THE 3D PRINTER IN KINDERGARTEN EDUCATIONAL ACTIVITIES

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Abstract. *owadays 3D technologies play an important role in the world of education. Students should acquire digital skills that enable them to become producers of digital artifacts themselves.The acquisition of STEAM (Science, Technology, Engineering, Art and Mathematics) skills increasingly leads to integrated learning based on dialogue and critical thinking. Maker education, based on the pedagogy of doing, should fully enter in the daily activity in the classroom. A kindergarten teachers group through the participation in an INDIRE[1] experimental research project are helping to prepare their children for success in the future by providing them with valuable STEAM skills and fostering their creativity and critical thinking abilities. This paper aims to discuss the value of Maker Education and the main strategies for organizing and planning its implementation to help young children acquiring STEM skills since an early age.*

Keywords: Maker Education, 3D Printer, Thinkering, Artefacts.

INTRODUCTION

3D printing technology is revolutionizing the way objects are manufactured and prototypes are created. It is impacting various sectors, from technology to art, and is significantly transforming the traditional craft and production system. This technology has provided a strong boost to the world of creativity.

Incorporating 3D printing into classrooms, from kindergarten to high school, provides the educational system with a new way of teaching digital skills. This enables students to move beyond simply being users of digital technology and become producers themselves. They can design and create digital objects of various types and characteristics on their own, which can help them develop a deeper understanding of the technology and its potential uses. This can be a valuable way for students to learn about design, prototyping, and problem-solving.

3D printing in the classroom can also help students develop skills in creativity, teamwork, and critical thinking. By creating digital objects, students are able to utilize a variety of skills, including design and knowledge of 3D design and modeling software. This process helps students gain technical skills, but it also provides opportunities for them to learn and practice empathy, teamwork, and problem-solving. The process of designing and creating digital objects can foster collaboration and communication among students, encouraging them to work together to find creative solutions to problems.

Furthermore, the use of a 3D printer in the classroom can help students develop advanced critical thinking skills. The process of designing and creating objects using a 3D printer requires students to think creatively, analyze problems, and make decisions. They must also evaluate their designs, make adjustments, and troubleshoot any issues that arise. This process encourages students to think critically and develop problem-solving skills. Additionally, the use of a 3D printer can also help students develop spatial reasoning and visual-spatial skills, which can be useful in a variety of fields.

[1] the National Institute for Documentation, Innovation and Educational Research – https://www.indire.it/

Overall, the use of a 3D printer in the classroom can provide students with hands-on learning opportunities that can help them acquire cognitive tools that help them think creatively, solve problems in a more effective and efficient manner, and develop problem-solving skills and ability to think outside of the box. Creativity and lateral thinking, the ability to preview a product are all skills that mature through laboratory activities. Understanding that redesigning an object is a normal part of the process can help foster a growth mindset and reduce the fear of failure.

This educational scenario explains why in recent years, in education, the "*Maker Movement*" (Halverson & Sheridan, 2014) is spreading more and more. The "*Maker Movement*", based on the traditional world of "*do it yourself*" applied to modern technologies, emphasizes hands-on learning, creativity, and problem-solving skills, which aligns with the goals of modern education. The Maker Movement has evolved over time and led to the development of a new type of artisan, the technological artisan. Today, these technological artisans refer to themselves as "makers" and are involved in producing or modifying engineering, electronic, or robotic products, (Guasti, 2017). This shift in the traditional craftsman profession reflects the growing importance of technology and the integration of traditional crafts with modern technologies.

This approach to education fosters creativity, critical thinking, and problem-solving skills, which are essential for success in the modern workforce. Additionally, the Maker Movement encourages students to embrace failure as a learning opportunity, promoting a growth mindset and resilience (Capone *et alii*, 2019). By integrating the principles of the Maker Movement into their curricula, schools aim to prepare students for the challenges of the future and equip them with the skills they need to succeed in a rapidly changing technological landscape.

In this work, our research wants to investigate on how *an educational path that involves creating artifacts with 3D printers may increase logical thinking and creativity in kindergartners*.

A Kindergarten teachers group partecipating in the INDIRE experimental research project "*Building toys with the 3D printer in the kindergarten*[2]", has been engaged in activities such as designing and printing toys with a 3D printer, building and assembling toys, experimenting and testing toys, collaborating and sharing with their students.

The project aimed to help young children develop STEM skills and creativity through hands-on Maker activities, and the teachers participated by incorporating these activities into their curriculum.

