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Digital Fabrication: 3D Printing in Pre-School Education

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Editorial

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Editorial: 3D printing and the (very) young: What do we expect from this meeting?

There is something astonishing about writing an editorial on 3D printing technology for kindergarten children. It was not terribly long ago that 3D printing was a toddler itself; in the late 1980s and early 1990s, it was viewed as a high-powered special-purpose expensive technology, primarily for the most rarefied group of users – large corporations and the military, for instance. The idea that we could now be talking about five-year-olds using 3D printers, or *owning* them would, at that time, have seemed beyond rational belief. Of course, the research is still in a primordial phase, but it seems appropriate to start with two of the most fundamental questions with which this special issue grapples.

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Question 1: Should young children work with 3D printers at all?

The question of whether children should be allowed to use advanced technology does not have a single answer across all cultures. Where does 3D printing, or fabrication more generally, fit within this landscape? On the one hand, there does not seem to be too much concern about children's physical safety in relation to the latest generation of 3D printers. It is unlikely that a child (with moderate supervision) will get hurt while using a 3D printer. But what of cognitive concerns? One might argue that the use of 3D printers supersedes or discourages the use of more material objects like clay or paper. This question seems reasonable – though difficult to resolve. It *is* beneficial for children to use their hands to work directly with a range of materials, but there are many ways of creatively combining 3D printing with material play. Might this enhance the experience of both?

One could raise still other concerns. Might the experience of using the device seem too much like 'magic' by decoupling the idea of construction from physical experience? Or perhaps the argument might be framed within a larger polemic against children's technology; that is, the broader context of technological encroachment on direct, unmediated experience. In practice, such arguments often seem oddly ahistorical; they seem to ignore the fact that such artifacts as paper, scissors, glass marbles, and many other staples of the kindergartner's environment (not to mention children's books!) are themselves 'hi-tech' objects. A more productive approach might be to ask what sorts of lives we value – both for adults and for young children – and in what ways technology can either enhance or detract from those lives?

With these complexities in mind, we proceed on the assumption that there *is* real value for young children in the use of 3D printers, and our present goal is thus to identify the potential benefits of that experience, and to imagine still newer versions of fabrication technologies that will give us greater confidence in those benefits. We acknowledge that there will undoubtedly be readers who disagree with this assumption, and who feel strongly that children's use of 3D printing technology is inappropriate.

The paper by Calzone and Bagattini contributes to this discussion by focusing on perceptions of school governance of 3D printing as an innovative tool in the preschool context. Monitoring the National Operational Program 2014-2020 "For the School: skills and learning environments", the authors describe several purposes and uses of the 3D printers for kindergarten children. While in Italy, the intention to use technologies in preschool education is still very limited, 26.8% of the schools equipped with 3D printers consider this as an opportunity to improve the classroom atmosphere and students' motivation, autonomy and inclusion.

The value of the printer also seems to emerge from a cognitive point of view. Mori and Niewint's paper adds another dimension to our question by focusing on 3D printing contributions to students' cognitive enhancement, based on the implementation of a method – *Think, Make, Improve* (TMI) – that promotes cognitive activation. The authors' specific research question is: Can teaching methodologies based on 3D printing support cognitive enhancement, especially in relation to executive functions and verbal and logical reasoning? The *Wechsler Preschool and Primary Scale of Intelligence* (WPPSI-III) administered in this research reports improvement in verbal skills. Therefore, it is suggested that exploiting the TMI method to improve the use of 3D printing could support cognitive activation and the development of cognitive functions.

Furthermore, Rosa and Niewint's paper contributes to this discussion by looking at how 3D printing could improve preschool children's capacity to achieve their own goals. This research found that 3D printing can mobilize resources that children already have at their disposal but are not usually activated in the early years of infancy. More potential can emerge when 3D printers are contextualized within the disciplinary content to, for instance, develop specific disciplinary skills. Mangione, Garzia, and Esposito analyze the impact of using 3D printers on geometrical competences and abstract thinking, and suggest that 3D printing seems to enhance children's natural interest in geometry and strengthens mathematical skills.

