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Creative Approaches for Inclusive STEM Learning in Early Years

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Abstract

This research aims to contribute to the field of inclusive early childhood education. It is a case study that explores creative approaches to STEM (science, technology, education, and mathematics) education in the context of an inquiry-based design project. The participants are three children (two girls and one boy, 6 to 7 years old) with diverse cognitive abilities and their teacher. The children created and tested prototypes, identified problems and developed solutions. The two research objectives are to examine children's creative products and processes; and to identify the features of the pedagogical approach that supported their engagement in the project. The data set consists of classroom video recordings and pictures, unstructured interviews with the teacher, and field notes. Results show that all children were able to successfully develop original and functional products through creative processes. In addition, the teacher's strategies that supported the children's performances are identified. Her practices were responsive and positioned the children's emotions at the center of teaching. It is suggested that a creative approach, paired with tailored scaffolding in an emotionally safe environment fosters inclusion.

Keywords STEM · Inclusion · Design-based learning · Inquiry · Emotions · Creativity

Introduction

The lack of access to early STEM (science, technology, education, and mathematics) learning opportunities affects later achievement and career choices (Mbamalu, 2001). Non-dominant ethnic groups, people with functional diversity and women in STEM professions are in minority, as they have traditionally been excluded from the culture of science. Early education can play a significant role in overcoming these inequities, as it can support the development of all children's STEM identities (Pantoya et al., 2015).

Sustainable Development Goal 4 aims to ensure inclusive and equitable quality education for all (United Nations [UN], 2015). Globally, approximately 40% of children are deprived of this right, as access to quality education in the early years is concentrated in developed countries (Alam, 2021). Children with special educational needs (SEN) due to conditions such as different cognitive abilities, disabilities, belonging to a minority culture, or being at risk, among other factors, do not have the same opportunities to benefit from available educational facilities (UNESCO, 2021). Inequities persist even in contexts where the state system guarantees access to early childhood (EC) education (UNESCO, 2021). Thus, an inclusive approach becomes relevant, as it aligns with ideas of social justice and equality, questioning how educational systems reproduce and perpetuate inequities (Liasidou, 2015).

Interest in inclusive STEM education has increased in recent decades (e.g., Brauns & Abels, 2020). Nevertheless, as shown by four recent reviews in the context of inclusive and non-inclusive settings, studies exploring STEM learning by children with diverse cognitive abilities in EC settings are scarce. Alber-Morgan et al. (2015) focused on all types of SEN and found only two studies in the context of EC regarding students at risk. Apanasionok et al. (2019) concentrated on studies about students with autism spectrum disorder and intellectual disability, also locating two studies at the EC level. García-Terceño and Greca (2023) examined studies about science learning by children with disabilities or serious behavior, communication, or language-related disorders, finding only one study in EC. Taylor et al. (2020) focused on intellectual and developmental disabilities, locating one study involving 8-year-olds. The four reviews highlight the

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benefits of inquiry approaches combined with specific strategies. However, drawing systematic conclusions is challenging due to the limited number of studies and the diversity of methodologies and contexts. Overall, these reviews indicate that STEM learning by young children with differing cognitive abilities in EC is an understudied field. A literature review conducted in indexed journals of EC, STEM, and Special Education using the keywords "STEM", "science education", "inclusion" and "early childhood", did not add any new studies regarding STEM learning by young children with cognitive-related SEN.

Using sociocultural perspectives to examine learning processes, this study aims to partially fill this gap in the literature. Three children (6 to 8 years-old) with diverse cognitive abilities are accompanied while engaged in a STEM design-based project with a creative pedagogical approach. The research questions are: (1) *What are the features of creative products and design processes of young children with diverse cognitive abilities*?; and (2) *What are the features of the pedagogical approaches that facilitated children's engagement in design processes?*

Design and Creativity in Early Years Education

This study is framed within sociocultural perspectives on learning. Cultural-historical learning theories emphasize social interactions as the sources of development. Learning is seen as a continuous and evolving process that occurs when children engage with their surroundings. According to Fleer and Veresov (2018a, 2018b), these interactions are vital for cognitive growth because they allow children to explore, ask questions, and understand their environment. By interacting with peers, adults, and their surroundings, children can acquire knowledge and improve their critical thinking skills, making learning a social and context-dependent activity. Framing interactions as the foundation of development, an increasing amount of research has explored social processes in EC STEM education. This research highlights inquiry-based (e.g., Wilmes & Siry, 2021) and playful (e.g., Fleer, 2023) environments as valuable learning contexts in which social interactions can stimulate the interests and meet the needs of diverse students.