By participating in this project, the teachers have gained valuable experience and insights into how Maker Education can be effectively implemented in a kindergarten setting. They have also helped their students acquire valuable STEAM skills, including design, engineering, and technology, as well as creativity, critical thinking, and problem-solving abilities.

Overall, the participation of the Kindergarten teachers group in the INDIRE research project has helped to advance the field of Maker Education and will likely have a positive impact on the children they teach for years to come.

THE MAKER EDUCATION

The "*Maker Education*" aims to develop practical skills, critical thinking and problem solving through an active and engaging learning experience: to design and create objects through technologies. It is based on the "Think-Make-Improve" cycle (Martinez & Stager, 2013) and

[2] https://www.indire.it/en/progetto/building-toys-with-3d-printers-3/

promotes collaboration and peer comparison to encourage social learning (Vygotsky, 1962); moreover, this methodology spreads the application of collaborative and inclusive teaching methodologies such as Peer Education (Damon, 1984). This type of teaching is capable of developing a range of competencies, including creativity, collaboration, and technology literacy, that are crucial for success in the modern world. By placing the student at the center of the learning process and providing opportunities for hands-on problem-solving, the Maker Education prepares students for the challenges of the future and helps them develop the skills they need to succeed.

The three phases of the "Think-Make-Improve" cycle can be described as follows:

- *Think* - Students engage in brainstorming sessions with teachers and peers to generate ideas and hypothesis for a project they are working on. They also use traditional methods such as drawing and coloring to create visual representations of their ideas.
- *Make* - Students move on to the implementation phase, where they bring their ideas to life. This may involve using software like Tinkercad to model 3D objects or printing out the designs.
- *Improve* - Students assess the functionality of the finished product and make improvements if necessary. If errors are found, they engage in discussions and further iterations to enhance the original design. This cycle allows for continuous improvement and emphasizes the importance of hands-on learning and critical thinking.

The Maker movement considers invention and creation of objects a fundamental human activity, and technology allows maximize this attitude. Makers are inventors, authors, and researchers who design and self-produce in their workshops, known as makerspaces or fabLabs, all sorts of mechanical equipment, electronic instruments, software, and robotic creations. In schools, the makerspace provides students with a laboratory approach to problem-solving through design and experimentation, combining traditional and innovative aspects of manual work. In the makerspace, students must be stimulated to interpret, to make judgments about the shape, size, movement and relationships between surrounding objects, to predict and manipulate 3D models. In schools, the makerspace provides students with a laboratory approach to problem-solving through design and experimentation, combining traditional and innovative aspects of manual work. The teacher's goal becomes to increase students' design knowledge, operational and instrumental skills in using design programs (such as 3D CAD) and printing procedures, as well as developing a problem-solving approach in their teaching skills.

RESEARCH AND THEORETICAL FRAMEWORK

Hands-on learning experiences with 3D printing technology can help students develop problem-solving skills, critical thinking, and creativity by allowing them to bring their ideas to life. In this work, our research question is "*may an educational path that involves creating artifacts with 3D printers may increase logical thinking and creativity in kindergartners?*"

The theoretical framework where the maker teaching may be included, is the active learning and the constructionism, together with the theory of experiential learning and some Piaget theories.

According to Constructionism, each single person builds mental models to understand the world around him, and active learning is an approach that involves students in the learning process through hands-on experiences and interaction with the material being studied. The theory of experiential learning suggests that people learn best through direct experiences and reflection on those experiences. Piaget's theories propose that children's cognitive development is influenced by their experiences and interactions with the environment. In Piaget's theory of cognitive development, assimilation and accommodation are the two mechanisms that drive learning. Assimilation refers to the process of incorporating new information into existing mental structures and making sense of it based on previous knowledge. Accommodation refers to the process of modifying existing mental structures in order to better fit new information. These two processes are constantly interacting, allowing individuals to adapt to their environment and continuously develop their understanding of the world.

In summary, the theories of constructionism, active learning, and experiential learning, as well as Piaget's ideas on the role of physical objects in learning, support the idea that a maker-based educational approach, which involves the use of 3D printers in the learning process, can contribute to the development of logical thinking and creativity in kindergartners. This approach is situated in practice and linked to the student's project, allowing them to learn through hands-on experiences and problem-solving. The use of 3D printers enables the creation of practical and real-world learning experiences, promoting a dynamic process of knowledge construction and adaptation.

AN EXPERIMENTAL PROJECT

In this paper we describe the activities of INDIRE[3] experimental research project "*Building toys with a 3D printer in kindergarten*[4]" within the "*Maker@Scuola*[5]" project.

