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Improving Social Skills of Pupils through 3d Printer

Alessia Rosa and **Manuela Repetto**

ABSTRACT: *Studies showing the positive effects of introducing 3d printers into learning contexts are still at an embryonal phase, especially those dealing with pre-schoolers. From early childhood, it is essential to develop key competencies such as social skills, but it is unclear if maker education could work in this context and how it could contribute to preparing pupils for formal instruction. With a sample of 80 pupils from two kindergartens, this study aims to provide empirical evidence about the development of social skills through the introduction of learning activities based on a 3d printer. A seven-month learning course based on the use of 3d printer was introduced adopting a social constructivist approach. To assess the results of this course, the participants' social skills were analysed using a pre-test/ post-test design through the Social Competence Test administered to their teachers. Results show a significant increase in social skills, pointing to the opportunity of anticipating the introduction of maker education for preschoolers.*

KEYWORDS: *3d printing, Social skills development, Early childhood, Maker education, Readiness*

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The project and the statistical processing were designed and realized by both authors. About the paper, Alessia Rosa wrote the abstract and the paragraphs 1, 3, 3.1; while Manuela Repetto wrote the paragraphs 2, 3.2, 3.3, 4 and Conclusion.

1. Maker education

Maker education emphasizes critical thinking, creativity, social competences, and generally and 21st-century skills.

Understanding the relationship among activities, sense of community and identities in the educational landscape is the current grand challenge, and the maker movement can support this new vision.

Before to discuss the theoretical definition of maker education and its possible declination in nursery school, we consider meaningful to present a common frame of reference for understanding the maker movement. Born in the mid-2000s, the maker movement represents the contemporary culture or subculture technology-based extension of DIY culture that intersects with hacker culture.

A growing number of people belong to the maker movement. In their daily lives, they are employed in the creative production of artefacts and who share in physical and digital forums their design, processes, and products with others (Walter-Herrmann, 2013).

Dougherty (2012) defines the maker movement more in terms of the people who associate with the ethos of making rather than in terms of how or where making happens.

Chris Anderson (2012) identifies three distinguishing characteristics in the maker movement: the use of digital tools, to be in the habit of share designs and collaborate online and the diffusion of common design standards to support sharing and fast iteration. «Dougherty (2012), Hatch (2014), Anderson, and others emphasize the democratizing nature of making through cheap hardware, easy access to digital fabrication, and shared software and designs» (Halverson and Sheridan, 2014a: 497).

According to the perspective described, the social competences, the object of this research, seems to be a central aspect of maker movement philosophy, because of the 'making' is not solipsistic but on the contrary, it is a communal and shared activity (Papavlasopoulou *et al.*, 2017).

Maker culture has become a way to express own creative and innovative drive and this interest has led to a wide diffusion of makerspaces across a range of instructional environments, including libraries, museums, independent no-profit, and for-profit organization and schools from kindergarten to higher education.

This approach requires rethinking the educational space according to a collaborative and socio-material perspective (Weyland and Attia, 2015).

In fact, materiality is not considered as the background context in which educational practice takes place or as a simple instrument of support. In that regard, Sørensen argues that often there is a «blindness toward the question of how educational practice is affected by materials» (2009: 2) and suggests that its consequence is to treat materials as mere instruments.

In recent times, it is evident a new interest in materiality in education considering objects, technologies, devices, spaces as 'protagonists' of the educational process that it's defined as a socio-material assemblage (Landri, 2014).

Socio-material approaches, offer sensibilities and methods of analysis that valorise the relations networks (Law, 2008).

Education and educational things in an ANT approach (Actor-Network Theory) are not seen as pre-existing objects of inquiry, but as emerging through various forms of association, as network effects (Fenwick and Edwards, 2010).

About the role of making, it is possible to consider only partially the introduction of the maker's approach in the school as an innovation because for decades the contribution of making in learning has been studied by a lot of pedagogues (Schelhowe, 2013).

