DOI: https://doi.org/10.34768/rl.2019.v451.07

Marzanna Farnicka[*]
Noemi Serrano Diaz[**]

3D PRINTING SKILLS AS A RESOURCE FOR THE DEVELOPMENT OF CREATIVITY IN MIDDLE CHILDHOOD

Introduction

Dream Makers is a project called "Creativity, Multiple Intelligences and 3D Printing in Pre-School Education for Disadvantaged Children". It is funded by Erasmus+ Cooperation for Innovation and the Exchange of Good Practices Programme, namely Action 2 – Strategic Partnerships and Specifically Strategic Partnerships for School Education. The main aim of this project is to develop innovation (2016-1.PT01-K201-023005).

In 2012, the European Commission, the European Parliament, the Council, the European Economic and Social Committee, and the Committee of the Regions indicated that skills such as critical thinking, initiative taking, problem solving, and collaborative work are important to prepare individuals to the changing and unpredictable world in which we live today (European Commission/EACEA/Eurydice, Compulsory Education in Europe – 2016/17). In particular, entrepreneurial skills and creativity are fundamental to creating new businesses, employability of young people, as well as to a country's economic growth. Creativity seeks novelty and value, and entrepreneurship also seeks novelty in business and new market ideas. Creativity is seen as the driving force behind entrepreneurship, which itself is linked to employment, poverty reduction and innovation. High-quality teachers and pre-schools can have a long-term effect on improving outcomes

[*]**Marzanna Farnicka** – Ph. D. in psychology, University of Zielona Góra; scientific interests: social and developmental psychology; ORCID: https://orcid.org/0000-0002-4274-1646; e-mail: m.farnicka@wpps.uz.zgora.pl

[**]**Noemi Serrano Diaz** – Ph. D. in educational studies, University of Cadiz, Spain; scientific interests: new technologies, education; ORCID: https://orcid.org/0000-0003-4543-450X; e-mail: noemi.serrano@uca.es

for children with development disadvantages and those from a disadvantaged social background (Pocinho, Correia, Carvalho, Silva 2010).

Backround to the Dream Makers Project

Within the pre-school environment, the Dream Makers Project aims to promote a more inclusive education by offering to pre-school children opportunities to engage in an array of activities fostering their creativity, intelligences (according to Gardner's Theory of Multiple Intelligences) and technological skills by enhancing their inherent abilities and giving them the tools to surpass economic obstacles. Thus, the core variables of the project are creativity, experiential learning and 3D printing technology, while its main focus is placed on social inclusion.

Basic concepts

Creativity is a broad concept that reaches further than ordinary paths of thought and problem solving. Creativity can be defined on a variety of levels: cognitive, intellectual, social, economic, and spiritual, as a trait of a person, skill or process. The creative process can be explained through a reference to ever better understood underlying mental abilities (Kirkorian, Wartella, Anderson 2008) and cognitive processes including a) attention; b) imagination; c) categorization of objects; and d) memory processes. Gardner suggested that intelligence is the ability to solve problems and create a product or outcomes that are valued by a culture (Gardner 1993). Each individual can be intelligent in their own way. Based on traditional approaches, thinking is the most important cognitive process that influences creativity. On the other hand, M. Csikszentmihalyi indicates that this creative process consists in creating something different and new, i.e. a variation on an already existing idea (1999).

Determinants of creativity

To analyse various determinants of creativity, an integrative model of creativity determinants based on the "4P" model by Rhodes is adopted for this project (Amabile 1996; Garcęs, Pocinho, Viseu 2016). Creativity consists then of four components, namely individual, process, product and environment. This means that creativity results from the interaction between the individual's life context and his/her individual characteristics. This integrative model draws attention to the resources of the environment in which the features of the creative process and the specific characteristics of the product are rooted – the product that is a result of the creator's activity, but also of a specific process and purpose of the action. In this approach, the analysis of the creativity process and its products assumes the non-linear direction.