The "*Maker@Scuola*" project examines the impact of the "Maker Movement" on school laboratory teaching. It aims to determine if the use of innovative tools and teaching methods in the classroom can improve traditional frontal teaching and support a more current innovative teaching in which the pupils become the protagonists of the own learning. The "Maker" approach to teaching has been shown to improve students' logical-mathematical, scientific, and linguistic skills, and emphasizes the development of meta-competences and soft-skills. It encourages a more participatory and problem-solving approach, where mistakes are viewed as opportunities for reflection and growth, rather than failures. The learning process, typically in the laboratory, is based on improvement cycles where errors are utilized as a learning opportunity. Schools that adopt the "Maker" teaching methods view new technologies as a driving force for creating innovative ways of learning and not just as a means to optimize the existing education system.

The "Maker" approach to teaching is based on:

- a "*hacker*" approach to knowledge, according with wich pupils acquire knowledge by disassembling things, analyzing their workings, and using the acquired knowledge to create new and more interesting things. This approach emphasizes hands-on learning by modifying software and hardware, with the goal of gaining a deeper understanding of systems and the world around us. This way of learning is in line with the principles of the "Maker Movement" in education, which seeks to create an engaging and participatory learning environment where students take a more active role in their education. (Steven Levy, 1984)
- a "*tinkering*" methodology, based on the think-make-improve cycle that guides students through the entire process and helps them to reflect on their work, making revisions and improvements along the way. Students, infact, first ideate, plan, and brainstorm; then create, program, and prototype; and finally verify and improve their work. Mistakes are seen as opportunities for progress, not failures.

[3] the National Institute for Documentation, Innovation and Educational Research
[4] https://www.indire.it/en/progetto/building-toys-with-3d-printers-3/
[5] https://www.indire.it/en/progetto/maker-at-school/

- an open "*sharing*" philosophy, that values collaboration and knowledge sharing, promoting an open and inclusive learning environment where students are encouraged to ask questions and share their ideas with each other. Copying is encouraged as a learning activity because promote dialogue and mutual influence among students.

CLASSROOM ACTIVITIES

Here we describe the educational approach studied by the teachers at the "Mother Teresa of Calcutta" Kindergarten in San Valentino Torio, Salerno, Italy, as part of the INDIRE experimental research project "*Building toys with a 3D printer in kindergarten*". This project aims to explore the potential of using 3D printers in the learning process for kindergartners and how it may impact their logical thinking and creativity. The didactic path created by the teachers within this project is an example of "Maker Education" in practice.

The "didactic maker" experience in the classroom involves using a 3D printer as a teaching tool to enhance lateralization, logical thinking, and abstraction skills in young children. The project, which was implemented in a kindergarten, involved using 3D graphic modeling software (Doodle 3D and Tinkercad) to complete specific tasks based on a story entitled "*A strange theft*" about a family of elves recovering an object stolen by an ogre (Guasti & Niewint-Gori, 2017). The aim of the project was to experiment with the educational use of a 3D printer and see if it could contribute to enhancing these cognitive skills in young children. Overall, the project aimed to integrate the use of 3D printing technology into daily teaching practice to provide hands-on learning opportunities that can help students develop valuable skills that can be applied in various fields.

All tasks involved designing a product to be 3D printed. The object design phase was always preceded by preparatory activities functional to learning the concepts subset the realization of the task, while the following one the printing concerned discussions about product evaluation. Teachers, through stimulating questions, encouraged children to reflect on the object correspondence to what was in the story required andon the contrary, to find the errors and the possible solutions to solve them. The error is no longer seen in its negative sense but as an opportunity to stimulate improvement. (Zan, 2007)

- The first task is "Drawing the characters of the story with 3D Doodles". The teachers introduced the 3D printer during a circle time session and told the part of the story related to the task, which involved printing all the characters with Doodle 3D as the final product.
- The second task: "Building the trunk of a hollow tree, home of a good witch, with the Tinkercad software", required the printing of a hollow tree as the final product.
- In the third task "Build the layered cake" the children discussed the overlapping of solids.
- The fourth task "Make footprints with the 3D printer" required the construction of a path that would later have to be walked by the characters.
- The fifth task "Building a bridge with Tinkercad" required that at the end of the path there was a river to be crossed by building a bridge.
- The sixth and final task "Making the special game" gave children space to free their imagination by creating one with Tinkercad to be delivered to the mischievous ogre.