Question 2: What do we hope to see in children's encounters with 3D printers?

Several intellectual domains seem to have a particular affinity with 3D printing for children. One of these is modular construction: the creation of larger structures from collections of compatible or interlocking pieces. There are numerous commercial examples of these construction kits; Lego is perhaps the most famous. The advent of 3D printing allows us to experiment with the creation and design of modular sets in all sorts of innovative and underexplored ways. The very same geometric piece designs could be printed out at varying scales, with younger children being able to print out larger (and thus less demanding in terms of dexterity) pieces modeled on the more advanced pieces that they see in the hands of their older brothers and sisters. Another experiment might involve pieces designed for a continuous range of ages: a young child might be able to contribute portions of a larger project, using simpler pieces that could be joined with the efforts of their older siblings. Typically, commercial construction kits are designed at *one* unique scale, but the flexibility and fine-tuning of 3D printing might overcome this limitation.

Another traditional element of construction kits is that their pieces, being standardized as parts of a larger 'system of construction', tend to be indistinguishable. A child cannot look at a large construction and easily say "I did that section", in the way that one might do with a painted mural. There might be inventive ways of identifying one's own contribution ("I put in the green pieces in that larger wall"), but the kits themselves do not provide much in the way of support for this sort of identification. One might therefore imagine experimenting with 3D-printed pieces that can be customizable in some way so that an individual child can make their own 'signature pieces: a small branding mark, a special stripe, or a filigree.

In this discussion, we claim that 3D printing allows us to consider an intellectual domain for children – that of modular construction – and re-examine the traditional design constraints of that domain. Maybe construction kits can be made for children of multiple ages to use in concert? Maybe construction kit pieces do not need to be *quite* so standardized, but could instead be customized to the individual user? Or maybe construction kit pieces could be geometrically re-designed to be combined with media such as clay or paper, so that constructions do not have to look so uniform? Alternatively, construction kits could be designed to be specific to a particular room or environment. On the other hand, could they be designed as 3D jigsaw puzzles?

Still another intellectual domain that meshes well with the affordances of 3D printing is the area of spatial cognition and visualization. We can once more avail ourselves of the unique capacity of 3D printers to create unusual or customized spatial experiences that are unlike commercially made items. One might extend the tradition of Montessori and Froebel to create a range of specialized geometric shapes for very young children to play with. How might children respond to sets of shapes that are designed as *enantiomers* – shapes with distinct left and right handed forms (like human hands)? Or perhaps one might design shapes that could only be held in specific ways, or held by two (or more?) hands in specified positions? Shapes could be printed out with varying density factors so that they balance on a child's bedroom shelves in unexpected ways, or to fit into areas of a child's room in particular ways.

We should start from the areas in which children already might take an interest – water, animals, gardens, preparing food, messing about with sand, and so forth – and design enhancements or customizations with the use of 3D printers. The running themes behind these enhancements include the notion of *personalization*, *customization*, and *social exploration*. Each of these notions to some degree obviates or subverts the 'commercialization' aspect of the past century of children's culture. Rather than printing out a mass-produced item, the 3D printer can be used to investigate the particular, irreproducible aspects of a child's environment and pattern of interests.

The contribution by Avanzini, Baratè and Ludovico focuses on a case of preschool and primary school music education supported by 3D printing that unveils the multi-faceted potential of such an approach. The concept of *modular construction* is applied to a user-defined music notation system, able to foster aspects such as personalization, customization, and social exploration. The idea of producing highly customizable components is applied to various aspects of music education, ranging from user-tailored parts of 'traditional' musical instruments to the definition of suitable models to improve the educational experience (e.g., action figures, new simple instruments, alternative forms of notation).

In the context of this discussion, we cannot know what lies beyond the very short-term horizon. The available tools for 3D fabrication are remarkably different from those of two or even one decade ago. What sort of fabrication tools, then, will a child born today have at their disposal at the ripe old age of six?