The theory of constructionism developed by Papert 'father of the maker movement' (Martinez and Stager, 2013) considers production-based experiences as a key to learning (Harel and Papert, 1991). Moreover, constructionism is the theory of learning that emphasizes problem-solving (Schwartz, Mennin and Webb, 2001) and digital and physical fabrication. A lot of tools and programs used in the maker movement activity as 3d printer, the Logo programming language (Papert, 1980), LEGO Mindstorms kits (Resnick, Ocko, and Papert, 1988), the Scratch programming language (Resnick *et al.*, 2009), and the Computer Clubhouse programs (Kafai, Peppler, and Chapman, 2009) are declinations of Papert's constructionism.

The term maker education conceived by Dale Dougherty in 2013 has been initially closely associated with STEM learning, but today it involves a larger number of educational contents. In an educational perspective, making refers to a set of activities that can be designed with a variety of learning goals in mind, but all the educational proposals engage participants in learning content and process.

Maker education is based on an approach to problem-based and project-based learning that relies upon hands-on, often collaborative, learning experiences as a method for solving authentic problems. This last aspect is facilitated by affordable and accessible technology. In maker education collaboration on interesting projects lead the pleasure to improve their competence and share lessons learned, without external incentives like grades (Blikstein and Krannich, 2013).

Especially in the formal educational context, maker education highlights the relevance of self learner-driven experience, interdisciplinary learning, peer-to-peer teaching, iteration and the notion of 'failing forward', because differently from linear design methodology, maker approach considers mistakes an opportunity to improve students' resolution strategy and their ability to reflect on the project (Smith *et al.*, 2015). Modern software makes designing a new solution testable, risk-free and cheap.

The functionality never compromises aesthetic originality, that is another important aspect of maker education (Halverson and Sheridan, 2014b).

The maker movement has been initially proposed in higher education settings. Today it is commonly accepted the idea that it is possible to adapt well the definition of the maker to pre-primary teachers' peculiarities and to their approach with children (Schön *et al.*, 2014).

As for 'makers', it is common between pre-primary teachers to build their own teaching tools (through paper and recycled materials). At the same time, the makers' perspective overlaps with the natural inclinations of children and their ability of learning by doing. Frequently pupils build or adapt objects by hand with the simple pleasure of figuring out how things work. In all school levels, the focus in design for learning is not on tools but on the process and on the product, and in the case of kindergarten, technologies such as 3d printers and coding toys allow a real children engagement.

In this research, we focused on 3d printers in kindergarten, where the 3d printer is not used for learning to make 3d objects but is the raw material for solving problems like how to create a bridge or the characters of a story.

2. Social skills development in early childhood

Children develop early skills they need to interact with and learn from the social world through their primary caregivers, who help them to internalise the social rules and to regulate their behaviour (Vygotsky, 1978). Skills learned within the parent-child relationship promote a positive classroom adaptation at the beginning of kindergarten and later (Goodrich *et al.*, 2015). Landy (2009) considers social and emotional domains as key areas for early childhood development.

Social competence is defined as that set of abilities to function socially with peers and adults such as interacting well with others and having friends, that can contribute to emotional development, self-esteem and school achievement (Tomlinson and Hyson, 2009). From the age of three, children experiment in the kindergarten their first real experiences with group-based learning (Goodrich *et al.*, 2015) and more structured activities.

In this context, teachers play a key role in supporting young children's development of social competence and in particular of prosocial behaviours which progress from the first forms of turn-taking with adults to cooperative interactions with peers (Hollingsworth and Winter, 2013) and to the skill of comforting upset children during preschool (Landy, 2009). Thus while growing up children develop the cognitive ability to understand others' feelings, teachers help them to develop prosocial skills such as cooperation, conflict resolution, participation in a group and empathy (Myck-Wayne, 2010).

Play is an important vehicle for developing self-regulation as well as for promoting language, cognition, and social competence (Copple and Bredekamp, 2009; Rubin *et al.*, 2006), that takes the simple form of parallel play, until more complex forms like associative play, based on sharing with others, and cooperative play. Teachers provide scaffolding and set the tone of the social environment in which children develop their social competence giving them the structure, supplying resources, giving rewards and providing guidance and strategies to sustain interactions with others (Hollingsworth and Winter, 2013).

