criteria listed below.

1. It is essential to keep Tangible Interaction intimately connected with the settings in which it occurs. The author suggests using objects that are meaningfully connected to the game. Otherwise, they could destroy the child and the child will lose the line of the game.

2. Items must be safe for children to use.
3. Physical objects should be abstract, this does not limit the imagination of the child. For example, we proposed using a portable light that changes color depending on the child's action.

4. Since embodied interaction is one of the significant kinds of interaction in a Multisensory room. Tangible interaction, interactions through physical objects with digital space, should allow the child's movement. For example, in one of the experiment sessions of activity in the Magic Room, children were asked to use a portable light to interact with the room. In the first part of the session, we got a positive effect, which increased the child's engagement. However, this effect dropped to a minimum in the second part of the session because holding a physical object and continuing bodily interaction tired the child. Therefore, the author recommends using tangible interaction for a short period or with breaks. Another possible solution would be to change the physical objects used in the game.

Expressive Representation. Tangible Interaction is about the physical representation of digital functions and data. Hybrid representations often combine physical and digital elements, each with different representation qualities. The author considered sensible surfaces such as a specialized surface of the environment, like a wall or the floor. An example of those interactions can be found in the smart floor in MEDIATE Pares, Masri, Van Wolferen and Creed (2005b). The digital media projection on the floor, wall, or top of the surfaces is frequently used and occurs in projects such as FUTUREGYM, Magic Room, and Kid Spaces (Takahashi, Oki, Bourreau, Kitahara and Suzuki 2018c, Anderson, Panneer, Shi, Marshall, Agrawal, Chierichetti, Raffa, Sherry, Loi and Durham 2018, Garzotto and Gelsomini 2018b).
The most relevant and immediate type of interaction for the users is when they want to select an element, especially a virtual one projected onto the screen. Selecting an element that appears on the surface is very natural, and the user will move to touch it. The technology used behind this interaction can be Laser grids, Lidar sensors, Capacitive paintings, and depth cameras (Laput and Harrison 2019, Murugappan et al. 2012, Singh and Nagla 2019, Sample et al. 2019).

1. When a game is aimed to force social interaction between participants, it is necessary to provide physical space for all to comfortably interact with the surface. For example, during our experiment, players were aimed to move the projection of an object in space. The size of the object was not sufficient, and the children did not have enough space near the projection of the object.

Proximity or Spatial interaction. Proxemics, as defined by anthropologist Edward Hall, is a research area focused on the culturally dependent use of space and physical measures (e.g. distance, orientation, and posture) to mediate and comprehend interpersonal interactions (Hall, 1963).

Interaction with spatial installations or interactive spaces can be interpreted as tangible interaction that relies on moving one's body. The first essential parameter is to de- fine participants' position in the game and render their movement in the space. Optical sensors such as Lidar technologies, sonar sensors, or cameras (mainly depth cameras) are the most frequently used solutions for these requirements. This is a typical issue inrobotics navigation (Yan et al. 2018).

The second important parameter is the identification of specific users or objects. According to computer vision technology, the detection of the specific user can be done by placing a marker on the user. The technology includes a colored spot for RGB cameras and a beacon for Bluetooth recognizer. Identifying other objects, instead, is a very common interaction used in IoT solutions, such as RFID or NFC tags (9, 16 citations).

1. The author suggests forming a small group of children that include 2-3 people. Otherwise, the optical sensor may confuse the participants, and the results of the participants' behaviors will be confused too.

2. To avoid sensor, overlap by the participant, the author advises using more than one sensor.

3. Another tip is to create a bounding box on the floor beyond which the optical sensor can't reach. This will improve the game experience, and there will be no data loss. For example, the author used a Kinect sensor, and if the child left the sensor coverage area, the game stopped.

## 5.8. Interaction Mood

Graphical interaction

Graphical interaction has a significant meaning and is based on the psychology of Piaget, Bruner, and others (Sutherland, 1963). Graphical interaction is something that happens in two dimensional space. Dourish wrote "graphical interaction is characterized by its use of space; information is spread out over a larger screen area, so that the locus of action is spread out over a larger screen area, so that the locus of action and attention can move around the screen from place to place or can even be in multiple place simultaneously(in different windows/projections)" (Dourish, 2004).

Visuals Metaphors

The graphical approach can add value to represent action and the context in which actions occur. It fosters the development of visual metaphors for information management. The most famous example is the desktop metaphors. Real-life actions are transferred to the context of the screen and are a metaphor, such as “close the window”. Is a real-life action but transfer in human-computer interaction. Dourish defines the inter- face design model as direct manipulation, resulting from the development of graphical interaction techniques. The fundamental principle of direct manipulation interfaces is to represent the object the user is interacting with and allow the user to operate with the object directly. A direct manipulation approach. The ability to directly manipulate the projection through the full body interaction simplifies the moment of understanding during the interaction with the projection and allows the child to focus on the game and its tasks. Interaction with visual projection occurs naturally and creates the effect of presence.

Visual interaction is a powerful instrument, and it is essential to know how to use it. Criteria for visual interaction are listed below.

1. Animations give a more immersive feeling and makes the environment feel alive.
2. There is no explicit requirement for an ending or a final goal due to its initial nature. The aim is to create an experience that includes the creation of engaging visual content without any specification on constraints for the in-game setting.
3. The author suggests creating something more abstract, more about having mesmerizing special effects than having a good plot.
4. However, the game would also have been positively impacted by including a plot.

## 5.9. Vocal interaction

Vocal interactions are sounds or verbal communication produced by a human. It is a natural channel of interaction due to the communication process. By Gianotti, vocal interactions were classified as contend-oriented and backchannelling.

Content-oriented voice interactions are aimed at giving instructions and ask and respond questions. Such interactions foster the desire to interact with the system by directly offering content to the user and conveying the user’s intention. These interactions are mainly directed at promoting information about what to do in the environment or constructing commands.

Backchanneling is an involuntary vocal interaction to express the user’s feelings. Although it does not convey the content of the user’s need, it conveys the user’s emotional state directly to consider.

Settings for Vocal Interaction:

Adding a storyline with a goal can motivate this type of experience; a narrating voice that acts like a guide can help in this aspect.

The author suggests a way of presenting the stimuli progressively, a little at a time; also, the adult can engage in telling the child about what they can do from time to time. So that, also to accompany the storyline, having more and more possibilities only after progressing, instead of having them all from the beginning, the experience can be more intuitive, especially for the atypical child, and less disorienting.
In our defense, for the scope of this project, there was no explicit requirement for an ending or a final goal, due to its initial nature: we were requested to create an experience that included the creation of engaging visual content, without any specification on constraints for the in-game setting. Thus, we hypothesize that the initial idea was to create something more abstract, that was more about having mesmerizing special effects than about having a good plot. Of course, our definitive proposal was widely accepted in the tutoring sessions, as well as appreciated, but in a real-life scenario, a game like this would have also been positively impacted by including a plot as well. We noted it for possible future work, as we believe it is also an occasion of inserting more rewards, like checkpoints, throughout the story, which the child will for sure appreciate.

## 5.10. Textual Interaction

The well-known and best-developed form of symbolic interaction is textual interaction. It is not only described computer operations, but it is a primary form of interaction. Textual interaction is the origin of computer interaction. Textual interaction means the appearance of the “interactive loop”. Dourish wrote in his book “A History of Interaction “that” interaction becomes an endless back-and-forth of instruction and response between user and system. Although there are many types of interaction, in some cases the most preferred is textual interaction (Dourish, 2004).
Textual interaction has such a powerful meaning in interaction because it includes a lot of functions by using grammar logic, such as separate characters words and set of words. Therefore, it is challenging to replace textual interaction. Often it is used like support interaction for other types of interaction. However, since the logic of our computer programs is still based on abstract objects and the logic of text interaction, it will be of significant importance in the field of interaction.
Another reason is a paradigm of text-based interaction with the machine. With the combination of language use and interaction we can receive responses from the

computer, we can see the result of our conversation (Sutherland, 1963).
The importance of text interaction for children can be seen from a linguistic point of view. First, textual interaction can foster "grammar". The author advises, to convey important information in the game, also use textual interpretation. For example, in introductory information and tutorial instructions, visual images can be duplicated by text.