Design based-learning approaches involve the creation of an original product that targets a particular need. Thus, students encounter real, authentic problems with multiple solutions (Hmelo et al., 2000). Crismond and Adams (2012) identified key design strategies that can be addressed by education, such as understanding challenges, reflecting on process, revising/iterating, representing ideas, and making decisions. Thus, DBL and inquiry are both student-centered pedagogies that share features such as involving authentic and hands-on tasks, allowing multiple approaches and solution pathways, and encouraging collaboration (Hmelo et al., 2000). The literature has reported that drawing tasks can play a core role in supporting the development of design competencies. Drawing is a frequently used activity in EC classrooms that is influenced by social interactions (e.g., Danish & Phelps, 2010; Monteira et al., 2024). Young children can create 2D drawings for design purposes, that resemble what they aim to build in 3D, although they lack detail regarding the construction techniques and materials (Fleer, 2000; Hope, 2000). Hope (2000) noted that drawing ahead of a task can support idea generation, but not the materials and planning of the construction. A review by Milne (2013) revealed that, when transitioning from 2D drawings to 3D objects, children face challenges such as lack of detail, running out of space, and insufficient 3D skills. She suggested that early education should clarify the purpose of drawing for design and explicitly teach these skills, highlighting the potential of skilled teachers in creating motivating conditions for children to develop more complex design skills over time. Kelley and Sung (2017) point to the affordances of sketching as a tool for supporting design thinking. In their study with third graders, they found that the potential of sketching can be enhanced by explicit instruction of its role in design thinking, providing students with examples of design sketches, techniques for symbols, labels, multi-views to communicate design ideas, and supporting questions for refining. Overall, these studies highlight the importance of the environment in the development of design competencies and the impact of working with materials for young children to foster cognitive and creative development. The relationships between creativity and design-based learning (DBL) approaches are further discussed next.

Creativity can be fostered by education (Shaheen, 2010) and different education systems around the world acknowledge this ability (Joubert, 2022). In our context, the national curriculum for 6 to 8 year-olds points to the development of STEM competences through engagement in guided projects and the use of *creativity* for generating a product with a specific objective. Findings from a recent systematic review identified seven characteristic and interrelated features of creative pedagogical practices: generating and exploring ideas, playfulness, encouraging autonomy and agency, problem-solving, risk-taking, co-constructing and collaborating, and teacher creativity (Cremin & Chappell, 2021). Cremin et al. (2015) point out that both DBL and creative approaches to education involve paying attention to play and exploration, dialogue, collaboration, reflection, questioning, or curiosity. Thus, creativity is often embedded in STEM instruction; namely in DBL (Bozkurt Altan & Tan, 2020).

Creativity has been defined both individually and collectively (Kupers et al., 2019). On an individual level, the field of psychology has examined the relationship between intelligence and creativity (e.g., Gardner, 2011). Other views state that creativity does not take place in an isolated mind and that it is socially embedded. Thus, the dynamic interactions between culture and the individual shape the creative process and the products of it (Csikszentmihalyi, 1988). As a consequence, educational settings are unique contexts where creativity can take place, and the learning environment features can either support or hinder creativity.

The analytical frameworks that examine creativity as emerging from the social context in educational settings, commonly focus on four aspects: the person, as both teachers and children can be engaged in creative doing and thinking; the products that are the outcomes of the creative process; the process itself, as it is relevant to describe which actions and dispositions are related to creativity; and the environment, that can either hinder or promote creativity (e.g., Cropley & Cropley, 2010; Soomro et al., 2023). Rhodes Four Ps of Creativity framework (1961) refers to the dimensions of *person*, *product*, *process*, and *press*, the latter corresponding to the features of the environment. Based on the four P's framework, Murcia et al. (2020) developed the *A to E Children's Creativity Framework*. This framework is informative to our research as it specifically addresses creativity in young children's educational settings, as explained next:

– A creative *product* can either be an abstract (an idea, a solution) or a concrete (a drawing, a craft) outcome that meets the criteria of being original and fit-for-purpose.
– Within the category *person,* three possibilities are contemplated: the educator uses creative strategies; the child is engaged in creative doing, following the educator's example; or the child is engaged in creative thinking, generating original outcomes to meet the task purposes.
– The dimension *place* (instead of *press*) focuses on how the educational context enables creative thinking. Three elements are identified, which are: resources, communication and socio-emotional climate. Resources refers both to physical materials, which should be stimulating and adequate, as well as to characteristics of the pedagogy employed, such as availability of time and providing stimulating materials. Communication refers to intentional learning conversations, hearing and valuing children's ideas, facilitating dialogic conversations, and using open inquiry questioning. The socio-emotional climate is defined by being stress and pressure-free, non-prescriptive, non-judgemental and one in which mistakes are allowed. Regarding *process,* five aspects are shown by children while they engage in creative thinking: agency, being curious, connecting, daring, and experimenting. Each one of these aspects conveys associated actions and attitudes, such as using materials differently, or acting autonomously.

Research Methods

Overall Design and Context

This research adopts a qualitative perspective (Merriam, 2009), suitable for understanding participants' experiences in context. It is a case study (Yin, 2003) conducted in a non-formal educational setting in Spain, a country where formal early childhood (EC) education is guaranteed by the state system. The study's context is a private non-formal education facility offering after-school STEM instruction for children aged 5 to 18 years, with a focus on design. Throughout the school year, students in this facility develop projects and present them at a Maker Faire organized by their teachers. This open event allows interested participants, including students and individuals, to share their own creations and projects, such as installations, crafts, and 3D printing projects.