Each element of the model is indispensable, irreplaceable and important at any moment for the creation of an effect. Individual characteristics are based on genetic conditions, but their expression is also a manifestation of specific conditions created by the context in which a given individual lives (this applies to historical, social and family context). The interaction of these two dimensions of creativity determines the course of the creative process and its product. Furthermore, the meta-analysis conducted by Loo (2017) suggested two dimensions for creativity: individual and team. The meta-analysis is based on a review of the literature in four areas: economics, management, sociology and psychology. Loo's conclusions indicate that to create new and innovative products, creators use cognitive abilities, personality, and specialist knowledge. The process of creation takes place individually and in a group. Education may foster creativity by focusing on a specific problem-solving process, trainings and a specific and supportive environment, which includes the infrastructure of supportive information, communication and electronic technologies (ICET).

Children's Creativity Development in the period of middle childhood

At this point, it seems necessary to reflect on the classic concepts of the development of thinking by Vygotsky (1967). According to Vygotsky, child development is focused on the formulation of scientific concepts, recognized by the creator of this theory as the best organized mental structures. At the same time, the term "concepts" is defined as "a manner in which the world is represented in our mind", in other words – a certain equivalent of sets of real or abstract objects. Vygotsky indicates that the functioning of the above-mentioned concepts is affected by their definition, which in an appropriate, well-defined teaching system strives to be concrete. At the same time, he points out that ordinary phenomena tend to develop without a fixed system and to generalize, which distinguishes them from spontaneous concepts.

In light of the presented theory and normative developmental achievements in the middle childhood period, it can be concluded that in the pre-school period, which is characterized by dynamic changes in cognitive functioning, children amaze with their curiosity of the world, proficiency and creativity in the reality processing. Studies on thinking and learning at this age indicate quickness in the acquisition of knowledge and the ability to fantasize and improvise. Therefore, it is impossible to disagree with conclusions of these studies indicating that children have natural creative potential. According to Gardner (1993), the level of development of this natural predisposition depends on the environment surrounding a given

young person. Therefore, it is very important to involve society in the shaping of optimal conditions, enabling the full use of the talents, skills and passions of the pre-schooler (emphasized in the above discribed concepts, e.g. Vygotsky and Rhodes). Premises derived from the practitioner and the educator reports emphasising the ineffectiveness of traditional education methods (which omit the development of significant cognitive processes, among others, perception and divergent thinking) ecouraged researchers to actively seek innovative solutions, both in education and in attempts to operationalize the creative process and creativity (e.g. Gardner's program).

Why 3D printing?

Learning in the early childhood education takes place through the basic principles of manipulation, experimentation and play. For this purpose, ink printers and 3D printers can be used. However, other materials and games can be used to allow children understand, through experimentation, the meaning of 3D shapes and thus develop their creativity. 3D printing allows children to move from theoretical concepts to practical products: it has an extraordinary impact on children's imagination as their ideas can be transformed into real life objects. Initially, 3-dimensional design programs were intended to be used by engineers or specialists, ultimately, however, by adults in general. In recent years, free and user-friendly CAD software tools suitable for young people and adolescents, who do not need much training, made 3D design programs ideal for classroom use. An example is Tinkercad[1]: it is simple to use, its appearance is attractive, and, after a few hours of training, children can acquire the skills necessary to use it. Moreover, as 3D printer prices have been dropping in recent years, they have become more affordable in educational contexts (Wolfe, Flewit 2010).

The experimental part

The Dream Makers Curriculum is based on the following indicators:

1. Children are active and engaged – valuable content is assimilated through investigation, play, as well as focused and intentional teaching. It builds on prior learning and experiences; it is comprehensive. All the time, children were active and engaged in the "Creativity Day" activities, and they worked in small groups. Gardner's intelligence methodology was used in all the activities.

[1]Tinkercad: an on-line software used to create simple 3D models. It is easy and quick to use one of the many specialized websites that provide visual tools for an easy and immediate creation and/or modification of a design (see: `www.tinkercad.com`).