## 5.11. Interpersonal Interaction

Extensive literature has focused on examining the factors influencing individual creativity, primarily with a narrow focus on how individuals working together generate creative output. However, research suggests that personal attributes interact with situational variables to impact group creativity. Therefore, a comprehensive analysis of creativity should consider the holistic interaction between people, tasks, and situations (Amabile, 1996; Slayton et al., 2019; Tromp, 2022; Zhou, 2021).
Evidence supports the significance of interpersonal interaction in group creativity, highlighting that a collaborative environment foster increased creative output. Moreover, effective teamwork requires group members to establish connections and coordinate their efforts (Slayton et al., 2019). However, it is important to note that high levels of group dynamics may extend the time required to complete a given task within the allocated timeframe, potentially impacting the productivity of the creative task. Therefore, further investigation is warranted to explore this relationship by comparing groups comprising individuals familiar with each other to those consisting of unfamiliar members, to gain deeper insights into the influence of group dynamics on creative performance. Additionally, group dynamics may influence creativity by constraining divergent thinking due to self-perception, where group members self-sensor and choose not to share their creative ideas with the group (Meyer Plucker, 2022). Furthermore, as argued, each component—person, task, and situation—plays an important role and can also serve as a compensatory function. A person who exhibits low creativity in a task, for example, may become more creative due to the right situational cues, such as group membership (Tromp Sternberg, 2022).

Settings for Interpersonal interaction:

1. The selection of children for the same play session is essential in interpersonal interaction and must respond to the child's expectations and educational requirements. The choice of the peer's companion in creative play can influence the following components: climate in the group, inclusive learning, group leadership, interaction between children of different age groups, improvement

of social skills, and context of gender interaction. Selection of the children can be made with consideration on improving the climate in the classroom. For example, children in a conflict situation can be placed in the Multisensory Room and perform the collaborative task with a child from the other part of the conflict. The second example presents inclusive education, where children form mixed groups, and the typically developing children tend to support their playmates. The third example is recruiting children in a group to identify their leadership qualities, those who are more active during the game and who put forward more assumptions. Another example of the selection of children in groups can also be aimed at learning to interact with peers and children of different ages. Also, selection can be aimed at helping the child learn to interact in a group and overcome his fears.

2. To ensure the right degree of cooperation between the players, it is necessary to measure and control the number of stimuli. The number of stimuli given may draw the child's attention to individual elements more than to another player.

3. There is the possibility that two children with different learning curves may face difficulties in interacting with each other; to make an example, a quick learner (or the typical child) will get more excited in discovering the secrets first, and can become eager to find all the remaining elements on his own, leaving little room for enjoyment to the slow learner (or the one with NDD).

4. A suggested way to address this, is to add small breaks into the game, to let the children talk with each other, and confront to reason on the occurring events; although we did not implement this throughout the project work, we discovered that the Magic Room already to offers the possibility to freeze the game for this purpose, by the means of the tablet.

## 5.12. Engagement

1. Insert more rewards, like checkpoints, throughout the story, which the child will certainly appreciate.

2. Visual, light and sound effects contribute to the involvement in the game process. Despite this, they must be treated with great attention and caution. Their over- abundance can distract the child from the assigned tasks or make it difficult to understand the game. This can tire the child and he will lose interest.

In the Figure 6.2 the Engagement model developed by the Author is represented.
In this model, the Author takes the child's requirements (CR) as a variable.

The goals of the Engagement model are:

1. **Understanding children's expectations**: By analyzing children's age, gender, educational level, and level of vulnerability, developers can gain insights into their preferences and needs, allowing them to design a game that resonates with their target audience.
2. **Monitoring children's behavior**: By tracking children's interactions with the game, developers can assess their engagement level and identify areas where the game could be improved. This real-time feedback loop enables continuous adaptation and refinement of the game.
3. **Adapting the game based on feedback**: Based on children's expectations and behavior, the game can be dynamically adjusted to maintain their interest and provide an optimal learning experience. This personalized approach ensures that each child receives the appropriate level of challenge and support.
4. **Encouraging interaction**: The game involves children in the learning process, making them active participants. This encourages exploration, experimentation, and discovery, leading to a deeper understanding of the concepts being taught.
5. **Providing positive reinforcement**: The game rewards children for their achievements, boosting their confidence and motivation. Positive reinforcement encourages them to continue playing and learning.

Ultimately, the Engagement model aims to create a game that not only entertains but also educates, fostering children's cognitive development and nurturing their curiosity and love for learning. By employing a data-driven and child-centered approach, developers and designers can create engaging and effective educational video games that make a positive impact on children's lives.

The child's requirements such as age, gender, educational level, social-cultural level. As mentioned by Montessori, the child is the center of education. Therefore, the author focuses on the child's requirements and uses them as the variables which change depending on the factors listed previously. A person who knows the child well, such as a teacher or parent can set the requirements.
Thus, based on Figure 6.2 , we see that the essential variables for us are child's requirements. Taking account of settings can help the teacher, who knows each class's school context and educational goals. Also, the parents could provide helpful information about the child's preferences. Based on these requirements the designer can facilitate a discussion which includes a conceptual example of rewards, checkpoints, and intermediate evaluation.