While the child grows up, teacher progressively reduces individual attention, while demands for children to focus attention, to inhibit inappropriate behaviours and to cooperate and follow rules increase (Goodrich *et al.*, 2015). Since child ratios are as large as 1:10 or even 1:20, children need to acquire the foundational skills helping them to face the group-based learning setting that characterises the preschool context (*ibidem*). Cooperating and complying with teachers' requests are considered the most important skills for access to formal education (Lim *et al.*, 2010; McClelland and Morrison, 2003).

The emergence of social skills in preschool, such as the ability to establish and maintain positive and effective relationships with peers, is an essential indicator of school readiness and is associated with a successful transition to the formal school and with positive educational attainments reached throughout the scholastic life (Hampton and Fantuzzo, 2003; Ziv, 2013). Indeed, a growing body of research (Darling-Churchill and Lippman, 2006; Blair and Diamond, 2008; Halle *et al.*, 2012) links the level of social and emotional competencies to child's attainments and a high level of them at school entry is a predictor of his/her scholastic success. As suggested in the Sameroff's transactional model of development and according to a dynamic systems view (Thelen and Smith, 2006), there is a continuous and dynamic interplay among the child's developmental skills, which are interrelated, as well as between the child and his social context that creates potential for change (Sameroff, 2009). As such, the development of social skills, school engagement and scholastic attainments are part of a dynamic system across the transition to formal school and any intervention before this transition has some effects (Goble *et al.*, 2017).

3. The research on socio-relational competencies in the kindergarten[1]

In the 2014/2015 school year, Indire's research has begun to map the opportunities of using the 3d printer in kindergarten through different experimentations.

Defined the lines of use (Guasti and Rosa, 2017), the research has analyzed logical (Garzia *et al.*, 2019) and socio-relational skills.

In this section, we are going to explain the structure of the research aimed at exploring the impact of maker activities targeted at children attending the last year of kindergarten on the development of socio-relational skills. Maker activities were managed by external experts and focused on the Think Make Improve approach and on the 3d printer.

[1] This research was funded by the Operational National Program (2014IT05M2OP001) 'For the school – competencies and learning environments' – Axis I – Specific Objective 10.8 – Action 10.8.4 – Project 'Didattica laboratoriale multidisciplinare' – Code 10.8.4.A2-FSEPONINDIRE-2017-1.

The Think Make Improve approach is composed of several phases and it begins with a problem situation, involving the group in an experiential cycle.

The original version of this approach, designed for teenagers, is composed by six steps, that in Indire's proposal for the kindergarten were reduced to three.

In the first phase (Think), children analyse the problem situation, making explicit the central question and investigating the possible solutions with their peers.

In the Make phase, children design and compare their solutions to define the best idea. The prototype is realized on this last one.

In the last phase (Improve) pupils analyse the prototype realized to identify the elements that can be improved.

After this consideration the planning and production restarts, ending only when all members are satisfied.

On the basis of this approach, the learning activities to develop social skills were designed and the research questions defined.

3.1. *Research questions, method and sample*

We investigated the possible influences of Think Make Improve approach and the possible effects of 3d printer on socio-relational competencies. The following five research questions were addressed.

1. Does an educational activity aimed at children in the last year of nursery school, conducted by external experts and focused on the Think Make Improve approach, influence socio-relational competencies?

2. Does an educational activity aimed at children in the last year of nursery school, conducted by external experts and focused on the Think Make Improve approach supported by the use of 3d printer for prototyping, influence socio-relational competencies?

3. Which of the areas characterizing the socio-relational competences can be influenced by an educational activity conducted by external experts, aimed at the children of the last year of the nursery school and focused on the Think Make Improve approach?

4. Which of the areas characterizing the socio-relational competencies can be influenced by an educational activity conducted by external experts, aimed at the children of the last year of the nursery school, focused on the Think Make Improve approach supported by the 3d printer?

5. What factors between belonging to a small or a large city, gender, and age influence the acquisition and improvement of socio-relational skills?

To answer the above-mentioned research questions a randomised controlled trial by cluster was adopted. A pre-test-post-test two treatment design was chosen using a scale to measure the improvement of social competencies comparing the children' level of competences present before the experimentation with the level reached after that.

