Abstract
Creativity is one of the most important and desired nowadays’ abilities as most developed societies are shifting from an industrialized economy to a creative economy. However, creativity seems to decline during school age years, in a phenomenon called “creative crisis”. Creativity is also known as an ability that can be developed and improved. The goal of this PhD project is to create and develop social robots to serve as boosters for creative-driven behaviors in children. The main question that this project addresses is if the interaction between children and social robots can enhance children’s creative abilities. To achieve this goal, milestones were set, including throughout literature analysis on creative strategies that informed the development and creation of the robot to be used in studies with children, to investigate if the creativity of children is influenced by the interaction.

Author Keywords
Creativity; children; social robots; child-robot interaction; collective creativity; creative support

ACM Classification Keywords
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Introduction

Creativity is considered one of the most important human abilities and is a crucial part of education, as it can aid in children’s problem solving ability and their perseverance when facing obstacles. Although there is no single definition for the concept of creativity, a sufficiently broad description is provided by Plucker et al. who describe creativity as the “interaction among aptitude, process, and environment by which an individual or group produces a perceptible product that is both novel and useful as defined within a social context” [10].

Intuitively, schools are perceived as potentially rich environments for enhancing children’s creative abilities. In reality, however, research suggests a “creativity crisis” in education, in the form of a decline of creative abilities, which seems to take place starting at elementary school [3]. Fortunately, scholars tend to agree that this ability can be nurtured and enhanced [8], making it an important aspect of the child’s development to stimulate it at a young age. This imperative is becoming increasingly critical, as possessing creative abilities is a factor of growing importance for success in today’s job market. In many countries, the economy is driven by ideas, as opposed than by the standardized knowledge that was desired in the industrial age [5]. Yet most school systems are still driven by the industrialized imperative based on factory lines and standardization, daunting children’s creativity [13].

Since Guilford’s speech in the American Psychological Association in 1950 for the need of more creativity empirical research, creativity became a now-thriving and well-recognised field [6]. This lead to the development and validation of a variety of training programs for enhancing creativity [14] using different creativity techniques. Several of these techniques are entering the educational system focused on a number of factors: Some are concerned with a change in the teacher model of delivering content, others with the students’ role in learning, and finally some with the role that technology could have in education. In its groundbreaking book Mindstorms, Papert was among the first to recognize that a massive change in the education system was needed, and at the same time that technology could have a role in this change, especially as part of the learning process [9].

The Robot–Creativity Project

The Robot–Creativity Project is grounded in the field of Human-Robot Interaction (HRI) in which robots are developed to be social actors that can interact with humans [2]. In this project, we envision social robots as tools that can be used to boost creativity in children, stabilising a new generation of physical manipulatives [12]. In the scope of this project we do not view robots as mere interactants with children, but instead as technological tools, or “objects to think with” (to use the language of Mindstorms [9]) to foster creativity in children in the educational context of a classroom. Robots emerge as powerful tools as they live in the same physical space as humans do, being governed by the same laws of physics, and thus provide opportunities for physical interaction and stimulation. In fact, when comparing a social robot with a virtual agent, people seem to engage more with the robot, perceiving it as exerting more social influence and being liked more over the virtual agent [11]. In this project, we will design, develop and evaluate how robots can influence creativity in children between 7-9 years old. We envision these robots as non-humanoid artifacts that resemble toys for children to play with, and at the same time can behave autonomously by expressing their own needs or reacting to the environment. Due to their autonomous behavior, they become unpredictable (i.e., not totally controllable for a child, as opposed to a traditional toy).
and fun for children to play with, having the potential to be a conductor of creative thinking. During playful interactions with the robots, specifically in storytelling activities, children will likely try to guess what the robots are expressing, enhancing the ingredients in their stories and at the same time not letting them take full control, as robots can influence and change the curse of the story due to their own motivations and needs. This means that robots will not only be used as mere toys that children project their unique ideas on, but additionally as autonomous agents that children can play with and that have a life on their own.

The specific research questions (RQ) that we aim to answer during this PhD project are the following:

RQ1 (Effectiveness) Can robots be used as tools that influence creative abilities of children?

RQ2 (Process and Product) Does the intervention for creativity using robots influences both the creative process and the creative product?

RQ3 (Domain) Which creativity domains (e.g., verbal and figural creativity) are most influenced by the intervention with a robot?

RQ4 (Group Size) Is the intervention for creativity more successful if performed in groups or individually?

The Robot–Creativity Project will enter in its second year in April 2017. A road-map of the Project is depicted in Figure 4. The work performed to date includes (a) a systematic review of the research literature concerned with theories of creativity (b) and three initial studies, described below.

Systematic review On the basis of the PRISMA-P guidelines for conducting systematic reviews, the protocol of the proposed systematic review was registered with the International Prospective Register of Systematic Reviews (PROSPERO) (registration number: anonymized for review) and the full article corresponding to the systematic review now is being finalized.

Study 1: Co-design In this study, children served as informants [4] for the development of the behaviors of the future robot. This includes animating a paper prototype of a robot in a creative activity. We looked for two types of behaviors: (1) social behaviors, i.e., forms of behaving that show personality and emotions, (2) and creative behaviors, such as the robot providing new ideas and building upon ideas of others. This study was performed in a school classroom and 64 children with ages between 6–10 years old participated in the study (see Figure 1).

Study 2: Educational robotics and creativity Educational robotics is an emergent field in which school subjects (usually related with STE[A]M curricula) are taught through the use of robotics (e.g., using robotic kits). The idea behind educational robotics ties directly with constructivism and constructionism theories in which children construct their own knowledge. Knowing that educational robotics acts as an element that enhances learning [1], we have investigated if it impacts children's creativity. A total of 153 children between 6–10 years old participated in the study and their creative levels were measured using a validated metric of creativity, TCT-DP [7] as a pre- and post- tests. The extensive data collection providing from this an the co-design study are still being explored and analysed (see Figure 2).

Study 3: Virtual environment testing We have developed a virtual sandbox for creativity named Cubus to test the role that digital technology can have in creativity and to gain further insights on the design of the robot. An experimental study was performed in a school setting with 20 children with ages ranging from 7–9 years old. In this study, strategies for enhancing creativity were tested by comparing how children interacted with virtual agents with autonomous be-
behaviors that were designed to boost creativity. A full paper with the study findings is under review.

Next steps in The Robot–Creativity Project

- **Usability study:** We plan to perform usability testings with children to improve the design of the robot;
- **Effectiveness of robots in creativity:** In our next study we will investigate if the interaction with a robot can influence creativity in children. For this, we will compare the interaction between children with an autonomous robot in contrast with a robot without autonomous behavior. This step is connected with RQ1 explained above.

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