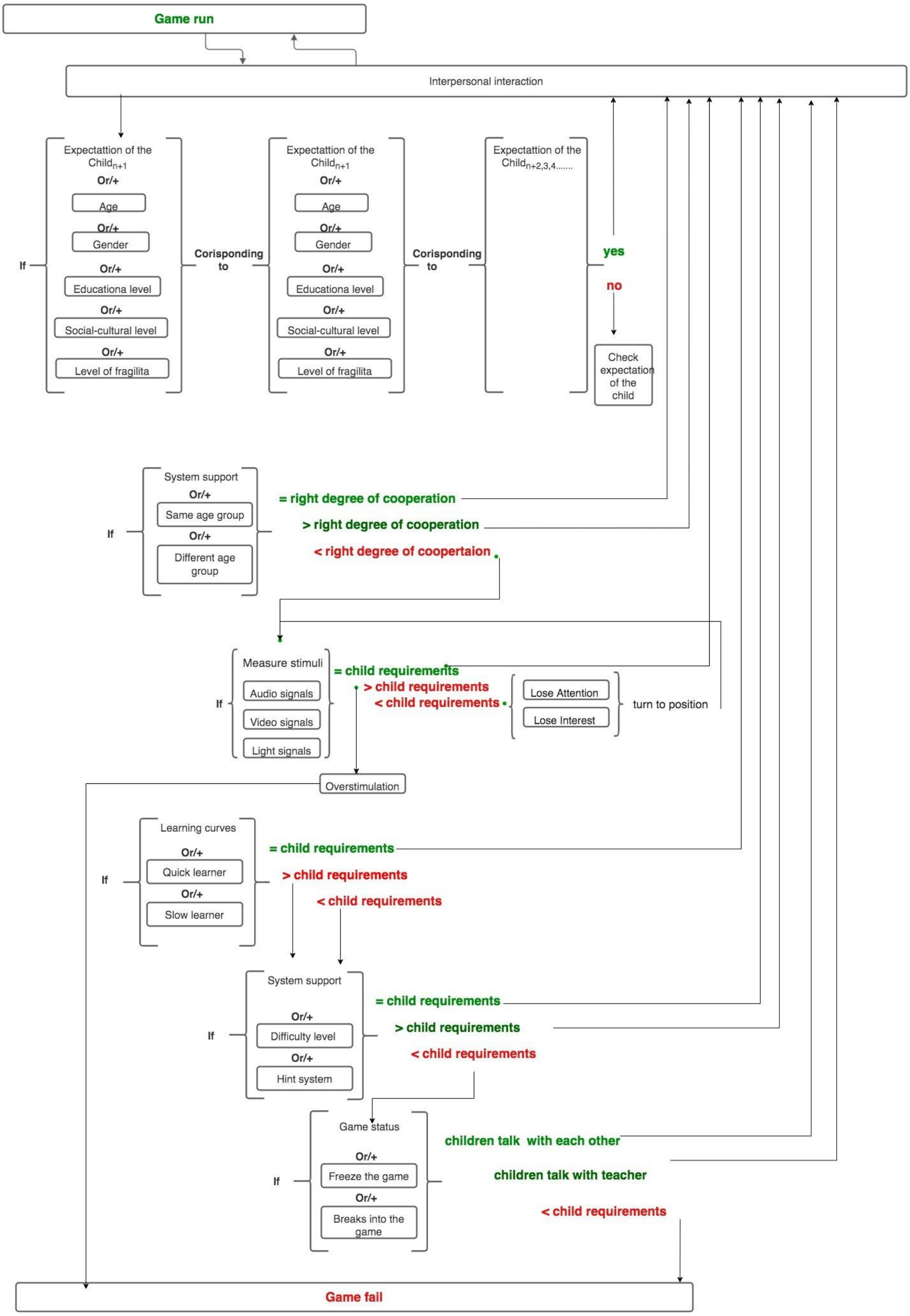



**Fig. 6.1** Social Interaction model.

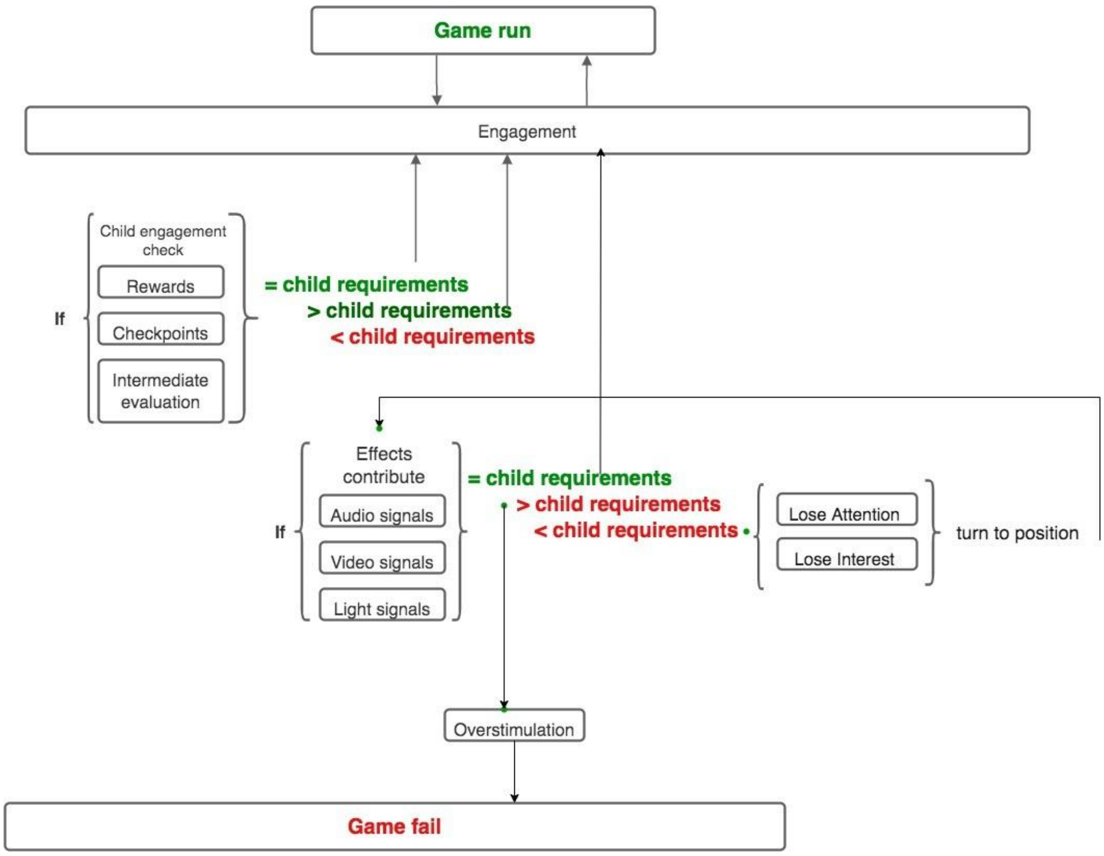



**Fig. 6.2** Engagement model.

Depending on the technological resolution of the system set by an engineer, a designer, in collaboration with the engineer, could propose a discussion with educators about audio, video, and light signals.

## 5.13. System Contractility

Contractility is an ability of a system to dynamically adjust its defined interaction flow in real-time based on user input or unforeseen circumstances (Grieves and Vickers 2017). This could involve features like:

- Manual overrides: Allowing users or instructors to temporarily change the system's behavior during interaction.
- Adaptive responses: The system automatically adjusting its responses based on user actions or environmental changes.
- Real-time feedback: Continuously monitoring and adapting to user behavior or environmental conditions.

The Multisensory Environment for inclusive education should understand the children behavior and performance and fulfill the intervention goal. To lessen the complexity in the system control, some of the developed system used in inclusive intervention applied the Wizard of Oz paradigm (WoZ) in which a human (teacher, system operator) manually controls systems behaviors (Huijnen et al. 2016, Thill et al. 2012b). This paradigm allows the investigation to focus on achieving a higher level of social interaction without the need to implement a higher level of artificial intelligence. However, WoZ requires a tremendous human workload not a sustainable technique for long-term, large-scale use (Scassellati et al. 2012). This type of control is out of our interest, because Multisensory Environments require more autonomous to both lighten the burden on human assistant and provide a consistent learning experience in regular education. Multisensory environments have three levels of controllability: no control, activity controlled, or complete control.

Fully automated system. No-controls systems such as MEDIATE or Lands of Fog autonomously deliver the user's stimuli, and no one could modify such responses while the system is active. No-control system is widely used because it eliminates the need for his secondary interface for control and by design prohibits the occurrence of conflicting states between the programmed spatial flow and the supervisor's inputs.
Gross system controllability. A system that allows multiple operations, which can be combined to create an experience, is the best choice in terms of availability, scalability, and maintainability of the system itself. In addition, by performing multiple reuses of the same hardware architecture, development and installation costs can be allocated more efficiently. In this condition, an alternative to an uncontrolled system is to let the user control at the experience level, while operations will happen automatically.
The system should allow human practitioners to be involved actively in the system development and operation to ensure ethical system behaviors.
Fine system controllability. A complete control solution that allows the system to be modified at any time. In this case, the system works in automatic mode and at any time this flow can be modified, and the system adapts to adjust, skip or go back to previous stages.

Settings for System Contractility:

1. The tutorial has an essential role at the beginning of the game. It provides basic information about the tools for interacting with the multisensory environment. Especially if the game is abstract and has creative settings, in order to enhance the children's experience, prior presentation of the interactional tools is needed.

2. Please familiarize yourself with the Motion Interaction Tool, it is better to accompany the pictures which invite the child to imitate.

3. Be sure to specify the context of the movement of the interaction. The child must understand in which context to carry out this or that movement.