Rather than thinking in terms of *today's* 3D printers as children might use them, it is probably more productive and meaningful to imagine what we *want* children's fabrication tools to look like, and then to set about designing tools that approximate those dreams. Should children's 3D printers have more materials or colors available to them? Should we try to make the printers faster? Should we experiment with new interfaces so that children can use their hands or bodies to design 3D objects, or alter them as they print out? Should we create new handheld tools that allow children to paint, shape, scrape, texturize, or warp already-printed objects?

In thinking about *children* as creators, builders, and constructors, we should remind ourselves that *we too* are, or can imagine ourselves, as builders. Adopting this stance might help us conceive and develop fabrication environments that our children can expand into even more wonderful creations.

Editorial

L'état actuel des recherches sur l'utilisation de l'impression 3D dans l'éducation n'en est encore qu'à ses prémices, et cela est encore plus vrai quant il s'agit d'étudier l'utilisation de l'impression 3D par les jeunes enfants. Ce numéro spécial traite de ce sujet en commençant par poser deux des questions les plus fondamentales en lien avec cette thématique, auxquelles les articles acceptés dans ce présent numéro tentent d'apporter des réponses: (1) est-ce que les jeunes enfants devraient utiliser les imprimantes 3D et (2) que devons-nous attendre de cette utilisation?

Les jeunes enfants devraient-ils travailler avec des imprimantes 3D?

À la question de la place des nouvelles technologies dans l'apprentissage et dans le développement du jeune enfant, il n'existe pas de réponse universelle. Quelle est la place de l'utilisation de l'impression 3D dans ce paysage des nouvelles technologies? Dans une perspective constructive, et afin d'éviter d'entrer dans un débat sur l'évolution et l'intégration de nouveaux outils dans le quotidien des enfants, nous pensons qu'il est préférable de nous interroger sur ces nouvelles technologies, non pas en nous posant la question de l'effet direct et immédiat de ces outils sur l'apprentissage mais en ayant une approche plus globale. Quel type de développement de la vie, voulons-nous pour nos enfants et comment la technologie peut-elle aider ou entraver ce développement?

L'article de Calzone et Bagattini contribue à cette discussion, en se focalisant plus spécifiquement sur la perception que les directions des écoles italiennes ont de l'impression 3D en tant qu'instrument d'innovation dans le contexte préscolaire. Les auteurs décrivent plusieurs situations d'utilisation de l'imprimante 3D et il apparaît que l'intégration de cette technologie permet une amélioration de l'ambiance entre les enfants du groupe, ainsi que de compétences transversales telles que la motivation, l'autonomie et l'inclusion.

Dans une perspective plus cognitiviste, l'étude de Mori et Niewint révèle que l'utilisation de l'imprimante 3D, impliquant la méthode *Think, Make, Improve* (TMI), a également un impact sur les compétences cognitives. C'est ainsi que les tests de l'échelle d'intelligence de Wechsler pour les enfants d'âge préscolaire et scolaire (WPPSI-III) montrent une amélioration du QI verbal. Les résultats suggèrent en effet qu'une meilleure exploitation de la méthode TMI pourrait alors engendrer une amélioration des capacités cognitives, et notamment en ce qui concerne les fonctions exécutives et les capacités liées aux raisonnements verbal et logique.

La contribution de Rosa et Niewint participe à la discussion en s'intéressant au rôle que peut avoir l'imprimante 3D dans l'amélioration des capacités des jeunes enfants à atteindre un objectif. Cette étude montre que les jeunes enfants mobilisent des ressources, qui sont certes disponibles, mais non mobilisées habituellement à ce si jeune âge. Il apparaît alors que l'utilisation de l'imprimante 3D dans un contexte disciplinaire spécifique permet de développer davantage les compétences en lien avec la discipline en question. Dans leur étude, Mangione, Garzia et Esposito analysent l'impact de l'imprimante 3D sur les compétences géométriques et d'abstraction des enfants. Les résultats suggèrent que l'utilisation de cette technologie permet de développer davantage l'intérêt des enfants pour la géométrie et de renforcer leurs compétences mathématiques.