2. Goals are clear and shared by all. The curriculum is likely to benefit children. The topics of each "Creativity Day' were known to all the staff, parents and children. All the participants knew that a second language and 3Dprinting skills would be included in the curriculum. The program lasted for 10 months, which means that in each kindergarten 10 Creativity Days took place[2].
3. Evidence-based Activity – Evidence-based manual and professional standards validate the curriculum subject matter. The study group ($N = 400$).

In Portugal:

– R Kindergarten (100 children, aged 3-6), Madeira, Portugal, all activities (Gardner course, English lesson, and 3 D printer training) for all the children (children from high-income families)

In Poland:

– P Kindergarten Poland (100 children, aged 3-6, low-income families, Gardner course, only 4 hours of 3D printing training),
– H D Kindergarten, Poland (100 children, aged 3-6, high-income families, Gardner course, English lessons, only 4 hours of 3D printing training);
– PB Kindergarten, Poland (100 children, aged 3-6, medium-income families, no special activities)

The procedures of participation in the project were as follows: A signed consent form from each child's legal guardian was required and, if needed, transportation was provided for the children, so that they could participate in the activities. All the children who participated in the project were between the ages of 3 and 6 (three grades), but, in the project reports, we controlled and evaluated the economic status of the parents included in the project. Teachers, who also participate in the project, are the most important agents in the training of children. They were highly motivated to participate in the project, and it was not the first time they had done this. **The methodology** used by the kindergarten teachers was that of Gardner's Multiple Intelligences. Teachers approach intelligences holistically, but the focus is placed on one intelligence at a, i.e., for example, when they want to develop creativity through multiple intelligences, activities are designed

[2]Creativity day – Once a month, this day is celebrated in schools. It is a challenge to children's creativity. They are modelling individually or groups.

specifically for each intelligence. For instance, to develop creativity by working on the spatial intelligence, students are asked to design a classroom treasure map. The teacher must find the Hidden Treasure using the map the children have drawn.
The project activities were evaluated through a set of procedures described below.

1. Children's skills were monitored for psychological, pedagogical and skills evaluation, making use of, for example, psychological tests (Raven's test, creativity test, Gardner's intelligence, pre-test, test after the training, and the post-test performed 6 months after the training).
2. Technological skills were monitored by teachers. Changes were observed based on five categories: 1) she/he is not able to do anything, 2) she/he is trying to do something, 3) she/he is interested in imitation, 4) she/he tries do something on her/his own, and 5) she/he is achieving the goals.
3. The evaluation of the 3D printed products was performed based on the level of 'novelty' and 'appropriateness', using a Likert scale ranging from 0 to 3 (0 – none; 1 – medium; 2 – high or 2+1 – very high) as an alternative and complement to Guilford´s creativity test. The measurement was made three times: at the beginning of the training after one and a half years, and after the project was completed as a follow-up and a long-term effect.

The Project Implementation Plan

The didactic program involved the whole study group. The project program consisted in a gradual introduction of the 3D printing concept. The whole program was hidden within "Creativity Days" which consist of: Garndner's Multiple Intelligences activities (conducted by students of kindergarten education in accordance with Gardener's methodology, and in the same way in each kindergarten), English language activities (on account of kindergarten curriculum, the program is the same in each kindergarten, additional two hours are provided during Creativity Days), and 3d printing activities (in one kindergarten the whole course consisted of 2 hours each month – together 20 hours, in other kindergartens, only 4 hours of introduction on the last two Creativity Days).

Skills within this scope are developed to learn the basics of 3D printing, so that children could use 3D modeling software and design objects. Before they could perform 3d designing and printing activities, children had been gradually familiarized with and performing creative and manipulative

activities with other materials, such as plasticine, magic sands, clay, or Masterchef 3D) (chocolate figures, jelly beads, cream-cookies, etc.). All that within a gradual, step-by-step process that helps children manage and understand object-oriented design through using 3D software and 3D printers. Once a month, children meet with a tutor on "Creativity Day". There are between two and ten meetings during which children can use 3D modeling software to create their own objects.