The Social Competence Scale (SCS), created in the context of the Fast Track Project[2], is composed of 25 items assessing children prosocial behaviours, emotional self-regulation, and prescholastic skills. The Italian version of it, after being validated by the teachers, was administered to them to assess social competencies of all the involved children, both of the experimental group and of the control one. Each item of the scale states a socio-emotional behaviour that a pupil may show during the preschool activities. Teachers evaluate how well each statement describes the pupil through a five-point Likert scale ranging from 'Not at all' (0) to 'Very well' (4).

Starting from the analysis carried out on several social competence scales, such as SDQ, TOCA-R, PKBS, PLBS, SSRS, PSMAT, PMS, six social competence areas were identified and mapped with SCS to classify the number of items into separate and mutually exclusive areas.

The social competence areas defined are:

– *social sensitivity*: the aptitude with which a subject perceive and understand contexts in social interactions for the social respect of other pupils;

– *collaboration*: the ability to work together with others in the pursuit of a common scholastic enterprise;

– *peer interaction*: the skill of being able to establish relationships with other pupils within a scholastic context;

– *social independence*: a set of autonomous skills effective for the functioning of the group;

– *interaction with adults*: the capacity to establish positive relationships with adults within a scholastic context, without excessively depending on an adult;

[2] https://fasttrackproject.org/.

TAB. 1. *Indicators considered for the assessment of socio-relational skills*

COOPERATION	PEER INTERACTION	INTERACTION WITH ADULTS	SOCIAL INDE-PENDENCE	SOCIAL SENSITIVITY	SELFREGULA-TION
Shares resources used for the task	Is confident in social situations	Follows instructions from teachers	Uses time in an acceptable way	Understands another child's needs	Observes rules without reminders
Takes turns for the use of resources	Interacts with several different children	Sits and listens to the teacher's instructions for the activities	Works or plays independently	Shows affection for other children	Completes tasks in an organized way
Participates in classroom or group discussions	Has skills or abilities that are admired by peers	Accepts decisions made by teachers	Shows self-control	Copes with peers who interfere with the group's goals	Completes tasks successfully
Takes turn in dis-cussion without reminders	Expresses hostility verbally	Asks for help from adults when needed	Attempts new tasks before asking for help	Comforts other children who are upset	Attempts new and challenging solutions
Responds appropriately when corrected	Expresses hostility physically	Seeks comfort from the teacher when hurt	Is consulted by other children during the development of the activity	Apologizes for accidental behavior that may upset others	Concentrates when working
Actively contributes to group activities	Makes many social ouvertures		Adapts well to different environments/ activities		Responds to instructions and begins appropriate task
Takes into account contributions of the other children	Joins group easily				Takes time to do his/her best work
Assertively expresses his own opinions	Is accepted and liked by other children				Sees own errors on task and corrects them
Help peers to stay on task					Returns to unfinished tasks after interruption

– *self-regulation*: the skill of being able to set and to pursue goals assigned by teachers, monitoring one's own and that of other peers' behaviour to ensure that it is in line with those goals.

About the sample, eighty pupils participated in this study, 28 females and 52 males of five-year-olds, from two kindergartens randomly selected among the population of schools equipped with the 3d printer in the Piedmont region.

The first school was selected among the scholastic institutions in the centre of Turin, while the other one was based in a small provincial town close to Cuneo.

The kindergarten of Turin comprised one experimental group and one control group for a total of 33 pupils, while the kindergarten of the small town included two experimental groups and one control group, with a total of 47 pupils. The average group size was made of 15 pupils, distributed into small work groups of four and five students, with three or four small groups in each of the participating group. The pupils were randomly assigned to the experimental or to the control group.

3.2. *Procedure*

The maker laboratory was run within a time frame of seven months and was structured in twenty sessions; each of them was assisted by two researchers leading the activities, while two teachers acted as participant observers.

Each activity was based on Think Make Improve approach; to stimulate sharing and collaboration, all activities were characterized by a limited number of resources.

The contents of the activities were organised as follows.

