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Learning Robotics, with Robotics, by Robotics

Educational Robotics

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iSTE

WILEY

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coordinated by
Jérôme Dinet

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Learning Robotics, with Robotics, by Robotics

Foreword

There has been a growing interest in the use of educational robots in schools. In the 1960s, after Seymour Paper introduced the LOGO programming language and the floor turtle, robotics became an issue in the educational environment. Robots are slowly being incorporated into our society and currently, the number of service and/or assistance robots has outnumbered industrial robots. So robots are slowly beginning a process of seamless integration into our everyday lives both at home and at school where their applicability is at the core of an increasing number of studies [ALI 13, MUB 13]. However, this does not include "robots for kids": the impact of educational robotics is even more crucial for children and teenagers, where robots can be used for their cognitive development and intellectual growth. As a consequence, greater attention must be paid to how educational robots can be better integrated into the lives and into the education of young people.

Traditionally, the majority of studies investigating "educational robotics" has attracted the interest of teachers and researchers as a valuable tool to develop cognitive and social skills for students from pre-school to high school and to support learning in different domains such as science, mathematics, technology, informatics and other school subjects or interdisciplinary learning activities. Even though a review of the scientific literature reveals that educational robotics is a growing field with the potential to significantly impact the nature of science and technology education at all levels, from kindergarten to university, this book is very original for three reasons:

1) In this book, educational robotics is viewed from a psychological point of view, i.e. from a human-centred approach. For some researchers, the main goal of our project is to understand the current and future needs of the robotics industry, the current robotics curriculum, and to analyze the gap that might occur between the two. In my opinion, the main goal is to understand the current and future needs of the users, the users being learners and teachers;

2) If there are many attitudes and opinions about educational robotics produced without scientific arguments, this book provides serious scientific answers to three questions:

– is educational robotics just a servant of other subjects? No. A wider range of possible robotic applications has the potential to engage young people with a wider range of interests [AMI 12]. Pursuing this challenge we need to develop new and innovative ways to increase the attractiveness and learning benefits of robotics projects. And different strategies exist for engaging a broad range of young learners in robotics [RUS 08]: projects focusing on themes, not just challenges; projects combining art and engineering; projects encouraging storytelling; organizing exhibitions, rather than competitions;

– is educational robotics just a fad? Yes and no. Even if robots can have positive educational benefits, they are no panacea [AMI 12]. In the scientific literature, there have been some studies reporting non-significant impact on learners observed in some cases [BEN 11]. It's the reason why the impact of the Educational Robotics in promoting student learning and in developing sensori-motor and/or cognitive skills needs to be validated through research evidence and scientific proofs. But …

– is educational robotics an excellent tool for teaching? It depends … Empirical and experimental studies are presented.

3) If educational robotics is a broad term that refers to a vast collection of different activities, instructional programs, physical

platforms, educational resources and pedagogical philosophy, this books proposes an innovative distinction between the following approaches associated with educational robotics:

– for "learning robotics", students use a robot as a platform to learn robotics, or, more broadly, engineering (i.e. mechanics, electronics, and programming) in a hands-on and collaborative way;

– for "learning with robotics", robots are used as human-like (e.g. robots such as Nao, Qrio, Rubi, Roobovie, iCub) or animal-like (e.g. robots such as Aibo, Pleo) assistants for teachers (e.g. displaying multimodal content) or companions for pupils and students (e.g. connecting images and words, memorizing new words of a foreign language).

Finally and as Alimisis [ALI 13] said, "*the role of educational robotics should be seen as a tool to foster essential life skills (cognitive and personal development, team working) through which people can develop their potential to use their imagination, to express themselves and make original and valued choices in their lives. Robotics benefits are relevant for all children*".

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Preface

This book is about how educational robotics (ER) is affecting the representation, acceptance and learning of its users. Through a psychological perspective, the book discusses the three ER learning paradigms that are distinguished by the different hardware, software and correspondent modes of interaction allowed by the robot: (1) *learning robotics*, (2) *learning with robotics* and (3) *learning by robotics* [TEJ 06, GAU 14].

For *learning robotics* [ALI 09], students use a robot as a platform to learn robotics or, more broadly, engineering – i.e. mechanics, electronics and programming – in a hands-on and collaborative way [PET 04, LIU 10, SOA 11, BEN 12]. In this framework, our objective is to investigate learning robotics under the issue of mental representation [GAU 15]. Here, the underlying research question is which representation users hold about robots when constructing and programming a robot? By robot representation, we mean its ontological and pedagogical status and how such status changes when users learn robotics. In order to answer this question, we will present an experimental study that we carried out based on pre- and postinquiries, involving 79 participants. The results show that building and programming a robot (Bot'n Roll®) fosters a more nuanced judgment about robots' belonging to the living and non-living categories but, on the other side, a more definite judgment about the pedagogical roles that a robot may serve.