The curriculum of the 3D Printing and 3D Modeling course

A set of variables needs to be planned and considered before 3D technology is introduced to children. Firstly, the age and the stage of cognitive development of children and, secondly, the most appropriate equipment to work with children need to be established. Considering the characteristics of children, the modelling and slicer software as well as 3D printer are carefully chosen. The following sections discuss the main technical guidelines for the project implementation, which are vital to start working with this technology.

3D Printer (obligatory 1 of the 5 hours)

To understand 3D printing technology and how it is used in the project, it is important to explain to parents and children the main concepts and materials that are used in this technology, and with which each team will deal in the course of the project implementation. The project envisages a 1.5-hour introductory and short training in the form of a workshop on the technical guidelines for 3D modelling and 3D printing. During the project, parents and children work in small groups. The training aims to raise their understanding of the creation of product with a 3D printing modeling software suitable for children and comprehending of the printing of 3D objects. Additional training is offered to children by staff and researchers to help them work with 3D printers and 3D modelling software programs.

3D Modelling Software (obligatory 1 of the 5 hours)

Prior to printing any kind of a 3-dimensional object, it is necessary to build a 3D model with an appropriate software. 3D modelling is a process of creating a 3-dimensional object through a specific software. 3D modeling skills include space manipulation and its awareness. This is achieved through drawing children's attention to important details which help maintain spatial orientation. Furthermore, 3D modelling is an important part of 3D printing technology, and while some modeling software is extremely detailed, other is very user-friendly and highly usable. In the Dream Makers Project, usability is a major issue: since the project involves very small children,

choosing an age appropriate software is important. Tinkercad, a free online 3D modelling software, was chosen for this reason. Tinkercad has the Basic Shapes panel from which shapes can be dragged to the workplane, is intuitive to use, and allows users to import 2D and 3D objects. It is one of the best softwares introducing to 3D modeling, which simultaneously allows the development of basic skills and raises the understanding of the process. The use of Tinkercad is simple, and the tool is available online. As mentioned above, children had been introduced to the 3D modeling software before they were able to learn how to use it and design 3D objects.

3D Slicing Software (obligatory 1 of the 5 hours)

A second important software that allows 3D printing is called a slicer. Once the 3D model is prepared, it has to has to pass through a slicer software which converts it into a series of thin layers recognizable to the 3D printer. The software generates an 'STL' file with the converted model. There are several slicer software programs on the market, however, the Dream Maker Project uses the slicer that come with the 3D printer. In this case, the Flash Forge Creator Pro 2016 came with the Flash Print software. This software allows the user to control many elements of the printing process (the height between layers, the extrusion and building platform temperatures, and the printing speed). It also has a basic command mode where more complex 3D printing definitions are already set up, which means it is little-kinds-friendly.

The 3D Printing Process (obligatory 1 of the 5 hours)

The project team is aware of one important aspect of using 3D printing technology, namely that it is not an instantaneous process: it requires time. By participating in 3D printing activities, children can develop their creativity, knowledgle of 3D printing technology and, because they are involved in joint group activities, communicational skills. The activities help improve communication and satisfaction in any given relationship, which is the ultimate expected impact on the participants. Overall, the project gives parents and teachers new insight into a new, open and innovative educational approach.

The project studied in this article, namely the one introduced in Poland and Portugal, is still in its infancy. Its first stage has been completed, i.e., the research design for the project has been developed and a gradual didactic program to work with children elaborated in accordance with the methodology explained in the above sections. Children have begun to perform 3D modeling activities using materials already known to them, such as plasticine or clay, etc. A gradual move to 3D design is being made. For example, children have worked with impressions of marine animals (dolphins, turtles)

related to the topics they covered in the classroom to check how the printer works. This way, they have prepared a jungle scenario with wild animals and plants. In addition, children have been introduced to Tinkercad and have developed "the house of your dreams". They made it during the "Creativity day" related to spatial intelligence.

The first results from the Polish and Portuguese study groups

The main purpose of the study was to compare the development of creativity in children from different groups that received different training. Two types of results were obtained: the general results stemming from comparison between the two national groups involved in the study, and more detailed results obtained from the analysis of the Polish study group.