• *To design nametags and to invent the group logo*. Kids, within small groups, were invited to reproduce their own nametag using a limited collection of cardboard letters. To reach this aim each pupil was constrained to trade letters he needed to compose his name. Then, they designed together a shared group logo. The control group carried out this task with little pieces of pasta, while the experimental one modelled a prototype of the logo with a 3d software and printed it with 3d printer.

• *To design common home objects.* Kids were invited to design the furniture presented in the fairy tale 'Stone soup' (Vaugelade, 2012), whose name was written in a paper randomly extracted by the children. Although children were unable to read, everyone knew some letters and they should share their knowledge to be able to recognise the entire words. Both the experimental and the control group carried out this task with clay, but the experimental one in addition modelled an artefact with a 3d software and printed it with 3d printer.

• *To design vegetables.* Kids were involved in the design of the vegetables present in the fairy tale that were represented on picture cards. Children of both the experimental and the control groups should realise a copy of these images designing an artefact with the 3d software; only the experimental group printed in 3d.

• *To design the fairy tale main characters.* Kids were involved in mixing various geometrical shapes for realising a complete animal presented in the fairy tale. The shapes for the control group were made of cardboard, while those for the experimental group were digital.

All the activities were inclusive since the same tasks were assigned also to kids with disabilities or special needs.

3.3. *Results*

To demonstrate if there are significant differences in socio-relational competencies before and after the maker laboratory both within the experimental and the control groups, comparisons of means test for paired data were used. Social independence, collaboration, peer interaction, interaction with adults, social sensitivity, self-regulation were the six competence areas examined to detect these differences. Results were analysed considered parametric (t-test) and non-parametric tests (Mann-Whitney Wilcoxon).

For the control group the t-test showed statistically significant differences between the two periods only for all the competence areas except for interaction with adults and self-regulation: social sensitivity ($t = -3.231$, $p < 0.01$), collaboration ($t = -3.799$, $p < 0.01$), peer interaction ($t = -8.206$, $p < 0.01$), social independence ($t = -2.587$, $p < 0.05$). A two-tailed Wilcoxon test performed as non-parametric test confirm the same results: social sensitivity ($z = -2.747$, $p < 0.01$), collaboration ($z = -3.096$, $p < 0.01$), peer interaction ($z = -4.164$, $p < 0.01$), social independence ($z = -2.695$, $p < 0.01$).

For the experimental group the t-test showed statistically significant differences between the two periods for all the competence areas: social sensitivity ($t = -5.670$, $p < 0.01$), collaboration ($t = -9.546$, $p < 0.01$), peer interaction ($t = -14.144$, $p < 0.01$), social independence ($t = -6.838$, $p < 0.01$), interaction with adults ($t = -4.906$, $p < 0.01$), self-regulation ($t = -7.995$, $p < 0.01$). A two-tailed Wilcoxon test performed as non-parametric test corroborate the above-mentioned results: social sensitivity ($z = -4.650$, $p < 0.01$), collaboration ($z = -5.850$, $p < 0.01$), peer interaction ($z = -5.985$, $p < 0.01$), social independence ($z = -4.805$, $p < 0.01$), interaction with adults ($z = -4.056$, $p < 0.01$), self-regulation ($z = -5.246$, $p < 0.01$).

The Levene's test of homogeneity of variance has been used before t-test to verify that the variances of the populations from which the samples were extracted drawn were equal. Levene's test confirmed that the samples come from populations with the same variance for all the examined variables.

After the analysis performed for the control and the experimental group, the differences between these two groups have been investigated as well. According to the t-test for independent samples that was performed to check the homoscedasticity of variance, the variables interaction with adults ($t = -1.982$, $p < 0.05$), collaboration ($t = -1.884$, $p < 0.05$) and especially self-regulation ($t = -2.473$, $p < 0.01$) resulted as the only variables with relevant variation. The non-parametric tests identify only for self-regulation a relevant variation between control and experimental groups: $z = -2.624$, $p < 0.01$ with the Mann-Whitney test and $z = 1.543$, $p < 0.01$ with the Kolmogorov-Smirnov test.