My collaboration with the teachers began during a previous research project aimed at developing STEM teaching and learning resources to foster the creation of school-based makerspaces (te Heesen et al., 2022). Makerspaces are physical locations equipped with tools where students engage in open-ended, collaborative inquiries focused on designing a product. They serve as "learning spaces, whether there are adults learning with other adults, youth learning by making projects for their community with adult mentorship, or students learning new skills and techniques together in design and engineering tasks" (Tucker-Raymond & Gravel, 2019, p. 124). Makerspaces and making are gaining *momentum* in educational practice and research globally due to their potential to support the development of essential competencies in both formal and non-formal settings (e.g., Martin, 2015; Rodriguez et al., 2018; Soomro et al., 2023).

The head of the facility was interviewed as an expert in makerspaces, and this collaboration led to an extended exchange due to our shared interests. I aimed to learn from the teachers' approaches to STEM education through making, and they were interested in reflecting on their practices. I visited the facility several times to understand the teachers' professional culture and practices. I sought permission to accompany and document the lessons of one of the most experienced teachers, responsible for the younger students, to conduct an exploratory study in one of the groups she was teaching. The participants are the object of study, and ethical issues were considered (Snape & Spencer, 2003). They were informed of the research purposes, and written informed consent was obtained from the teacher and families at the beginning of the school year to accompany and document the sessions. It is a non-intervention study where the teacher designed the instruction, and my role was that of a participant observer. The teacher introduced me to the children, explaining my interest in their projects. My interventions involved asking the children about their activities and assisting them with tools when requested by the teacher.

The teacher, a former biologist, has been teaching science to young children for over 10 years. She began her career in Research, Development, and Innovation (R&D&i) as a biology researcher, which provides her with valuable insights into scientific work and a genuine interest in STEM disciplines. Consequently, she incorporates in her teaching opportunities for children to engage in STEM disciplinary practices, explore in-depth content knowledge, and use various tools and resources. The group was made of four girls and four boys (aged 6 to 8), from whom four have high abilities and one has cognitive difficulties. I accompanied them over a school year. Two girls and one boy are the focus of analysis, as they represent a range of cognitive abilities within the group. One child has high abilities, demonstrating mastery in both oral and written communication, an intense curiosity about the surroundings, rapid comprehension of new information and complex ideas, and strong analytical and problem-solving skills. This child easily applies new knowledge and uses new tools. Another child has difficulties solving problems and understanding the use of tools and the purpose of tasks. Once the goals of the activities are understood and the child is engaged, solving the tasks takes longer than for the rest of the group. The remaining focal child does not have any special educational needs (SEN) and displays abilities that are average for a child of this age, falling between the two extremes mentioned above. Data that could lead to their identification is avoided. The classroom climate is emotionally safe, as the teacher fosters respectful conversations and peer support during tasks. The three children participate in class activities and interact with their peers and teacher according to their personalities, without any significant behavioral difficulties.

This study reports results from one unit on the topic of Architecture. The entire unit involved learning about important STEM concepts such as balance, proportions, function, and sustainability. The children designed and crafted building projects and cities; researched technological and biological information; presented their projects to peers; used and coded educational robots; and programmed simple circuits for house automation, among other tasks that helped them build competencies in the STEM disciplines. Within this longer unit, the research focuses on one of the design projects, developed over seven weeks (1.5 h/week) (Table 1), with the overall purpose of designing and crafting a house. The sessions took place in an open and bright 100 m^2 room, equipped with modular furniture (tables, drawers) that allowed for adapting the space to the tasks, a screen, a whiteboard, and a wooden dome.

Data Sources and Analysis Methods

I recorded the sessions (audio, video, and pictures) and took field notes. After the sessions, the teacher and I discussed them, and I took reflexive notes, which were also discussed with the teacher through unstructured interviews. To ensure methodological integrity, the analytical procedures and preliminary findings were peer-reviewed, and the results were examined and discussed with the teacher.

The two interrelated foci of analysis, creativity and inclusion, emerged from my research interests and the interaction of data with the literature discussed earlier. First, through observations, field notes, and discussions with the teacher, I became acquainted with the different cognitive abilities present in the class and noted that all children were able to progress and participate in class activities. The teacher highlighted that a notable feature of the teaching practices in the school was the inclusion of students with diverse cognitive abilities. She reported that the methodologies used by the teachers created an inclusive environment where all students had opportunities to improve their skills at their own pace and according to their interests. As a result of my observations and the teacher's input, the three focal children and two tasks were chosen for convenience. The teacher identified these three cases as representative of the range of cognitive abilities present in the class. Throughout the project, the