For *learning with robotics* [DAU 03], robots are used as human-like (e.g. robots such as Nao, Qrio, Rubi, Roobovie and iCub) or animal-like (e.g. robots such as Aibo and Pleo) assistants for teachers – e.g. displaying multimodal content [HYU 08] – or companions for pupils and students – e.g. connecting images and words [TEJ 06], memorizing new words of a foreign language [MOV 09, CHA 10]. In this framework, our objective is to investigate learning with robotics under the issue of users' functional and social acceptance of robot [KAP 05, AVR 13, LE 13, DIN 14, DIN 15, FRI 14, DE 15]. Here, the underlying research questions are: do students trust in robot's functional and social savvy? Is trust in functional savvy a prerequisite for trust in social savvy? Which individuals and contextual factors are more likely to influence this trust? In order to answer these questions, we will present an experimental study we have carried out with 56 participants and an iCub robot [IVA 13, IVA 16]. Here, trust in the robot is considered as a main indicator of acceptance in situations of perceptual and sociocognitive uncertainty and is measured by participants' conformation to answers given by iCub. In particular, we are interested in understanding whether specific user-related features (i.e. desire for control), robot-related features (i.e. attitude toward social influence of robots) and context-related features (i.e. collaborative vs. competitive scenario) impacted trust in iCub. The results show that participants conformed more to iCub answers in functional than in social task. Moreover, the few participants conforming to iCub answers in the social task also conformed less in the functional task: trust in robot's functional savvy was not a prerequisite for trust in social savvy. Finally, desire for control, attitude toward social influence of robots and type of interaction scenario did not have an impact on trust in iCub.

Contrary to these two preceding learning modes that have been labeled as robotic-assisted instruction [VAN 91] – in so far the robot is a passive assistant of the teacher or a passive platform for the students – learning by robotics is named robotic-based instruction (RBI [KIM 14]), in so far the robot constitutes a medium between the students, the school subjects and the teacher: the robot is a tool – i.e. a constructible and programmable kit – that tangibly embodies the concepts of the lesson, and stimulates creative and collaborative problem solving [DEN 94].

For *learning by robotics* [RES 96, PAP 80], students learn both about the content of the lesson and about robots (Lego Mindstorms®, Lego WeDo®, PicoCricket®, Robotami®, etc.), by acquiring subject-specific knowledge [BAR 09a, WHI 07, HUS 06] as well as transversal competences [DEN 01, LIN 07, SUL 08], and fostering the four dimensions of learning – cognitive, affective, social and meta-cognitive [CAT 12]. Although by taking the role of facilitator, the teacher is not seen anymore as the only owner of the knowledge or as the evaluator of students' performance, but he/she catalyzes students' ideas around a concrete activity and guides their progress [GAT 03, SUL 09]. In this framework, our objective is to investigate learning by robotics under the issue of impact of RBI on students' knowledge and competence acquisition (when educational robots are used within a specific pedagogical approach, that is inquiry-based science education (IBSE) [QUI 04, BEL 10, RIE XX, GAT XX]. Here, the underlying research questions are as follows: to what extent the combined RBI and IBSE frame [WIL 07, EGU 12, DEM 12, RIB 12] has a positive impact on cognitive, affective, social and meta-cognitive dimensions of learning? Does this combined educational frame improve both domain-specific and non-domain-specific knowledge and competences of students? In order to answer these questions, we will present an experimental study carried during a 1-year RBI and IBSE in the frame of the RObeeZ school project[1]. The longitudinal experiments that involved 26 pupils and two teachers was based on assessment jointly elaborated by teachers and researchers in order to evaluate the RBI and IBSE effects on four dimensions of learning [FLA 79, SHO 89, VER 96, SAL 98, AND 01] as well as on grades attributed by teachers for evaluating students' knowledge and competences. Main results show significant improvements in mathematics (measures, geometry and problems) and positive impact of RBI and IBSE on the four dimensions of learning.

1 The research has been made through the FP7 EU project Pri-Sci-Net: http://www.prisci.net/.

The recent field of investigation of effects of ER on learning is extensively spreading in scholar and extra-scholar contexts. At the crossroad of artificial intelligence, psychology and science of education, our book discusses how the processes of these learning paradigms (*learning robotics*, *learning with robotics* and *learning by robotics*) might be improved.