## 5.14. System Adaptation

The system requires it to be adjustable for different user requirements. Therefore, it is essential to make a system flexible. Since the teachers' role is to support the children to reach their objectives, they have the responsibility to identify each participant's requirement and set the system. System adaptation covers several points listed below. The system should be more flexible and adaptive that can easily be adapted and personalized based on perceived behavioral, cognitive, and emotional state of the user.

The Adaptive play environment can deliver a meaningful and personalized interaction e.g. selecting suitable scenarios, adapting the level of difficulty of tasks/games, adjusting the level of social cues. System Adaptation can increase the robot's abilities to access child's behavior and life-like behavior expression.

From technological point of view there are three system configurations: no-configuration, parametric configuration, full Customizability.

1. Different stakeholders from engineers to practitioners are involved in the system design and implementation in a concurrent manner. This approach considers perspectives from different parties especially understanding needs and attitudes of human practitioners.

2. While it is easier to assume that the typical children will enjoy playing this type of activity, in which figuring out the interactions can already be rewarding for them, and make them excited, it is more difficult to predict whether the atypical child would enjoy it as well. In other words, an atypical child would need extra attention paid by the adult while playing this game because, while they love it when they succeed, they can also get frustrated as easily in the opposite case.

3. Because of this uncertainty, in a game thought of as purposefully challenging, it would be safe to introduce a higher level of personalization of difficulty. For instance, a simplified version of the game would be beneficial if we are dealing with a child with intellectual impairment. At the same time, the standard difficulty might be more damaging than beneficial (in the worst case).

4. The teachers discussed the importance of the child's preparation before using the activity. In the last point, we addressed an approach to target two sub-

categories of primary users in a more fitting way. In this point, we discuss another distinction that we need to make inside our target segment: age.

5. The teachers noted that between 6 and 12 years old, there is a huge gap in terms of behavior, learning curve, and interests. For instance, a 6-year-old, especially if followed by an adult, can find the perfect balance of challenge in this game, while a 12-year-old may burn out quicker and get bored more easily. Consequently, we need to narrow down the selection of our target and, make a choice in the future on whether we keep the upper (10-12 y.o.) or the lower range (6-9 y.o.). Again, the third-grade age was the most suggested threshold to consider.

On the Figure 6.3 author presented the adaptation model.

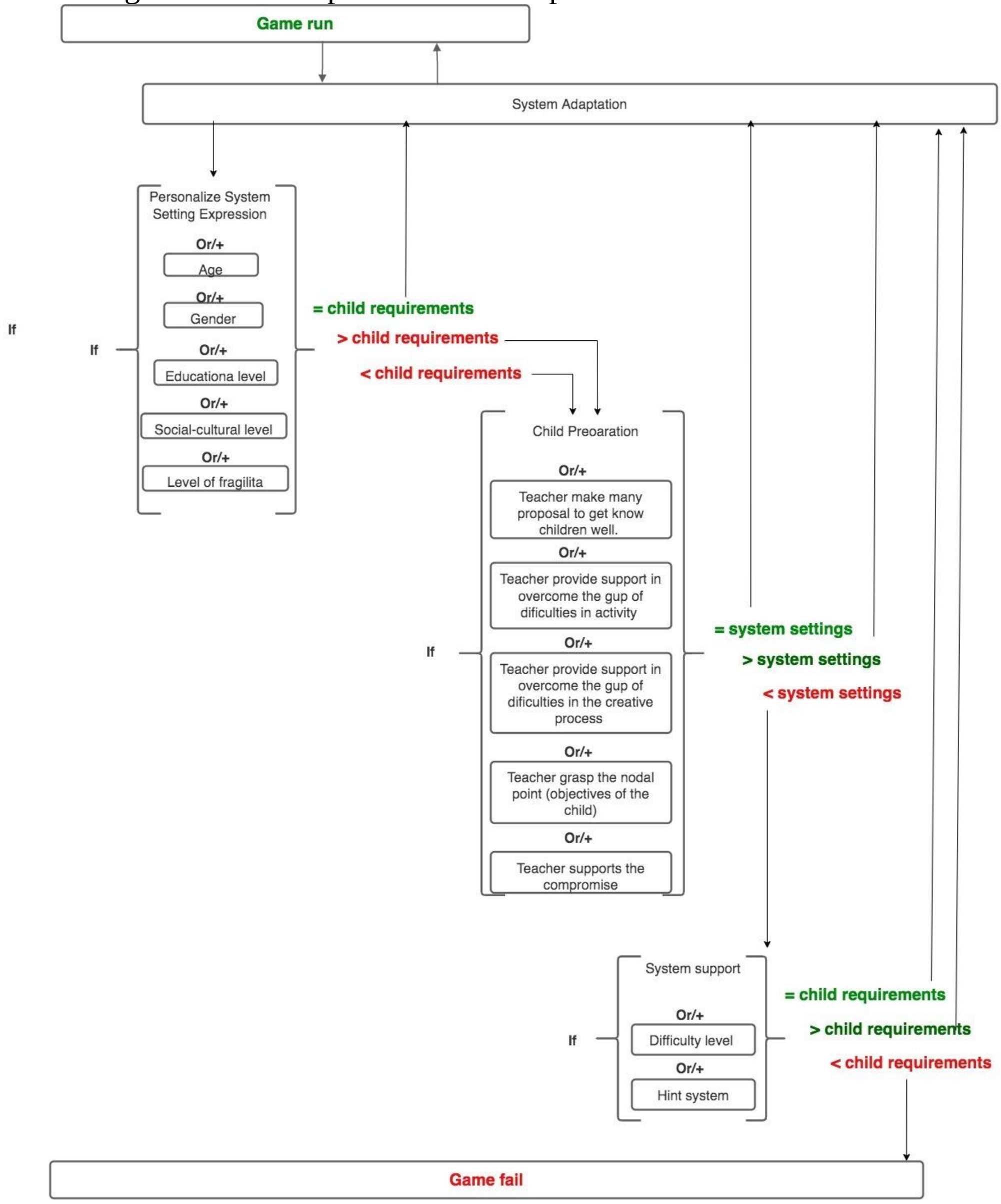



**Fig. 6.3** System adaptation model.

## 5.15. User’s Data Management

Data management is a very sensitive and important aspect in a Multisensory environment that needs to be addressed. It is important to collect data on both the behavior of the child and the behavior of the system. Comparison of these data will provide an opportunity to improve the system for a more complete experience of the child. There are two types of data collection manual and automatic. These abstracts offer an application for automatically collecting data that can be compared with the system log files and seethe behavior of the system and the child in time.

1. We recommend automatic data collection; this will allow you to determine the result of the system’s efficiency and make the necessary additions in the future more accurately.

## 5.16. Conclusion

This thesis initiates a discussion about the importance of applying strategy in educational creativity settings. Firstly, it offers a historical overview of theories that anticipated the needs of creative settings and applied them, such as Dewey. The focus is on daily creativity, aiding children in adapting to contextual settings and underscoring the significance of environmental settings. Additionally, the thesis addresses creativity for all, signifying the inclusion of children with diversity, including those with autism. It emphasizes that only the flexibility of creative settings in the educational environment can facilitate inclusion and support the equal development of the skills of a group of children.

The author defines creativity based on the literature review and employs this definition for the study settings. The thesis illustrates the development of the environment with creative settings from past studies up to the present day, highlighting gaps in previous studies and environmental settings. It advocates the Multisensory Environment as the optimal solution for inclusive education with creative settings, supported by a thorough analysis of existing technological solutions, participants' skill development analysis, and the complexity of the technology. The Multisensory environment yields the best results and is chosen as the most effective tool for implementing creative settings in the educational process.