Table 1 Timeline and contents of the sessions

Week	Contents
1	Introducing the topic of Architecture. Exploration of initial ideas. Evaluating real buildings: functionality and aesthetics. Crafting buildings with milk cartons and recycled cardboard
2	Crafting and decorating buildings to create a city for Tiny bot. Programming Tiny bot to navigate from one building to another
3	Scaling up the buildings: measuring tools and basic orthogonal structures
4	Designing a safe city for Ozobots using the upscaled buildings. Designing a signal
5	Examining and discussing crazy houses. Designing a crazy house (2D)
6	Crafting a crazy house (3D)
7	Crafting a crazy house (3D)

group engaged in various tasks. The 2D drawings and 3D craft tasks were selected for in-depth analysis due to their characteristics: they are individual products that allow for examining how a design project is developed from an initial sketch to a final product. Additionally, while absences are frequent in an afterschool context, the three focal children completed both tasks. Second, the focus on creativity emerged from the interaction of the literature (Cropley & Cropley, 2010; Murcia et al., 2020; Soomro et al., 2023) with discussions with the teacher, who stated that children's creativity needs to be nurtured.

Coherently with the literature reviewed in the theoretical framework section that addresses the influence of the social environment on children's development of design competencies and creativity, the overall analysis perspective is rooted in sociocultural views of learning in early ages, appropriate for examining the social context that mediates learning and highlighting the diverse resources children bring as learners of science (e.g., Fleer & Pramling, 2015; Siry, 2012). This perspective is especially fruitful for unpacking how social interactions facilitate inclusion in EC science (Fleer & March, 2015). Alligned with the view of creativity as the product of social interactions mediated by cultural artifacts, the analysis focuses on the dimensions of product, process, and environment, aspects highlighted by the literature reviewed in the framework section (Murcia et al., 2020).

To answer RQ1, the foci are: (1) the products created; and (2) the process through which these were created. To examine the products, the data sources are pictures of the focal children's individual products: the 2D designs and the 3D crafts. They were examined to determine whether or not creativity was embedded in them and how, as they evidence the children's diverse abilities and approaches to meeting the task goals. The analytical method chosen is inspired by comparative content analysis (Bell, 2001), appropriate for examining comparable visual content, as explained next. These were analyzed through iterative cycles to identify and define variables. Three variables were identified: (1) resources, referring to the materials used to produce the 2D and 3D designs; (2) appearance, referring to the overall visual aspect of the creation; and (3) solutions for stability, referring to the strategies employed to ensure the constructions could stand on their own. The children developed the designs according to their individual approaches. Each variable's expression reflects the value it takes, which is shaped by the children's personal choices. For example, the value for the variable resources could be "black marker pen." This type of analysis has proven valuable in EC science for identifying patterns and differences in class assignments, such as drawing tasks (e.g., Monteira et al., 2024).

To examine the children's creative process, the videotaped sessions and field notes were analyzed using content analysis. This method involves categorizing and coding the content into manageable units to identify patterns, themes, and meanings (Bardin, 1986), and it was employed to map the sessions and organize them into episodes. The episodes were examined to identify and describe the children's actions and attitudes related to creative thinking (Murcia et al., 2020).

To answer RQ2 regarding the teacher's pedagogical practices, videotaped sessions, pictures, and field notes were analyzed using content analysis. This approach facilitated the identification and description of elements within the categories of resources, communication, and socio-emotional climate, as defined by Murcia et al. (2020), which mediate the design processes. Children interact with these elements, such as the teacher's interventions and the available tools, that are accessible in their social environment.

Results

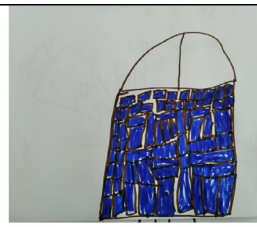
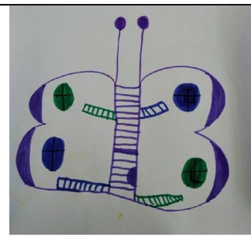
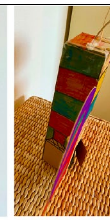
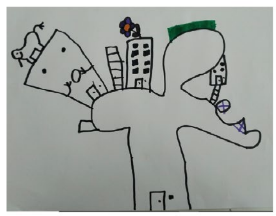
Next, the results of the analysis are presented with focusing on how this setting enabled all children to progress despite their different cognitive abilities. The first research question is: *What are the features of creative products and design processes of young children with diverse cognitive abilities?* The answers to this question are organized into two parts. The first part addresses the results of the analysis of the children's products. The second part discusses the design processes they followed. Finally, the second research question regarding the teacher's practices is addressed: *What are the features of the pedagogical approaches that facilitated children's engagement in design processes?*

Children's Creative Products

The three focus children's designs evidence their creativity, as they are original products made to meet the goals of the proposed tasks. The pictures of their products are shown in Table 2. Regarding the variable *resources*, all children used an A3 white sheet, as required by the teacher, and either a few colored (Child 2) or mainly black marker pens (Child 1 and Child 3) for their 2D initial design. For the final product, they used tools such as scissors, glue, and hot glue guns and chose different materials available in the classroom to make the models. Child 1 chose a paper bag and a piece of paperboard and painted the structure using only a blue marker. Child 2 and Child 3's final products were created using paperboard. The variety of colors was achieved by Child 2 using markers, whereas Child 3 additionally decorated the craft with colored tinkering supplies.