To demonstrate if there are significant differences before and after the Maker Lab the six social competence areas were considered as dependent variables, while the contextual factors such as age, gender, teacher and type of school were used as regressors. Age and gender don't represent an explicative factor in any of the six social competence areas. Instead the type of school appears relevant for interaction with adults ($F = 18.843$, $p < 0.01$), self-regulation ($F = 16.585$, $p < 0.01$) and social independence ($F = 4.312$, $p < 0.05$), while the teacher factor is always relevant except for social independence and for social tolerance.

These results confirm that the belonging to the experimental group rather to the control one affects mainly collaboration, interaction with adults and self-regulation.

4. Discussion

These findings support the view that the approach Think Make Improve in itself enhances the development of socio-relational competencies of preschoolers. When the approach is complemented by the use of 3d printer, it is possible to reach even better and more extended ratings on the investigated competence areas, speeding up the process of growth of preschool children and even affecting and continuously redefining the dynamic system made of social skills, school engagement and scholastic attainments described in the scholarship. In fact, the control group obtained the most relevant ratings only on social sensitivity, collaboration, peer interaction and social independence areas. Instead, in the experimental group also interaction with adults and self-regulation were interested with better ratings in all the examined social competence areas.

The results obtained by the control group were predictable since the adoption of the Think Make Improve approach acts on collaboration and negotiation dynamics. In addition to that, to print in 3d and to reflect on the possibility to modify the prototypes to improve them, require to use all the considered social competence areas. For the control group is more complex to judge their own artefacts realised by hand. When the artefact was realised by 3D printer, it seems that children of the experimental group were more likely to find limits and design mistakes.

Furthermore, the development of verbalisation skills induced by the dialogue between the different viewpoints and perspectives of pupils and their teachers, mainly during the modelisation phase, represents an interesting exercise functional for the improvement of the relationships with adults.

These activities with 3d printer require a high level of concentration on the task and the use of metacognition abilities functional to the development of self-regulation competencies.

For this reason, self-regulation and interaction with adults represent the two main social competence areas on which the use of 3d printer has a major impact. The improvements detected with the use of 3d printer combined with the Think Make Improve approach appear only to a limited extent subject to contextual factors such as type of school or teacher. According to a sociomaterial perspective (Landri and Vitteritti, 2016; Ferrante and Orsenigo, 2017), this 'hybrid assemblage' of humans and objects represents in itself both a technological and pedagogical innovation for preschool education.

Conclusion

The results confirm that the approach Think Make Improve lead by external experts improves socio-relational competencies, leading to a general enhancement of all the social competence areas of the preschoolers. The kids who participated in this study connected with the use of 3d printers demonstrate a more relevant enhancement in all the social competence areas considered, especially in collaboration, interaction with adults and self-regulation in the post-test application of the SCS Teacher Test.

The research shows that a 3D printer educational activity can be effective to set up situations where all pupils have the opportunity to engage and share ideas and perspectives according to the maker movement approach.

A limitation of the study was that data concerned with a further group of participants not using the Think Make Improve approach and neither 3d printer were missing. Thus it should be envisaged a more complete research plan at three groups instead of two, introducing a further control group.

Since the number of pupils of this study is limited, these results can't be extended to other similar contexts at a national level and neither can be universalised. Even more so these results can't be transferred to other countries or other schools levels. It could be interesting to apply the same research design to other technologies belonging to maker education as coding and robotics.

If the research context could be extended, then its results would guide national educational policies for the adoption of maker approach in preschool and for the refinement of the tools to improve social competencies envisaged in the Italian kindergarten indications and in the European Recommendation on key competences for lifelong learning.

Another area of development for future research concerns the potentialities of 3D printer to support socio-relational competencies of special needs children.

On the light of the recent sociomaterial approach in education and in addition to the influences of 3D printer on the development of socio-relational competencies of children, it could be interesting to explore also the ambivalences and the effects of a materiality such that within formal and informal learning spaces (Landri and Vitteritti, 2016). According to this approach, 3D printer can't be considered as a black box bringing innovation, but rather as a social and relational component that, combined with human, is able to sustain new sociomaterial infrastructures (Ibid.) and to 'produce particular effects in education' (Fenwick and Landri, 2014).

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