Next, the author focuses on the settings and criteria that can foster creativity development. A child's mind differs from an adult's in its unfiltered absorbing properties. The author emphasizes that it is essential to create the most effective learning environment that meets the needs of the future. Given the challenge of predicting the future for today's child, the child can best be prepared by leveraging the properties of their absorbing mind, indirectly teaching appropriate qualities through the environment. Based on these reasons, the author decides to consult individuals who are closer to the target users teachers. This decision marks the beginning of the practical part of the thesis, presenting focus groups with teachers and providing guidelines for creative settings in the multisensory environment as the results. Specifically, to ensure a more precise analysis, focus group sessions were conducted. Teachers with experience in inclusive education were invited to participate. This factor facilitated a focus on the inclusivity of educational settings as proposed by the teachers. The most frequently repeated themes from the dialogues were selected to be presented as basic guidelines for future research.

These guidelines support the notion that children need to be prepared to generate new ideas and develop creative thinking. The focus groups affirm that technologies are more effective than traditional learning methods and suggest that multisensory technologies must be introduced into the learning environment. The experimental part of the study aimed to examine differences and identify specific behaviors in both spatial settings.

The theses, originating from the empirical study, formed the foundation for the experimental study. In the experimental section, a series of studies was conducted to investigate the association between social interaction and creativity in two distinct environments: the traditional setting of the research laboratory 'SCINTILLAE' and the technological setting of the Multisensory Environment 'Magic Room.' The study focused on validating the guidelines outlined by teachers and analyzing the behavior of children in both settings.

A comparison was drawn between the traditional creative environment of 'SCINTILLAE' and the technologically enhanced Multisensory environment of the 'Magic Room,' with the goal of incorporating relevant properties and exploring the evolution of creativity promotion. Each experiment aimed to illustrate the behaviors that creative settings endorsed and how these behaviors evolved over the duration of the experiment.

These practices were developed and tested to answer the main questions of our study: to determine the methods and criteria for creating creative activity in the social interaction setting. In the first case, the practice was carried out in an experimental place with traditional creative material, that was LEGO. The second practice was held iMSE. iMSEs affect the basic skills that are considered essential for education and daycare.

Multisensory practices were based on psychological theories such as Embodied Cognition (Wilson and Foglia 2016, Wilson 2002) and Sensory Integration theories (Ayres 1996, Ayres and Robbins 2005). These practices enabled the child to receive information through their entire sensorimotor system. This gave the child a choice to use their more developed sensory skills, contributing to progress in learning and the assimilation of the program. This approach was especially suitable for inclusive education, addressing sensory integration limitations presented by children with conditions such as Autistic Spectrum Disorder.

In the research laboratory Scintillae, special attention was paid to identifying behavioral patterns related to creativity and social dynamics. We have determined five behavior patterns, two of them were linked to creativity, and three to social dynamics.

Especially creative action and creative thinking were linked to creativity; play, group process, and distraction were linked to social dynamics.

We conducted a study on how these behaviors interact with each other and whether the gender of the group members influences the behavioral patterns.

There is evidence that interpersonal relationships are essential in group creativity, and a collaborative environment increases creative output. Furthermore, group members must be able to connect and coordinate to effectively work as a team. Therefore, high levels of group dynamics may increase the time taken to perform a given task within the allocated time, reducing the productivity of the creative task. There is a need to investigate this relationship further by comparing groups of people who are familiar with each other and groups who are not.

Additionally, group dynamics may influence creativity by constraining divergent thinking due to factors such as self-perception where group members self-sensor and choose not to share their creative ideas with the group.

Premising results in the correlation between creativity and social dynamics gave us the confidence to move forward with our research.

Despite its limitations, this study has attempted to bridge the gap between group dynamics and creativity, focusing on gender influences. There are numerous essential aspects along which teams should be studied, such as their size, how work is distributed among their members, and the similarities and differences in the members' experiences and backgrounds (Klug Bagrow, 2016). This study did not focus on these characteristics of the participants, yet these factors could influence group behaviors. Specifically, as previously mentioned, the assessment of individual creativity before the group task could allow a further study to draw a baseline and investigate the relationship between individual creative factors, the experience of group dynamics, and the creative process of the group.

The second practice was conducted in the Magic Room. The existing types of activities were not specifically intended to develop creativity in social interaction settings. The objectives of these theses were to design the criteria for creative types of activities, the implementation of an example of such activity, and the experimental observation of previously identified social dynamics variables and creative variables and their correlation with each other.

In-depth research in State-of-Art on the multisensory approaches to applying creative settings was conducted. All relevant examples have been analyzed with attention to the parameters: target user, the technology they are based on, the context of use, and the evaluation parameters used to determine the results. The missing criteria were figured out by conducting the focus group with experts. Then the MS students were asked to develop such activity by following the extracted criteria. The result was evaluated by an expert. The experimental session in the Magic Room shows promising results in the

correlation between creativity and social dynamics. Even if these data could be affected by the novelty effect, it is a confirmation of results previously measured in the Magic Room (Garzotto et al., 2020c) that pose even more attention to the power of iMSE to engage the users and open new possibilities for research in terms of application field for this technology.

Since in the literature about the multisensory approach in applying creative settings is hugely limiting when the requirements are to apply it with social settings, we decided to figure out our findings using the framework.

The framework has been defined as a tool to support multidisciplinary teams' co-operation and teachers to introduce creativity more effectively into inclusive learning using multisensory technologies, improve design quality, and expand the future generation of multisensory environments.

The framework for Interactive Smart Spaces fostering Creativity is composed of several parts. In the first part, the framework helps designers and developers to define the interaction domain. Since the children are the main figure in defining creative types of activity, all interactions start from their requirements.

Our experiment confirms a positive correlation between creative action, group work, and group conversation. However, our results also indicate a moderate negative correlation between the two primary components of creativity. In other words, a higher level of creative thinking is associated with a lower level of creative action.

The interaction section of the framework includes Embodied, Tangible, Visual, Textual, and Vocal. Special attention is done to the Social interaction setting while the children pass the game.

Then the framework provides the technological element that is necessary for the target user, abstracting from their implementation.

The framework includes another setting. For example, it is essential to make a system flexible. Since the role of the teachers is to give support to the children to reach their objectives, they have the responsibility to identify the requirement of each participant and do set the system. This setting is described in the section of the framework called System Adaptation.

To understand the progress of the child and the possibilities for improving the system, the date of the sessions held is always saved and allows interested parties to conduct analyzes.

Despite some limitations, this study is unique; it bridges the research gap between social interaction and creativity. This thesis investigated novel ways children cooperate and how these influence the creative processes shown.

The experimental part of the thesis presented an inaugural project, which included new unexplored research aiming to measure differences in creativity between atypical and typical children. Despite some Covid-related limitations in the study, the results inspired us to continue working in the indicated direction.

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# LIST OF PUBLICATIONS

Magic Room

Conferences


1. Komarova, S., Gianotti, M., Atanassov, A., Bordonaro, G., Rousseau, C., Goldschmidt, M., Caslini, G., Garzotto, F. (2022). Investigation and perspectives about the promoting creativity to children with ASD in a Multisensory environment Magic Room. Generative game “Explora!” EdMedia+ Innovate Learning, 696–710.


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Conferences


2. Komarova, S., Ndungu, F., Gavazzoli, A., Mineo, R., Others. (2022). The Role of Group Dynamics in Creativity: A Study Case from Italy. Proceedings of World Academy of Science, Engineering and Technology, 16(08).

3. Komarova, S., Ndungu, F., Gavazzoli, A., and Mineo, R. (2022). Group dynamics and creativity: the case of experimentation with young adults. Proceedings of 8th International Conference on Lifelong Education and Leadership.


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4. Komarova, S., Ndungu, F., Gavazzoli, A., Mineo, R. (2023). Group dynamics and creativity: research with young adults in Reggio Emilia, Italy. Creativity Studies, 16(1), 297-314.