Regarding *appearance*, Child 1 aimed to create a "bag-house" (sic). Child 1 explained that the initial design was a plastic bag with several squares resembling the different rooms and spaces of a building, for which black and blue

Table 2 Children's creative products: 2D initial design, 3D final product, age and sex

Child	2D Initial Design	3D Final Product	Age	Sex
#1			7	Boy
#2		 	6	Girl
#3			7	Girl

markers were used. In the final craft, the same two colors were kept, and functionality appeared as a new focus. Aside from showing different floors, with doors on the basement and stairs, the building also had spaces for sports. Child 2 wanted to build a "disco-house" (sic) with the shape of a butterfly, shown both by the 2D initial design and the 3D final product. Both had a door to enter and several floors and windows, as real houses do. The door in the 3D design was cut so it could be opened. Like Child 2, Child 3's initial idea also showed a mix between reality and imagination: the base of the building resembled the squared shape of a real one and had a door. On its top emerged buildings with windows, doors, and smiles, together with curvy shapes and different natural elements, such as an animal, a flower, and grass. These two last elements were the only ones that were colored. The 3D final structure was more colorful than the initial design, due to the use of green, blue, and black marker pens and colored pipe cleaners. It kept the shape of a building, the smile, and the curvy shapes on the sides and the top, but the natural elements were no longer present. Instead, more colored curvy shapes were added to the main structure using pipe cleaners. Child 3 explained that the green cardboard surrounding the building was the garden. Two windows were depicted above the smile, resembling two eyes.

Regarding *stability*, when moving from the 2D initial designs to crafting the 3D houses, all children encountered difficulties they had to solve to create structures that could stand on their own. Child 1 discovered that the plastic bag was not stable and decided to use a paper bag instead. The second prototype, using the paper bag, could not stand on its own. Child 1 resolved this issue by preparing and pasting a piece of paperboard to cover the hole at the top of the bag. Child 2's house physically resembled the initial design of a colorful butterfly house. As shown by the side view, stability was achieved by using a paperboard orthogonal structure as a base, with the butterfly shape pasted on the front. Child 3 faced challenges in achieving the curvy and irregular shape of the initial design in a way that the final product could stand on its own. This is why some elements from the initial design were not present in the final product. After several attempts, Child 3 also chose to use the same basic paperboard structure as Child 2. Additionally, the green cardboard around the house served not only to include a natural element, the grass of the garden, but also provided a base for the structure to stand on, along with a cardboard square similar to that used by Child 1. Child 3 decided to use pipe cleaners to maintain the initial curvy design's shape, as they are lightweight and did not affect the stability of the building.

Children's Creative Processes

The five aspects of creative processes (Murcia et al., 2020) were present, as illustrated below. Actions and attitudes described by Murcia et al.'s (2020) framework are identified in italics.

- Agency: the recordings show all children engaged actively in the project, *acting autonomously* and developing ideas for their houses. The children went around the classroom, selecting materials and tools to design and craft their projects *freely and according to their personal choices*. Each child developed the tasks according to their *purposes* and found their own *personal meanings*. For instance, Child 2 aimed to build a discotheque and pointed to the elements depicted in the drawing to explain how to access the different dance floors:

  > My house is a disco-house. This is the door to enter it. Then you go up here [pointing to the stairs] and you can come in [pointing to the room on the left of the first floor] and then you go here, and you can come in here [pointing first to the stairs and then to the room on the opposite side].