Nous devons développer des situations permettant aux enfants de rentrer en contact avec l'impression 3D afin de promouvoir le développement d'habiletés ou de programmes qui répondent non seulement à nos valeurs d'adulte mais également aux lacunes qui entraînent par la suite une faiblesse professionnelle à l'âge adulte. C'est ainsi que Rosa et Niewint présentent un projet pédagogique qui donne à l'imprimante 3D un rôle d'outil permettant de combiner les conditions d'expérience et la flexibilité de schémas pour permettre le développement de compétences. En réfléchissant aux pratiques pédagogiques et à la nécessité d'intervenir sur les dimensions disciplinaires pour la formation, les travaux de recherche de Mangione, Garzia et Esposito présentent une intervention de développement pour un nouveau programme qui passe par l'utilisation de la modélisation et de l'impression en CAD. La 3D pousse vers la compétence géométrique et l'internalisation de la pensée abstraite.

Qu'attendre de la rencontre entre les enfants et les imprimantes 3D?

Plusieurs domaines intellectuels semblent se prêter naturellement à l'impression 3D pour enfants. L'un d'entre eux est la cjonstruction modulaire: des kits de construction pourraient être fabriqués pour des enfants d'âges différents travaillant en groupe de manière collaborative; les pièces du kit pourraient ne pas suivre un modèle standard mais s'adapter aux utilisateurs; les pièces pourraient être redessinées géométriquement pour être ensuite assemblées avec différents matériaux tels que l'argile ou le papier, afin que les constructions ne soient pas uniformes.

Un autre domaine intellectuel qui correspond bien aux avantages de l'impression 3D est le domaine de la cognition spatiale et de la visualisation. Pourrions-nous ainsi considérer l'utilisation de l'imprimante 3D comme un prolongement de la tradition de Montessori et Froebel, visant à créer une gamme de formes géométriques spécifiques pour de jeunes enfants? Ces formes pourraient également être imprimées avec divers facteurs de densité pour s'adapter à différentes zones de la chambre d'un enfant. Les thèmes à la base de ces améliorations incluent les notions d'identifiabilité, de personnalisation et d'exploration sociale.

La dernière contribution de ce numéro spécial, rédigée par Avanzini, Baratè et Ludovico, se focalise sur le cas tout particulier de l'éducation musicale préscolaire et primaire, assistée par l'utilisation de l'impression 3D. Le concept de construction modulaire est alors appliqué à un système de notation musicale, défini par l'utilisateur et capable de favoriser des aspects tels que la personnalisation, la personnalisation et l'exploration sociale. Le potentiel des technologies d'impression 3D de pointe est exploré, tel que la fabrication de composants métalliques ou l'impression multi-matériaux.

Par ce numéro, nous souhaitons amener le lecteur au-delà des conditions actuelles de l'utilisation de l'impression 3D et imaginer l'avenir de ces outils de production pour les enfants. En considérant les enfants comme des concepteurs, des constructeurs et des réalisateurs, nous devons nous rappeler que nous sommes nous aussi des concepteurs et des constructeurs, ou du moins nous imaginer comme tels. Adopter cette position pourrait alors nous aider à concevoir et à développer des environnements de fabrication que nos enfants peuvent développer et améliorer.

Editoriale

Lo stato della ricerca sull'uso della stampa 3D in ambito educativo è ancora in una fase primordiale, soprattutto quando gli studi esplorano l'interazione fabbricazione digitale e i "piccoli". Questo *special issue* attraversa il tema a partire da due domande tra le più fondamentali a cui i lavori accettati provano a dar una prima risposta.

I bambini piccoli dovrebbero lavorare con stampanti 3D?