# Appendices

**Table 4** Primary studies. Skills and Target user.

| Citation | Skills | Primary user | Secondary user |
|---|---|---|---|
| Anderson, Panneer, Shi, Marshall and others (2018) | Math skills, drawing skills | 16 typically development children; ages = 5-8 | parents |
| Arnone et al. (2020) | Cognitive skills, motor skills, social skills | Children with cognitive dis- ability | therapists |
| Cosentino et al. (2019) | Learning performances | typically, development children, children with cognitivedisability | Teachers |
| De Luca et al. (2021) | Cognitions skills, attention process, adaptivebehavior | M=1 student with ASD, age=16 | caregiver |
| Dow et al. (2007) | Play skills, social skills | 12 (F=6, M=6) typically development participants; ages = 18-33 | - |
| Garzotto et al. (2020*a*) | Cognitive Skills (attention, memory, motor skills, language, visual and special processing, executive function), Learning performance, Autonomy, co-operation skills, well-being | 1-st study, 39 children (F=18, M=21) neurotypical=22, atypical=17; ages = 5-11; 2-nd study, 36 children (19 males and 17 females, 22 neurotypical and 14 atypical); ages = 7-8 | 1-st study, 10 teachers, 5 researchers;2-nd study, 10 teachers, 7 observers |
| Garzotto & Gelsomini (2018*a*) | Life skills, social skills, emotional skills, cognitive skills, motor skills,communication skills | 19 (F=5, M=14) (Children with Neurodevelopmental Disorders (NDD) (Intellectual Disability, AttentionDeficit Hyperactivity Dis- order, and ASD – autism spectrum disorder); ages = 8-13y | Therapists or special educators |
| Garzotto et al. (2019) | Gross motor skills, knowledge skills, social skills, practical skills | 19 (F=5, M=14) (Children with Neurodevelopmental Disorders (NDD) (Intellectual Disability, AttentionDeficit Hyperactivity Dis- order, and ASD – autism spectrum disorder); ages = 8-13 | Therapists or special educators |

| Citation | Skills | Primary user | Secondary user |
|---|---|---|---|
| Garzotto et al. (2016*a*) | Motor skills, cognitive skills, emotional skills, motor skills, socialskills, relaxation | 20 children with Intellectual Disability (ID); ages = 7 - 14 | Caregivers |
| Garzotto et al. (2016*b*) | Cognitive skills, emotional skills, motor skills, and social skills | 20 children with Intellectual Disability (ID); ages = 7 - 14 | therapist |
| Gelsomini et al. (2020) | Cognitive skills (memory long term, memoryshort term), Selection, Classification, Reordering, Identification, Association | 70children (F = 35, M = 35) children; ages = 6-8-9 | Teachers |
| Graf et al. (2019) | Motor skills | children, 7 people with mobility disabilities (5 powerwheelchair users, 2 manualwheelchair users) and 2 childwithout disabilities; ages = 7-19 | caregiver |
| Hotz et al. (2006) | Cognitive skills, social skills, (1) Relaxation; (2) Development ofself-confidence; (3)Achieve sense of selfcontrol; (4) Encourage exploration andcreative activities; (5)Establish rapport withcare takers; (6) Provideleisure and enjoyment. (7) Promote choice; (8) Improve attention span, and (9) Reduce challenging behaviors | 15 (F=4, M=11) (Children with traumatic brain injury); ages = 1.2–16.9 | Caregivers |
| Johnston et al. (2019) | Real-life skills, social skills, cognitive skills, motor skills | 29 (F=2, M=27) (Children with ASD); ages = 9–19 | Caregivers |
| Johnston et al. (2020) multimodal virtual reality game environment | Reduce anxiety, cognitive skills, social skills | 6 (F=2, M=4) (Children with ASD); ages = 16–19 | Caregivers |

| Citation | Skills | Primary user | Secondary user |
|---|---|---|---|
| Kanellos et al. (2018) | Cognitive skills, Motor skills | Children with Attention Deficit and Hyperactivity Disorder (ADHD) | parents, clinicians, and specialneeds educators |
| Marwecki et al. (2013) | Social skills, Communicative skills, motorskills, cognitive skills | Children with High Functional Autism and Asperger syndrome ; ages 8-12 | Educational advisors for autism,therapists |
| Mora-Guiard et al. (2016) | Social skills, cognitive skills | 68 (34 children with HFASD and 34 typically developed children); ages = 10–14 | psychologists of the school, parents of the children |
| Mora-Guiard et al. (2017*a*) | Social skills, communication skills | 40 children (20 ASD (f=4, m=16, 20 typically development children); ages = 11–15 | Psychologists, Special Educational Needsteaching assistantl |
| Parés, Carreras ,Durany, Ferrer, Freixa, Gómez, Kruglan-ski, Parés , Ribas, Soler and Sanjurjo (2005) | Social skills, communication skills, creativeskills | 90 children (low functioning persons in the autistic spectrum (ASD ); ages=6-12 | Psychologists |
| Parés et al. (2006) | Communication skills, social skills, imagination skills | 90 children (low functioning persons in the autistic spectrum (ASD); | Psychologists |
| Pares, Masri, van Wolferen and Cree d(2005*a*) | Communication skills, social skills, imagination skills | 90 low functioning PAS children | Psychologists |
| Ringland et al. (2014*a*) | Motor skills, Social skills | 15 children(M=15) (with neuro developmental disorders);ages = 10-14 | physiologists (n=2) and therapists (n=4) |
| Ringland et al. (2014*c*) | Attention, Social skills | 15 children (M=15) with neuro developmental disorder, 4 children with autism; ages = 10-14 | Pediatric therapists |

| | | | |
|---|---|---|---|
| Takahashi, Oki, Bourreau, Kitahara and Suzuki (2018*a*) | Cooperation skills, attention | 23 children (F=3, M=20) (mild/moderate ASD); ages = 6-12 | 5 researchers, 21 teachers |

| Citation | Skills | Primary user | Secondary user |
|---|---|---|---|
| Takahashi, Oki, Bourreau, Kitahara and Suzuki (2018*b*) large-scale floor projection system | Social skills, cooperative skills<br><br>Pre-trial, Trial, andPost-trial | 20 children (F=6, M=14) (with mild/moderate ID and/or ASD ); ages=15-18 | 16 teachers |
| Takahashi, Oki, Bourreau and Suzuki (2018) | Cleaning skills, cooperative skills | 24 children (with mild/moderate ASD and/or ID ); ages=15-18 | 5 researchers, 21 teachers |
| Williams (2008) | Creative skills | 11-year-old male with Down's Syndrome and an-other 12-year-old male with Autistic Spectrum Disorder (ASD) | teachers |