- Being curious: in week 1, the teacher introduced the project with pictures of civil constructions around the world. The group engaged in *wondering* and *questioning* the functionality and design of these constructions. For instance, Child 2 pointed to a bridge that was crooked and indicated that the design was wrong. In week 4, the children discussed different designs of houses in terms of stability and ease of living in them, aspects that should be considered, together with aesthetics, in their designs. For instance, Child 3 said: "How are you going to be able to live inside [pointing to the picture of a house that looked upside-down], if it is inclined?". After the presentation, they engaged in *imagining* their own designs.
- Connecting: children *shared* their projects, ideas and difficulties *with each other*. They acknowledged their peers' designs: "It looks very nice!". Those who faced similar problems while building the structures, joined to find a solution together. For instance, Child 2 and Child 3, who used the same orthogonal structure as a basic framework. Child 1 *made a connection* with an earlier task that involved the use of paperboard rectangles and squares to improve the stability of structures. Child 1 then *combined* this structure with the paperbag, so it could stand on its own. Children also shared the tools and resources in a collaborative manner, showing its use and possibilities to their peers.
- Daring: as shown by the evolution of the 2D initial designs into the 3D final products, children *persisted* in achieving their designs and *put their ideas into action*, even when they encountered difficulties. Child 2 went through several attempts at closing the house from behind, so that it could stand whilst keeping the butterfly shape and both Child 1 and Child 3 had to implement many changes, as discussed earlier. Children *learned from failure* along the process by identifying which materials and tools were necessary or the most appropriate. For instance, all three children found out that using a measuring rule, which was not appealing to them at the beginning, made it easier to achieve a stable structure and, therefore, used it consistently.
- Experimenting: all children had to *solve problems* and, to do so, they *tried out new ideas*. An example of *using materials differently* is Child 1, who used a bag as a basis for a house. Child 1 also showed mastery at *tinkering and adapting ideas* when moving from a plastic bag to a paper bag, subsequently adapting it for its purpose. Child 3 made several adaptations of the initial ideas to turn them into 3D. Child 3 *played with possibilities*, both regarding the ways to attach the structures (tape, glue, hot glue…), as well as regarding the materials that were functional (cardboard, paper, pipe cleaners…). When the 3D house was almost crafted, Child 3 decided to improve it by opening the four sides on the bottom of the structure and pasting a paperboard square to give it extra stability (Fig. 1).

Pedagogical Practices That Foster Creativity

This section describes the pedagogical practices identified in the analysis, organized according to the categories:

Fig. 1 Child 3 crafting the 3D house

resources, communication, and socio-emotional climate (Murcia et al., 2020), each comprising several features.

Resources: this category refers to both non-physical structures, such as time distribution, and physical resources made available by the teacher. All sessions followed the same routine: engaging in a dancing game, which the teacher named "activation time"; explaining the purpose of the sessions; introducing the materials, such as presentations, physical tools, and resources for working; carrying out the tasks; and tidying up the room. Finally, the dancing game was repeated during closing time.

The preparation of the project by the teacher involved extensive research on the topic and related educational projects and tools, as well as getting to know the children. Through conversation, introductory tasks, and games, the teacher conducted an initial evaluation to adapt the project to the group. She particularly focused on their interests, identifying who would need more support, and who would need more challenges to stay engaged in the project.

Regarding the distribution of the space, all tools and materials were available in drawers installed at a height children could reach, allowing them autonomy to get the resources and tidy up once they were done. The children worked sitting at the same table so they could all see each other developing their projects and move freely to cooperate.

The complexity of the project increased over time, as shown by the contents of the sessions (Table 1). During the initial sessions, the teacher proposed simple tasks aimed at teaching the safe and proper use of tools (silicone guns, rulers, or scissors) and their usefulness for pursuing their projects. Figure 2 shows the children sitting around a working table, about to begin a craft task during week 1, while the teacher explains. The screen shows pictures of the tools and materials they had available.

Fig. 2 Children sitting on the working table and teacher explaining

Fig. 3 The teacher is demonstrating how to create an orthogonal structure using recycled materials, measuring with a set square

Another initial task in week 3 was designed to model a simple strategy for achieving a stable structure. Using a template (Fig. 3), students built orthogonal structures out of recycled cardboard.

> Teacher: [*At the table with the children*] "So, we're going to learn how to make, look, a very simple structure that you can use to make almost anything you want. You can also do it at home. Depending on the size of our cardboard, we can make a house, buildings this wide, Hogwarts castle... okay? It's just about learning the technique, so later, if I want to make a castle, I need to make four identical towers, okay? So, you're going to do it on your own, I'll do the first one so you can see, and the rest you'll do on your own."

Only by week 5, once the children became familiar with structures and stability, functionality, and the use of tools, and had opportunities to discuss and reflect on real constructions, they engaged in designing and building their own projects.

The category *communication* refers to the features of the classroom dialogue. The teacher promoted sense-making and respectful conversation, encouraging children to present their projects to each other on several occasions and share their difficulties.

The presentations she used were designed to prompt discussion about specific aspects. She used these discussions to explore the children's understanding of key aspects of the project and to determine how to support them accordingly.

Her instructions for the tasks were clear and direct. She used repetition and emphasized a few key aspects. For instance, the instructions that preceded the 2D design task in week 5 focused on functionality and feasibility (teacher's emphasis in bold):

> Teacher: I would like you to draw your 'crazy building.' It must be **functional**, meaning it should include doors and windows. Think about what you want to create, because next week we will see **if we can bring it to life**. Make sure it's something **we can actually build.**

The category *socioemotional climate* refers to how the relationships were shaped by the classroom environment and how children's interests were taken into account.

The teacher's talk fostered creativity. She publicly acknowledged children's ideas and prompted them to pursue them and build their projects according to what they imagined, as illustrated by the differences between houses. She also used exaggerations as prompts for children to feel free to imagine, such as for instance: "I want to live on a waterfall".