The comparison between the Polish and Portuguese groups showed differences in the evaluated and observed dimensions (3d skills). This obviously results from the difference in the number of hours of 3D training that the groups received. Differences between groups were noticed in the scores on creativity tests but not on general intelligence. As a possible interpretation, one may use Vygotsky's concept which suggests considering differences between the closest spheres of particular children's development (including the sphere of creativity). It is worth mentioning that this is a verbal procedure.

The first results from the Polish study group showed that the general level of all functions have changed over time (between the first and the second measurement, t – student test, p level 0.05). But comparisons between the three involved groups showed that the kind of training and the level of parents' income are not important for the development of global intelligence in children (Anova test, $p > 0.05$). The kind of training was important for other evaluated functions, such as verbal creativity, Gardner Intelligence and 3D printing. The results are very interesting. So, the authors as a team are waiting for the third measurement and long-term consequences of the projects. The second direction of future research will be to analyze the level of differences within each group from the longitudinal perspective.

Conclusions: future research directions

The development of natural predispositions, such as creativity, depends on the environment of young people and their interaction with it. Therefore, it seems justified to research, diagnose and support the natural creative potential of individuals. Adequate conditions and opportunities should be created in the environment and actions undertaken (process, product). Future research could involve longitudinal research into the relation between the functioning of the child's cognitive processes and creativity and the impact

of various psycho-pedagogical interactions that change the environment of the child's development. This type of study is important as measurement of changes in creativity and a prediction of such changes in future achievements. This is very important in view of rapidly ocurring developmental processes in lifelong perspectives. Despite these difficulties, one may state that researchers of creative processes identify human creativity in a twofold way: as a cognitive process based on adequate skills, which is used to solve problems, and as a situation-adequate ability to present creative expression. That is why innovations and creativity merge with perfection, concrete knowledge, and skills. Research could also investigate parents' and teachers' attitudes towards the project activities, children's creativity, as well as the use of 3D printing. Additionally, 3D designing is currently introduced at the primary or secondary level of education, rarely in pre-school years. Very young children can participate in projects like the Dream Maker, which aims to add value to the childhood education. The authors of this article hope that other researchers will conduct similar projects, especially among economically disadvantaged children. The Dream Maker Project contributes to raising the awareness that education starts at the pre-school stage. These days, children are accustomed to technology. They adapt quickly and have an easy learning curve. They learn faster than their parents (even though they are so young).

The Dream Makers Project aims to put emphasis on the early childhood education and to focus attention on this important stage. Due to ignorance, but unintentionally, creativity is frequently curtailed in these first years of schooling. Creativity must be fostered, as it is an ever valued skill in the modern society. The project intends to show all the aspects that are considered fundamental in the childhood education. Moreover, the project authors pay particular attention to economically disadvantaged children. If measures to reduce differences are not addressed, differences will always exist. Therefore, this project includes economically disadvantaged children and tries to empower them, so that they can have tools that can be useful in their uncertain professional future. And creativity is understood as a skill which can be developed.

Practitioners consider the conventional system of schooling to be "stifling" to creativity and attempt (particularly in the pre-school/kindergarten and early school years) to provide a creativity-friendly, rich, imagination-fostering environment even to the youngest children. Researchers applaud this because technology helps societies progress at an unprecedented rate and creativity will be needed to cope with numerous challenges as they arise. Besides helping to solve problems, creativity also helps students identify

problems that others have failed to identify. The authors of this article believe in the project structure and in its ability to help children in becoming successful in a wide range of areas at later stages of their lives.

Acknowledgment

Special thank you to the European Union and the KA-2 project Dream Makers (2016-1-PT01-K201-023005)

Literature

Amabile T. M. (1996), Creativity in context: Update to "The Social Psychology of Creativity", Westview Press, Boulder.

Csíkszentmihályi M. (1999), Implications of a systems perspective for the study of creativity, [in:] Handbook of creativity, R. J. Sternberg (ed.), Cambridge University Press: Cambridge, pp. 313-335.