**Table 5** Special features of MSE.

| Citation | Special features of MSE | Research design | Data collection method | Context of use |
|---|---|---|---|---|
| Anderson, Panneer, Shi, Mar-shall and others (2018) | Augmented reality projection, TV, Floatingprojection | Post-test | Qualitative observation, qualitativeinterviews, survey | Controlled researc h environ ment |
| Arnone et al. (2020)<br><br>Cosentino et al. (2019) | Interactive interface, Multisensory environment<br><br>Multi-modal and multi-sensory environment | Post-test<br><br>Post-test | Focus group, observation<br><br>observation | Controlled research environme nt<br>Classroom environme nt, therapeutic center |
| De Luca et al. (2021) | Virtual reality environment | Pre-test and post test | observation | Controlled researc h environ ment |
| Dow et al. (2007) | Augmented reality environment, computing based implementation | Post-test | Observation of player behavior, opened-endinterview | Controlled researc h environ ment |
| Garzotto et al. (2020*a*) | Interactive Multi-Sensory Environments (iMSEs) , digitally enriched physical materials, ambient embedded devices | Pre-test and post test | Observation, focus group, Smiley Metr | Classroom environ ment |
| Garzotto and Gel somini (2018*a*) | Multisensory multimodal interactive environment called Magic Room | Post-test | Quantitative data from clinical tests (including IQ), subjective qualitative observations by therapists and parents | therapeutic center |
| Garzotto et al. (2019) | Multisensory envir onments, Intern et ofThings (IoT) | Pre-test and post test | Workshop, clinical tests (including IQ) and subjective qualitative observations by therapistsand parent | therapeutic center |

| Citation | Special features of MSE | Research design | Data collection method | Context of use |
| --- | --- | --- | --- | --- |
| Garzotto et al. (2016*a*) | Interactive multisensory smart spaces,wearable device thatautomatically detectsand interprets EEG signals | post-test control | Automatic data collection, feedback coming from the EEG, remote observation | Therapeutic center |
| Garzotto et al. (2016*b*) | Smart space, wearable EEG headset | post-test control | therapeutic data collection and automatic ambient adaptation | Therapeutic center |
| Gelsomini et al. (2020) | interactive immersive smart space | post-test control | - | Classroom environment, Controlled research environment |
| Graf et al. (2019) | Projected augmented reality (AR) (Interactive floor projection) | Pre-test and post test | questionnaire, Observation data, Ratings and rankings, post-study interview | Rehabilitation center |
| Hotz et al. (2006) | Multi sensory room | Pre-test and post test | Observation data | Controlled research environment in Rehabilitation center |
| Johnston et al. (2019) | multi-modal virtual reality game environment | Pre-test and post test control group | Observation data | Classroom Environment in special educational school |
| Johnston et al. (2020) | multi-modal virtual reality game environment | Pre-test and post test control group | audio based questionnaire, observation data | Controlled research environment in Rehabilitation center |
| Kanellos et al. (2018) | multisensory mixed reality game | Pre-test and Post test group | questionnaires, observational sessions andinterview | Classroom environment |

| Citation | Special features of MSE | Research design | Data collection method | Context of use |
|---|---|---|---|---|
| Marwecki et al. (2013) | hybrid interactive surfaces | Post - test | - | treatment center for autism |
| Mora-Guiard et al. (2016) | full-body interactive virtual environment | Pre-test and Post test group | video coding analysis, the tracking system,and questionnaires | Controlled laboratory in inclusive school |
| Mora-Guiard et al. (2017*a*) | full-body interactive virtual environment | Pre-test And post test control group | Questionnaires, Social Communication Questionnaire (SCQ), post-session interviews, observing | Controlled laboratory in Inclusive school |
| Parés, Carreras, Durany, Ferrer, Freixa, Gómez, Kruglan-ski, Parés , Ribas, Soler and Sanjurjo (2005) | interactive environment Pre-testand post test group | Pre-test and Post test group | Qualitative assessment by the psychologists, observation, data analisis | special education centers |
| Parés et al. (2006) | interactive environment | Pre-test and Post test group | Observation, data anal-isis, interview | special education centers |
| Pares, Masri, van Wolferen and Cree d(2005*a*) | adaptive environment that generates real-timestimuli (visual, aural,and vibrotactile) | Pre-test and Post test group | Video recording, Systematic data collection | special education centers |
| Ringland et al. (2014*a*) | Natural User Interfaces (NUI) | Pre-test and post test control group | Interviews, observation audio-video recording | treatment center |
| Ringland et al. (2014*c*) | Multimodal system | Pre-test and post test control group | Interviews, observation audio-video recording | treatment center |

| Citation | Special features of MSE | Research design | Data collection method | Context of use |
|---|---|---|---|---|
| Takahashi, Oki, Bourreau, Kitahara and Suzuki (2018*a*) | Pre-test and post test group | Three observations, three work-shops, six meetings, and two feasibility studies | gymnasium of the school | |
| Takahashi, Oki, Bourreau, Kitahara and Suzuki (2018*b*) | large-scale floor projection system | Pre-trial, Trial, an dPost-trial | Video recording, viability testing, observation | The gymnasium of a special needs school |
| Takahashi, Oki, Bourreau an dSuzuki (2018) | augmented gymnasium | post-test | Observation, interview, workshops, visibility test | The gymnasium of a special needs school |
| Williams (2008) | audiovisual immersive interactive environment | post-test | Semi-structured interviews, observation, data collection,) video footage of the pupils in the Picturing Sound environment; inter-views and discussions with staff; the author's field notes; and notes made by the supporting teachers | special school |

**Table 6** Primary studies, evaluation parameters

| Citation | Evaluation parameter |
|---|---|
| Anderson, Panneer, Shi, Marshall and others (2018) | Detection of air gestures, touch gestures, pose, and facial expressions, the distance of children from the AR characterOscar. |
| Arnone et al. (2020) | System adaptation for each child. |
| Cosentino et al. (2019) | Speaking language, body position, different gestures and movements are expected as reactions to the challenges pro-posed and detected by the embedded sensors. |
| De Luca et al. (2021) | An infrared video camera analyzing the patient's movements, it creates interactivity. At the end of each work session, it is possible to export the full list of all exercises per-formed and the score obtained for each one. |
| Dow et al. (2007) | Each participant played Facadee three times, between each episode authors did open-ended interview. Authors also collected quantitative data (player and character dialogue, body/head position and rotation, and AI processing logs). |
| Garzotto et al. (2020*a*) | Observations were annotated manually by the observer to record the relevant phenomena in children's behavior. Final feedback was collected from children using a four-values Smileyometer, organized a focus group with teachers. Questionnaire results were analyzed and scored according to the standardized QBS procedure that interprets the questionnaire values in terms of six different indicators.The principal one is the General Score that summarizes an individual's general well-being in the school context. |
| Garzotto and Gelsomini (2018*a*) | Defined an activity plan customized for each group, therapist observed participants and took notes, season were vide-recorded. |
| Garzotto et al. (2019) | Observations reported by the caregivers, the analysis of video-recordings (performed by therapists not participating in the session), and a final interview to the entire therapeuticteam. |
| Garzotto et al. (2016*a*) | Using a passive brain-computer interface (BCI) to perform environmental adaptation instead of asking children to be-have in a predefined manner to complete the assigned tasks.display the levels of attention and relaxation along the time-line, and how they relate to the different moments of inter-action, tasks, and smart objects use. |

| Citation | Evaluation parameter |
|---|---|
| Garzotto et al. (2016*b*) | Stimuli to the children's current state as modelled by the data generated by the EEG headset. |
| Gelsomini et al. (2020) | Analysis based on school tests results, given their quantitative nature that enabled to make comparisons between groups, across time, and with current national performancescore Tested and quantified children's knowledge about thetopic before and after the training, evaluating each child's starting level could. Research variables: (1) Short term retention; (2) Long term retention; (3) Memory Loss; (4)Con-tent Retention Rate; (5)Active Learning Turn Efficacy. |
| Graf et al. (2019) | Interviews with health professionals in a customer discovery program following the Lean LaunchPad approach and casual observations of physical therapy sessions of people with mobility disabilities. |
| Hotz et al. (2006) | Observation: heart rate (HR), systolic blood pressure (SBP), diastolic blood pressure (DBP), mean arterial pressure (MAP), oxygen saturation (02 SAT) and muscle tone (Modified Ashworth Scale) The cognitive and behavioralmeasures included: Ranchos Los Amigos Scale (RLAS), Agitated Behavior Scale (ABS), Functional Independent Measure (FIM). |
| Johnston et al. (2019) | An accuracy metric was used to evaluate participant performance during the spatial audio A two-way mixed ANOVAwas conducted |
| Johnston et al. (2020) | Each participant completed an identical audio-based questionnaire in which they would rate their perception of specific sounds: Modified Smiley-Face Assessment Scale; Tracked Voluntary Participant Interaction with Target Audi-tory Stimuli. |
| Kanellos et al. (2018) | Monitoring methodology: (a) mobile device embedded sensors, (b) Electroencephalography (EEG) neurofeedbackmechanisms, (c) Augmented Reality (AR) user tracking, (d)RFID-based object tracking for tangible user interaction,<br>(e) in-game cognitive skill performance measurements, (f) cloud performance analytics, and (g) web-based secure access for remote profile monitoring and management |
| Mora-Guiard et al. (2016) | Evaluation criteria of the system focused on motivation of the child to play in the system, propensity of the child to engage with other people, and visible social interaction attitudes. |