She was keen on maintaining children's interest in the tasks by adapting her interventions to each child. Consequently, the time devoted to achieving the tasks was also adapted to each child's requirements. The child with higher abilities than the average designed more than one project during week 5. This project was difficult to build, and the child needed support to avoid frustration and use the difficulties as learning opportunities. The child with learning difficulties needed support to develop initial ideas, so the teacher prepared printed examples of houses to discuss together and foster brainstorming. She gave this child extra time to complete the project, and the child was able to finish the design by week 6. She also assisted when necessary with the use of tools. Her approach to mistakes was to view them as opportunities for learning. Failures were not penalized but rather shared with the group to solve difficulties together.

The teacher created a playful climate, as exemplified by the use of a dancing game as part of the routine. She also asked children to play with their creations. For instance, children in this group liked to play with robots. Once they had built their houses, they were asked to create a city and work together to program an educational robot to navigate the city streets (Fig. 4).

> Teacher: We are going to build houses for our robots. We can create anything we want, like a police station or a castle. Then, we will program our robots to travel from one place to another.

Fig. 4 Children programming the Tiny bot to navigate from one building to another

She used purpose, wonder, and surprise as triggers for learning, fostering the children's curiosity. The purposes of the tasks were made clear and introduced as individual or collective endeavors, as shown by the earlier transcript. She created engaging presentations, such as the one introduced as "crazy houses." These included the Big Basket building in Newark (USA), the Upside Down house in Szymbark (Poland), and the Crooked House in Sopot (Poland).

Discussion

First, the results regarding the children's performances are addressed, followed by a discussion of the teacher's practices. Then, the implications for practice and teacher education are discussed. Finally, the limitations of the study are considered.

A main conclusion derived from this study is that all children enjoyed and were able to creatively engage in design because they were given opportunities to do it. While creating their projects, children actively engaged in STEM practices, such as experimenting, integrating knowledge from different disciplinary areas to create a new product or solution, which is one of the potentials of DBL approaches (Henriksen, 2014).

- The results show a great diversity regarding children's decisions and interests. The diversity of products met the demands of the tasks together with the two core features of creative products: originality and appropriateness for purpose (Runco & Jaeger, 2012). To craft their designs, the children analyzed and solved the difficulties they encountered. They tackled issues concerning the suitability of the initially chosen materials and the stability of the houses they constructed, while also striving to meet aesthetic concerns. The findings about the limitations of young children's 2D designs in planning junctures and materials align with previous studies (Fleer, 2000; Hope, 2000; Milne, 2013).

- Children developed their projects through interactions with peers and the materials at hand in a stimulating environment. As Alam (2023) highlights, quality interactions, learning materials, and surroundings are essential for supporting children's development.
- Each child went through a process of his or her own, due to the diversity of their designs, facilitated by the openness of the tasks. Some children had the ability to predict and some others needed to experiment to realize the need to find an alternative solution. As acknowledged by UNESCO (2021), inclusive education settings must be able to satisfy the needs of all students, regardless of their characteristics or the groups they belong to. Children in this study encountered opportunities to explore and learn according to their own needs, due to the structures provided by the teacher, as discussed next.

The teacher's strategies to promote children's STEM learning were grounded on a holistic approach towards children's physical, socio-emotional, and cognitive development, aligned with recent views on the synergies between science education and EC education (Larimore, 2020). The teacher acknowledged children's contributions, fostered their curiosity, followed their wonders and used emerging situations to stimulate learning with challenging questions. Four interrelated dimensions are highlighted that supported children's engagement in the project and the development of their creativity: the alignment of her practices with the recommendations of the literature in STEM education; her responsiveness; and her focus on emotions, and on fostering children's autonomy.

- She used a contextualized approach to inquiry-based STEM. She proposed contextualized and authentic tasks that demanded children to take part in disciplinary practices to solve them, developing problem-solving skills and using specific tools. The open-ended nature of the tasks she proposed allowed children to develop their unique interests and abilities, participating in science in her or his own way, as part of the broader community that is the classroom. As pointed out by te Heesen et al. (2022b), inquiry is an inclusive process.
- Responsiveness is evidenced by her attention to each child's own way to address the project, tailoring her support to meet their individual needs, adapting the time for the tasks and the instructional support. Aligned with findings from other studies at the EC levels (e.g. Sundberg et al., 2016), attention to children's interests shaped the teacher's practice. She used specific supports and promoted cooperative work, which are strategies aligned with the findings of Finkelstein et al.'s (2019) review on inclusive teaching practices. Moreover, she enacted dialogic teaching, an approach that fostered children's participation in purposeful conversation to support meaning making (Kim & Wilkinson, 2019) and that has been shown to be effective in EC (Monteira & Jiménez Aleixandre, 2016) and for promoting design thinking (Kelley & Sung, 2017). Dialogical classrooms, where teachers and students listen to each other, create an emotionally healthy environment in which students feel safe and their contributions are valued, and encourage young children to participate in science, promoting their learning gains (Andersson & Gullberg, 2014). She prompted children to listen to each other, to exchange ideas and to cooperate for solving problems. Listening and dialogue are inclusive practices as they allow exploring and understanding different ways of thinking and understanding, and they are well alligned with the view of STEM disciplines as social practices constructed in interaction.
- The teacher kept children's motivation by prompting them to pursue their ideas. Her instructions for the tasks, such as the creation of the 2D designs or the craft of the simples structures, were explicit and focused on purpose, which are features that are known to support children's design thinking (Kelley & Sung, 2017; Milne, 2013). Motivation was also supported by the playful approach (Fleer, 2021). With her choice of appealing resources, she fostered their curiosity about the disciplinary content and, in turn, their engagement and progress. Aligned with previous research (Fleer, 2013), this study shows that pedagogical strategies that position emotions at the center are a key factor in facilitating all children's STEM learning and for developing their design skills (Milne, 2013).
- She fostered autonomy through the organization of the resources and time. The tools and materials were available and at hand and she focused on learning basic skills during the initial sessions. Other studies also emphasize the importance of interaction with materials in providing young children with opportunities to develop their design competences (Milne, 2013). Regarding the organization of time, she followed a routine. As acknowledged by Mora-Márquez (2017) these organizational practices can empower children, as they can predict and decide what they are going to do. Autonomy, in turn, supported children's motivation,