The tasks provided the teachers with a valuable learning experience from both a technological and educational perspective. They likely gained hands-on experience with using Tinkercad software and 3D printing technology, as well as insights into how these tools can be used effectively in the classroom to enhance student learning and creativity.

The second task, building the hollow tree trunk, involved the children applying the "Think-Make-Improve" cycle. In the "Think" phase, they discussed and agreed on using a cylinder with a hole as the base shape. In the "Make" phase, they showed proficiency in modifying basic shapes, but had difficulty in creating a hole in the trunk. The "Improve" phase involved printing several versions of the trunk and observing and discussing any errors or design flaws, allowing for refinement and improvement of the final product.

Throughout the task, the teacher played a *facilitative* role, allowing the children to freely express their ideas and perspectives.

During the activities, the children showed interest and curiosity in printing their own designed objects, but also important reflections on why their printed objects were incorrect.

Here are some excerpts from the conversation as evidence of what was said:

Marco:	Wow, I can touch my drawing! (It is the first reaction of the children when for the first time they see their printed object).
Maria:	The tiered cake is broken because I didn't use the Merge function, (Referring to the tiered cake that didn't come out whole but three separate cylinders)
Francesca:	The tree is not a case because the sphere was not transparent. (Referring to the realization of the hollow tree, unsuccessful)
Michele:	The elf's foot is smaller than the ogre's, so the elf has to walk more steps than the ogre to reach the house. (Referring to the comparison between the ogre foot print and the elf foot print for stamp making)

Maria and Francesca's comments are very significant, as they not only highlight the mastery of the technological tool that the children have acquired, but also and mainly the acquisition of a specific mathematical language. At the end of the project, the teachers were able to verify how it had become natural for the children to use terms specific to mathematics teaching.

Michele’s comment, instead, shows how the comparison of the footprints is a simple and effective way for young children to learn and understand the concept of measure. By observing the difference in the size of the footprints and the number of steps required to reach the house, children can develop an intuitive understanding of how measure is used to describe and compare physical quantities. This hands-on approach to learning can make the concept of measure more meaningful and accessible to young children. It is an excellent example of how play and exploration can be used to support the development of mathematical thinking.

The results obtained by following an experimental path in functional spaces related to the concepts of making and production workshop through the use of 3D printing push us to continue the research towards the hypothesis of a new curriculum capable of promoting innovative educational scenarios aimed at developing geometric and spatial-visual skills starting from early childhood. Compared to three-dimensional manipulative activities such as Lego and Pongo, which allow modification of the project in progress, working with a 3D printer requires children to pay particular attention during the design phase, which favors the formation of concepts through the recognition of invariants that characterize certain figures.

In conclusion, the experimentation showed that new technologies, such as 3D printing and Tinkercad software, can be effectively utilized in the classroom as teaching aids to optimize instructional procedures, as well as to facilitate new modes of learning and conceptualizing. The support from INDIRE researchers and collaboration with teachers from other participating schools helped the teachers come to this realization.

CONCLUSIONS

Maker Education is valuable as it encourages hands-on, experiential learning and helps children develop STEM skills, creativity, critical thinking, and problem-solving abilities.

The Kindergarten teachers group of St. Valentino Torio participating in the INDIRE experimental research project "*Building toys with the 3D printer in the kindergarten*" have showed how incorporating a 3D printer in their activities can be effectively implemented Maker Education and help young children develop STEM skills and creativity.

Some of the educative activities that the teachers may be using include:

1. Designing and printing toys with a 3D printer: Children can learn about design, engineering, and technology by creating their own toys using a 3D printer.
2. Building and assembling toys: By working with the printed parts, children can learn about construction, problem-solving, and fine motor skills.
3. Experimenting and testing toys: Children can learn about scientific concepts and the process of experimentation by testing and evaluating the toys they have created.
4. Collaborating and sharing: By working together on Maker projects, children can develop teamwork, communication, and social skills.
5. The fact that the children also showed important reflections on why their printed objects were incorrect is also significant. It indicates that they were thinking critically and actively trying to improve their designs. This type of problem-solving and critical thinking is a valuable skill that will benefit them in many aspects of their lives.

By engaging in these activities, young children are acquiring valuable STEAM skills and developing their creativity, critical thinking, and problem-solving abilities. The teachers are also learning how to effectively integrate Maker Education into their curriculum, helping to prepare children for success in the future.

Overall, these results suggest that the Kindergarten teachers group of St. Valentino Torio's participation in the INDIRE experimental research project was successful in engaging the children and helping them develop important STEM and problem-solving skills.

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