| Citation | Evaluation parameter |
|---|---|
| Williams (2008) | The child's gestures were captured through a digital camera and mapped to computer vision algorithms to create a 'moving painting', and then further to a MIDI sound source that responded to the movements of the child |
| Mora-Guiard et al. (2017*a*) | The results were evaluated based upon the system's ability to promote users' engagement and scaled socialization andcollaboration through intelligently sparking interaction in the children with ASD and the TD peers: (1) system would motivate users to play; (2) children's level of participation, activity level and flexibility while playing the game; (3) time spent engaging in active game play |
| Parés, Carreras, Durany, Ferrer, Freixa, Gómez, Kruglanski, Parés, Ribas, Soler and Sanjurjo (2005) | Data logged by the system corresponding to the user's sensed behavior during session. |
| Parés et al. (2006) | Qualitative evaluation by psychologists. |
| Pares, Masri, van Wolferen an dCreed (2005*a*) | Independent emulator: (1) Independence. (2) Person-centered. (3) No parental demands. Data about the environment's use, in the context of monitored changes in the children's general behavior over time. |
| Ringland et al. (2014*a*) | Interviews with physiologists, observation of children with autism during sensory therapy |
| Ringland et al. (2014*c*) | Evaluate the impact of SensoryPaint through two user studies: a lab-based study and deployment study. |
| Takahashi, Oki, Bourreau, Kitahara and Suzuki (2018*a*) | Observe reactions to the game interface, the viability testing for evaluation the following minimum factors required for the game: (1) difficulty of the game; (2) how well the game keeps the children's attention focused on the contents provided; (3) how well the game attracts the children's interest. |
| Takahashi, Oki, Bourreau, Kitahara and Suzuki (2018*b*) | Videos of the students' running were obtained from the fish-eye camera on the ceiling with a frame rate of 15 fps. The position of each runner was detected in the videos by usingKinovea. RMSD(i) (Root Mean Square deviation) was calculated. |
| Takahashi, Oki, Bourreau an dSuzuki (2018) | The feasibility for cleaning instructions was investigated by comparing percentages of swept areas in the cleaning fieldbefore and after intervention. |

| Citation | Evaluation parameter |
|---|---|
| Anderson, Panneer, Shi, Marshall an dothers (2018) | Determine whether children would remain enthusiastic over time or across a wider range of activities. Application types: (1) A health and fitness suite to guide children and encourage them to be active (2) Creation-themed applications to allow children to bring toys and sculptures into a mixed reality environment (3) Providing a new interaction model withcharacters from movies and television |
| Arnone et al. (2020) | Evaluate "Smart Buckets" on the long term from both children and therapists perspectives to observe performance and engagement about the former and the adaptability and sustainability of the latter. To include the product in the therapeutic center curricula. |
| Cosentino et al. (2019) | Allow each user to find the preferred and facilitating way of learning and propose its commonly successful solutions forprofiles with the same weaknesses or difficulties. |
| De Luca et al. (2021) | Further studies are needed to explore the VR potential in ASD. |
| Dow et al. (2007) | Defining and measuring the important concept of engagement, independent from presence. |
| Garzotto et al. (2020*a*) | Teachers become creators of new ways of exploiting iMSEs for educational purposes. Involving teachers in de-sign work; offering them a simple yet powerful configuration and control tool for the children experiences inside the iMSE; investing time and human resources in training teachers. |
| Garzotto and Gel-somini (2018*a*) | Involve 60 subjects and complement descriptive results with clinical tests performed before, during, and after the study,to compare the effects of the Magic Room against regular interventions and against treatments in a Snoezelen. |
| Garzotto et al. (2019) | Empirical evidence of long term or generalization effects. |
| Garzotto et al. (2016*a*) | Expand the system by taking into account also attention levels and will progressively adapt other stimuli offered by theMagic K-Room to attention. |
| Garzotto et al. (2016*b*) | Extending the set of adaptation functions associated to relaxation; considering also attention levels as a sourceof adaptation. |

| Citation | Evaluation parameter |
| --- | --- |
| Citation | Future work |
| Gelsomini et al. (2020) | (1)Co-creatability: involving children as co-creators and collaborative problem solvers; (2) Adaptivity: technology is able to automatically track each learner's improvement; (3) Inclusivity: supported both s children with greater difficulties and empowered high performers; (3)Trackability: profiling students and tracking their results; (4) Embodiment: activities comparable with textbook- style tasks. |
| Graf et al. (2019) | The design goal is to further develop the system for multiplayer games on a larger scale. Introducing the lens of the "intermediate body" for the subjectively experienced virtualbody that players access in the form of our peripersonal circle. |
| Hotz et al. (2006) | Future studies consider utilizing a well-developed methodological design to assess the main effect of the treatment and of this Multisensory environment. |
| Johnston et al. (2019) | Measure self-reported presence within virtual environments that use spatial audio rendering techniques. |
| Johnston et al. (2020) | Future investigations would require two experimental groups with a larger sample to compare the use of spatialized sound to traditional audio rendering techniques such asstereo. |
| Kanellos et al. (2018) | Further studies are needed to explore the multisensory mixed reality potential in ADHD. |
| Marwecki et al. (2013) | Evaluate the game by testing it with groups of children in a treatment center for autism, Qualitative interviews con-ducted with the therapists observation. |
| Mora-Guiard et al. (2016) | Focus on evaluating specific design mechanics implemented and how they affect users' behavior by controlling them as independent variables. Compare the effect of this collocated, face-to-face, full-body interactive paradigm with respect to other videogames based on other types of interface. |

| Citation | Evaluation parameter |
|---|---|
| Citation | Future work |
| Mora-Guiard et al. (2017*a*) | Further research must focus on the gender distribution during Participants Design and how it affects acceptance of thefinal design by both genders. |
| Parés, Carreras, Durany, Ferrer, Freixa, Gómez, Kruglanski, Parés, Ribas, Soler and Sanjurjo (2005) | Design more interaction models to low functional PAS children and analyze which are more successful in generating acreative activity. |
| Pares, Masri, van Wolferen an dCreed (2005*a*) | To gain information about the part the MEDIATE experience may play in these children's general development |
| Ringland et al. (2014*a*) | Developing a multiplayer version of SensoryPaint that help to improve skills in socializing and communication |
| Ringland et al. (2014*c*) | Larger deployment of a new version of the system that will give data to explore Sensory Paint's impact on body aware-ness, sensory skills, attention, and socialization. |
| Takahashi, Oki, Bourreau, Kita-hara and Suzuki (2018*a*) | To improve the quality of the game through ongoing design sessions at school. |
| Takahashi, Oki, Bourreau, Kita-hara and Suzuki (2018*b*) | Developing a multiplayer version of SensoryPaint that help to improve skills in socializing and communication |
| Takahashi, Oki, Bourreau an dSuzuki (2018) | Larger deployment of a new version of the system that will give data to explore Sensory Paint's impact on body aware-ness, sensory skills, attention, and socialization |
| Williams (2008) | To improve the quality of the game through ongoing design sessions at school |

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