as all the children, with differing complexity, were able to develop a project according to their interests and the purposes of the tasks.

In sum, STEM education practice in the early years can build on creative approaches to learning, paired with tailored scaffolding in emotionally safe environments that promote cooperation. These approaches benefit the development of STEM competencies by all children. This project was not designed for the purpose of specifically supporting one type of diversity. Rather, it allowed all children to develop their creativity and achieve their interests despite their different abilities. As highlighted by Colucci-Gray et al.'s (2019) critical review, a focus on creativity as an essential part of problem solving, can provide a valuable perspective on how to address individual learning needs in inclusive educational environments. This study adds that such approaches are also fruitful for addressing cognitive diversity in inclusive settings.

Regarding the implications for teacher education, aligned with other authors (e.g., Crawford & Calabria, 2018), this study points to the importance of an emotionally-safe climate that models social interactions in promoting inclusion, as well as in children's healthy development. Thus, empathy should be embedded in teacher education (Crawford et al., 2019). Early childhood teachers spend extended time with their students connecting with their emotions and interests. Thus, they have a great potential as agents of change, promoting inclusion through their pedagogical practices (Zembal-Saul et al., 2022). In that regard, EC teacher education may contribute by addressing empirically-based STEM teaching strategies that promote emotional wellbeing (e.g., Eshach et al., 2011; Monteira et al., 2022). The teacher's scientific background facilitates authentic ways to address STEM-related skills such as understanding challenges, reflecting on process, revising/iterating, representing ideas, and making decisions; which, according to Crismond and Adams (2012) are also core in design. Nevertheless, often EC teachers' lack of self-confidence in their content specific knowledge, hold misconceptions about the nature of scientific and technological knowledge (e.g., Akerson et al., 2010); and may perceive the culture of science as excessively academic and very distant from the culture of care that permeates early childhood education (Sundberg et al., 2016). These issues influence both the content of instruction and the affective approach from which it is presented. As a consequence, frequently, the time devoted to the STEM disciplines in EC classrooms is little in comparison to other subjects such as the arts. Teacher education with a focus on diversity benefits pre-service teachers' preparation for science (Zembal-Saul et al., 2022), and creative approaches can be a trigger for inclusion, as shown by this study. Thus, it is suggested that addressing creativity in teacher instruction may be aligned with teachers' interests and motivations and could support the development of professional competences in STEM education.

Regarding the limitations of the study, the family and the school contexts cannot be examined with the available data, and they could add valuable information for the interpretation of the findings. The families' culture and socioeconomic status play a core role in children's educational opportunities (Alam & Ogawa, 2023). Regarding these aspects, all children in the group are of ethnic and social origins alike and are supported by their families, who can address SEN that are often unattended by the educational system (Rodríguez-Naveiras et al., 2019). Moreover, the analytical lenses partially address the reality under study. STEM education is a cultural practice that is constructed in interaction. The disciplinary discourse of STEM disciplines uses multimodal forms of representation and communication (Lemke, 2004), also reflected in the classroom (Kress et al., 2001). This analysis examines children's verbal discourse and interactions with tools and resources. Multimodal analytical methods could have been used to examine interactions such as gestures, gazes, voice and drawings, among others. Several studies have documented that these perspectives are useful to unpack interactions and resources that diverse children brought with them as learners (e.g., Siry & Gorges, 2020; Wilmes & Siry, 2018).

In sum, the findings of this study show that contextualized DBL projects can be coupled with creative approaches to generate inclusive STEM learning environments. Moreover, given that the attention to emotions is a core part of teaching practices in EC, early years STEM education can be a fruitful arena for examining inclusive contexts.

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Declarations

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