> A robot […] is virtually a chimera: all of its components are real, yet it does not exist as an entity. It will affect and transform our lives similarly to the discovery of fire and the inventions of the wheel, the steam engine and the mobile phone. But will it transform *us*? This fascination with robots is merely an expression of humanity's seemingly endless ability for discovery: leaving Africa to go and discover what lay beyond. Arriving in Asia and from there Europe and America. Prehistoric men discovered the American continent through its Northern point by crossing the Bering Straight when it was frozen over; they explored it from one end to the other and only then did they begin to dream. The oldest painted caves of the continent are located to the South, where man had reached the end and had nowhere left to explore, no looking glass to go through, other than through thought. The walls of these caves are covered in carvings of men with animal-faces. Robots represent the last frontier for men who have conquered lands, seas and danced with the stars; the only Universe left to explore is themselves.
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> M.N HIMBERT (2012). *Le Robot Pensant*, pp. 201. Paris: Editions du Moment.

> "Teach me to imagine a result without mourning if it emerges differently"
>
> P. ARTISAN'S

> The *Robolution* isn't a rhetorical term or a marketing strategy. It is an entirely new approach to Science and Technology. This *Robolution* causes so many upsets to our way of life that it is essential to think about it not only in economic terms but in pedagogical terms as well (…) Most robots are so recent that their perceived value is often higher than their real value. (…)
>
> B. BONNEL (2010) *Viva la Robolution*, pp. 279–284. Paris: Editions JCLattès.

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Introduction: Educational Robotics

The process of democratization of technology that has taken place since 1980 in the professional, tuition and entertainment spheres has paved the way for a renewal of education. Soon after the computer entered our society, Papert and Solomon [PAP 72] published "Twenty things to do with a computer". At that time, these authors observed that, when asked what they thought about computers in education, people had different ideas. Some imagined future students as computer programmers: these people thought that the next generation would have learnt and mastered programming as a normal process of alphabetization; others, by contrast, apprehended the possibility that the computers would have "programmed" the students, i.e. a massive use of technology in education could have irreversibly transformed students ways of thinking and communicating in a machine-like manner.

Today, a new technological revolution has started, namely the robolution [BON 10]. This revolution seems to be so powerful and pervasive that our times have been defined as "the era of the robot". Daily use of robotics is encouraged in an extensive range of domains, among which is the educational domain. However, caution should be used with regard to a revolution that could be dictated by industrial development and technological progress more than by authentic educational needs.

It thus becomes urgent to understand the usefulness of integrating robots in the educational system. Such urgency results in the emergence of a new specific field of study: educational robotics (ER) [EGU 10]. ER aims to introduce to the classroom a variety of embodied artificial intelligence technologies (human-like as well as animal-like robots and robotic kits). According to Bussi and Mariotti [BUS 09, p. 2], who borrow from Vygotsky's notion of semiotic mediation [VYG 78], educational robots are intended as "semiotic tools":

> "(…) semiotic potential resides in any artifact consisting of the double semiotic link that the artifact has with both the personal meanings that emerge from its use and the knowledge evoked by that use (…) in educational settings".

By means of such tools, the general objective of ER is to scaffold and renew teaching on the one side and learning on the other side [DEN 94].

After 30 years since the arrival of Logo Turtle[1] [PAP 80, PEA 83, KLA 88, CLE 93], the first educational robot, we believe it is time to clarify the nature of ER and to start thinking about "Twenty things to do with a robot", in particular with an educational robot – Appendix 1 [RES 96].

In order to do this, we will first outline the historical origins of ER and describe its position with respect to other current information and communication technologies (ICTs). Then, we will illustrate the three learning paradigms presently supported by the types of robots available on the market: *learning robotics*, *learning with robotics* and *learning by robotics*. These three learning paradigms are the focus of our research and motivate the tripartite structure of this book. Their definition is of pivotal importance for introducing our three experimental investigations and will therefore be deepened all along the present work. Finally, we will present the research questions from which we have moved to develop this work.

I.1. Origins, positioning and pedagogical exploitations of ER

ER finds its origins in a historical moment where the gap dividing the generation of "digital natives" and the previous one of "digital

1 http://turtleacademy.com/.

immigrants" becomes manifest in terms of technology fluency and ways of thinking [PRE 01]. Surrounded by digital technologies from their birth, young people today might treat information differently from their predecessors, who nowadays experience difficulties in adapting to such an omnipresence of technology.