European Commission/EACEA/Eurydice, Compulsory Education in Europe – 2016/17. Eurydice Facts and Figures. Luxembourg: Publications Office of the European Union; https://webgate.ec.europa.eu/fpfis/mwikis/eurydice/images/2/24/Compulsory_Education_in_Europe_2016_2017.pdf [access: 2018.06.30].

Garcęs S., Pocinho M., Viseu J. (2016), The Impact of the Creative Environment on the Creative Person. Process, and Product, "Avaliação Psicológica", 15(2), pp. 169-176.

Gardner H. (1993), Frames of mind: The theory of multiple intelligences, BasicBooks, New York, NY.

Kirkorian H. L., Wartella E. A., Anderson D. R. (2008), Media and young children's learning, "The Future of Children", 18(1), pp. 39-61.

Loo S. (2017), Creative working in the knowledgee Econom,. Routledge Ltd.: Abingdon, Oxfordshire.

Pocinho M., Correia A., Carvalho R., Silva C. (2010), Influences of gender, family and vocational guidance services on career decision making, "Revista Brasileira de Orientação Profissional", 11(2), pp. 201-212.

Wolfe S, Flewitt R. S. (2010), New technologies, new multimodal literacy practices and young children's metacognitive development, "Cambridge Journal of Education", 40(4), pp. 387-399.

Vygotsky L. S. (1967), Play and its role in the mental development of the child, "Soviet Psychology", 5(3) pp. 6-18, http://psycnet.apa.org/record/1969-09514-001 [access: 5.03.2018]

Marzanna Farnicka
Noemi Serrano Diaz

3D PRINTING SKILLS AS A RESOURCE FOR THE DEVELOPMENT OF CREATIVITY IN MIDDLE CHILDHOOD

Keywords: constructivism, inequality, innovation, pre-school education, skills.

The article aims to describe the Dream Makers Project. The main objective of the project is to improve creative thinking and skills at the stage of pre-school education through 3D printing activities. The main concepts of this project are entrepreneurship education and training. This perspective is a well-established field of study that fosters entrepreneurial mindsets and skills which integrate socio-emotional aspects, such as self-confidence, leadership, creativity, motivation, resilience and self-efficacy. The article presents the background information on the main concepts of project activities and, next, describes the processes of project implementation and the evaluation project. The authors hope that this project will be useful to teachers and other researchers who conduct similar projects, especially among economically disadvantaged children, in order to help children develop skills which can benefit them in the future.

Marzanna Farnicka
Noemi Serrano Diaz

UMIEJĘTNOŚCI OBSŁUGI DRUKAREK 3D JAKO ZASÓB WSPIERAJĄCY ROZWÓJ KREATYWNOŚCI W ŚREDNIM DZIECIŃSTWIE

Słowa kluczowe: konstruktywizm, nierówności, innowacje, edukacja przedszkolna, umiejętności.

Celem artykułu jest opisanie projektu Dream Makers. Głównym celem tego projektu było wsparcie rozwoju kreatywności myślenia i umiejętności w edukacji przedszkolnej poprzez działania związane z drukiem 3D. Główne koncepcje projektu to kształcenie i szkolenie w zakresie przedsiębiorczości. Ta perspektywa jest dobrze ugruntowanym obszarem badań, który sprzyja duchowi przedsiębiorczości i rozwoju umiejętności, które łączą aspekty społeczno-emocjonalne, takie jak pewność siebie, przywództwo, kreatywność, motywacja, odporność i poczucie własnej skuteczności. W artykule przedstawiono podstawowe informacje obejmujące główne koncepcje działań projektu, a następnie opis przeprowadzanych procesów wdrażania i projekt ewaluacji. Autorki mają nadzieję, że projekt ten będzie przydatny dla nauczycieli i innych naukowców realizujących podobne projekty, zwłaszcza z dziećmi w niekorzystnej sytuacji ekonomicznej, aby rozwijać swoje umiejętności, co może dać im pewną przewagę w przyszłości.