Dove si colloca la stampa 3D o la fabbricazione digitale rispetto al dibattito che sta dietro questa domanda? Allontanandoci da un dibattito antistorico che ci porterebbe a riflettere sulla tecnologia per i bambini, nel contesto di un processo più ampio di invasione tecnologica sull'esperienza diretta e non mediata, pensiamo sia più produttivo chiedersi: quale tipo di sviluppo di vita vogliamo per i nostri bambini e in che modo la tecnologia può favorire o ostacolare questo sviluppo? Il contributo di Calzone e Bagattini si inserisce in questa discussione, concentrandosi in particolare sulla percezione che la governance scolastica italiana ha della stampa 3D come strumento di innovazione nel contesto prescolare. Il monitoraggio condotto giustifica l'uso da parte dei bambini come un'opportunità per migliorare il clima nel gruppo classe e atteggiamenti trasversali in particolare, la motivazione, l'autonomia e l'inclusione. Il valore della stampante sembra emergere anche dal punto di vista cognitivo. Nel lavoro di Mori e Niewint la somministrazione del *Wechsler Preschool and Primary Scale of Intelligence* (WPPSI-III) e la rielaborazione dei dati indicano un miglioramento cognitivo, specialmente per ciò che riguarda le funzioni esecutive e le abilità relative al ragionamento verbale e logico.

Dobbiamo progettare interazioni tra i bambini e la stampa 3D in modo da promuovere lo sviluppo di capacità o schemi che incontrano anche i nostri valori da adulti o rispondano a carenze che si traducono in debolezza professionale da adulti. In questo contesto, la ricerca di Rosa e Niewint restituisce al lettore un progetto educativo che adotta la stampante 3D come strumento per combinare condizioni esperienziali e flessibilità di schemi da consentire lo sviluppo di abilità di capacitazione anche nei più piccoli. Riflettendo sulle pratiche di *education making* e sulla necessità di intervenire sulle dimensioni disciplinari per la formazione della persona, il lavoro di ricerca di Mangione, Garzia ed Esposito riporta un intervento di sviluppo di un nuovo curriculum che tramite l'uso della modellazione CAD e la stampa 3D spinge verso *la competenza geometrica e l'interiorizzazione del pensiero astratto*.

Cosa vogliamo vedere nell'incontro tra i bambini e le stampanti 3D?

Esistono diversi domini intellettivi che sembrano prestarsi naturalmente alla stampa 3D per bambini. Uno di questi è la *costruzione modulare*. Forse i kit di costruzione possono essere realizzati per bambini di età diverse che lavorano assieme? Forse i pezzi possono essere personalizzati per il singolo utente? O magari possono essere riprogettati geometricamente per essere combinati con materiali come l'argilla o la carta, in modo che le costruzioni non appaiano uniformi nella loro costruzione?

Un altro dominio intellettivo che si sposa bene con i vantaggi della stampa 3D è l'area della *cognizione spaziale e della visualizzazione*. Si potrebbe, ad esempio, estendere la tradizione di Montessori e Froebel per creare una gamma di forme geometriche specializzate per bambini molto piccoli? Oppure tali forme possono essere stampate con vari fattori di densità per adattarsi alle aree della stanza di un bambino in modi particolari. I temi alla base di questi miglioramenti includono le nozioni di *identificabilità*, *personalizzazione* ed *esplorazione sociale*.

Il contributo di Avanzini, Baratè e Ludovico, si concentra sul caso specifico dell'educazione musicale prescolastica e primaria supportata dalla stampa 3D, applicando il costrutto di modularità a un sistema di notazione musicale in grado di promuovere aspetti di identificabilità, personalizzazione ed esplorazione sociale. Viene inoltre esplorato il potenziale delle tecnologie all'avanguardia per la stampa 3D, ad esempio la fabbricazione di componenti metallici o la stampa multi-materiale.

Il numero vuole condurre il lettore oltre le condizioni odierne e immaginare il futuro di questi strumenti di produzione per i piccoli. Nel pensare ai bambini come progettisti, costruttori e realizzatori, dovremmo ricordarci che anche noi lo siamo, o possiamo immaginare di esserlo. Cominciamo a costruire ambienti di fabbricazione e lasciamo ai bambini la possibilità di migliorarli.