If so, this technogenerational gap is particularly relevant in educational contexts, where these two generations, represented by teachers and students, interact to develop new knowledge and competences by using educational tools, which are capable of shaping students' intellectual growth. For this reason, a debate has been raised about limiting new technologies to extra-school contexts (e.g. summer campus and competitions) versus employing them at school [ARR 03]. Although education is already familiar with questions about the suitability of technologies in the class, it is indeed new to questions about the suitability of this specific technology, i.e. robotics. It is thus crucial to systematize theoretical and experimental knowledge about ER to understand its possible applications and consequent impacts on education. In fact, though being still a "babbling" discipline [MAT 04], ER already presents three fundamental characteristics: (1) a multidiscipline heritage, (2) a specific positioning with respect to other current ICT, and (3) different hardware–software combinations, which serve different pedagogical exploitations. In the following sections, we will examine these three characteristics to delineate the identity of ER.

I.2. A cross-disciplinary heritage

ER is at the crossroads of three disciplines belonging to the broader area of research of cognitive sciences: psychology, educational science and artificial intelligence.

Fundamental studies from psychology on the role of experiential learning [PIA 52], intrinsic versus extrinsic motivation [LEP 00], social dynamics of learning [VYG 78] and meta-cognition [GAG 09] are crucial for investigating the mental processes implied by the use of a new technology for educational objectives [AND 08].

Educational sciences, which seek to implement research on cognitive and emotional mechanisms at play during learning

[MEL 09], provide a number of case studies that are representative of current pedagogical approaches [BRU 02], monitor trends in learning results – see, for example, OECD-PISA (The Organisation for Economic Cooperation and Development-Programme for International Student Assessment)[2] – and also support the design of guidelines for the adaptation of the educational system to contemporary society [VOS 01].

Artificial intelligence [HEU 94], more recently labeled as "cognitive informatics" [WAN 10], continuously raises new challenges in terms of robot prototypes with physical and functional features engendering a variety of interaction possibilities. In this sense, ER confronts young students with a technology at the boundary of living and non-living entities, which can be built and programmed for obtaining specific functions and behaviors [MAR 00].

We argue that it is the combination of these three disciplines that contributes to defining the technological status and pedagogical exploitations of educational robots, as distinct from previous educational technologies.

I.3. The educational robot: an ICT like others?

In the last 20 years, different types of technologies, suited for different educational exploitations, have appeared. A variety of educational softwares have been conceived for interactive learning on traditional hardware supports (computers, tablets, etc.) [DE 01]. Other tools – such as the e-learning platforms [ROS 01] and the digital schoolbag [TIJ 06] – allow customization of the educational interface according to students' needs.

Critical reflections about the integration of ICT at school have been at the heart of committed debates among educators, researchers and decisions makers, engendering questions such as "What is the role of media in education?" and, among the media, "What is the role of the

2 http://www.oecd.org/fr/edu/scolaire/programmeinternationalpourlesuivides acquisdeselevespisa/.

computer?". With the birth of ER, further questions have been raised: what similarities do robots share with their technological precursors? What distinguishes the former from the latter?

As a first answer, two features of the robot and of its precursor, the computer, can be examined: their "technological status" and their "pedagogical exploitations".

With respect to *technological status*, the computer presents a double specificity: this technology can be either an end in itself – i.e. an engineering object that it is employed as a platform to understand how computers are assembled and programmed – or an ICT [AND 08] that can be defined as a medium, a processor and a tool [BAR 96]. As a "medium", the computer supports software that students use to interactively acquire new knowledge. As a "processor", the computer facilitates treatment and storage of information in a way that is specific to the type of content. As a "tool", the computer can be employed to elaborate documents, visualize numerical data, etc.

If we apply this distinction to robots, we find that, as an ICT, the robot can be defined in terms of object – i.e. a constructible and programmable device that can be used to learn mechanics, electronics and informatics (e.g. [MIK 06]) – or of tool – i.e. a device employed to acquire new knowledge and competences [ION 07].

With respect to *pedagogical exploitations*, when using a computer, students can learn either "from" or "with". In the first case, the computer is used to augment pupils' knowledge with software, which facilitates the understanding of subject-related knowledge [BOT 02]. In the second case, technology can be applied to enhance higher-order thinking skills [RIN 02]. This is the case of those software that aim at developing meta-cognitive competences [ZIB 11], as well as motivation and engagement [PRE 05].

Although the pedagogical exploitations of educational robots are related not only to the type of software but also to the type of hardware, as embodied artificial intelligence entities, robots are endowed with shapes and behaviors that add something to computers and consequently raise new learning paradigms.