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Perspectives on the Use of Educational Robotics in Health: A Systematic Review

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***Abstract*—This paper presents a systematic review of the literature (SRL) on works related to educational robotics in health. This review emerges from the interest to identify the advances of scientific productions in this field. The lack of specific literature in this area was a motivation, and the research is carried out based on papers dated from 2000 to 2017. With this systematic review we answer some important questions for the elucidation of the contemporary framework of educational robotics applied to health. Results show an increasing interest of the scientific community in this area, especially for the treatment and improvement of the quality of life of people with autism. In relation to the geographical distribution of the works, authors in Europe and in the United States are responsible for most part of the found researches.**

***Keywords*-Educational Robotics; Health; Literature Review; Autism Spectrum Disorder**

I. Introduction

The popular interest in robotics has systematically increased in the last decades, mostly due to the media appeal and the insertion of the technology in the daily life. In addition, robotics has becoming visible by many people as a tool that offers great benefits in education, at all of the levels [1].

It is noticed that the use of robotics in the school environment allows students to apply their theoretical knowledge in practice, by solving problems through stimulating logical reasoning, investigative thinking, motor skills, creativity and team work [2], [3], [4], [5]. Besides those skills enhancement, the use of innovative technologies like educational robotics in classroom enables for a transformation of school life into a dynamic, creative, and challenging environment, mainly if combined with robotics competitions[5], [6].

Educational robotics is currently a growing field of research, which has started its first investigations in the last century developed by a group of researchers from the Massachusetts Institute of Technology (MIT), led by Seymour Papert, in the late sixties [7], [8], [9]. Papert' acting phylosophy is mostly based on Jean Piaget's constructionist theory, which is defined by the construction of knowledge through interaction with the environment in which it is inserted, and this interaction is conducive to the development of student learning [10], [11].

From the several researches carried out, which we found in the proceedings of Brazilian and international conferences, and in journals of the area of Education and Robotics, we perceive a great use of educational robotics as a tool to aid the teaching of transversal disciplines of the traditional curriculum. In these works, an improvement in creativity, motor coordination, logical reasoning and social relations through team work are reported. In addition, we noticed the growing use of social robots as a tool to aid the rehabilitation process of some diseases and disorders.

Thus, the present systematic review of the literature (SRL) emerges from our interest to identify the advances of these scientific productions about the use of Educational Robotics methods in Health. The lack of specific literature in this area has motivated our research. This research is carried out based on papers that are dated from 2000 to 2017. In this systematic review we will try to answer important questions that arise, allowing for the elucidation of the contemporary framework of educational robotics applied to health.

In the next, we draw the methodology used for the systematic review, followed by an analysis of these productions mainly mapping those that are most related to health. Final remarks are lastly given pointing directions of researches in this so important area.

II. Method

For this work we propose a systematic review of literature (SRL) in order to extract significant approaches and main issues in the use of educational robotics in health. According to Kitchenham [12], a systematic review of literature is carried out to search and evaluate in a quantitative and qualitative way the studies already done in the area that have been made available to the scientific community and that have certain academic importance as a research base.

These reviews can be considered as retrospective observational studies or experimental studies of retrieval and as a critical review of the literature. They test hypotheses and aim to collect, critically evaluate the methodology of the

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research and synthesize the results of several primary studies in order to guide the development of projects, indicating new directions for future research and identifying which research methods are used in a certain area.

To conduct this systematic review, we followed the process proposed by Kitchenham [13] and by Khan et al. [14], which covers the following steps and activities:

1) Step 1: Review Planning
   - Activity 1.1: Identification of the need for a review
   - Activity 1.2: Development of a review protocol
2) Step 2: Execution of the Review
   - Activity 2.1: Research ID
   - Activity 2.2: Selection of papers
   - Activity 2.3: Evaluation of study quality
   - Activity 2.4: Extraction of data
   - Activity 2.5: Data synthesis
3) Step 3: Review Results
   - Activity 3.1: Results presentation

A. Review Planning and Execution: Steps 1 and 2

Initially, a research was conducted to identify the existence of systematic reviews involving the use of the methodology of educational robotics in health, but no specific research was found about this subject. Based on this assumption, we began the systematic review stage, with the definition of the research questions that will led to the search of the relevant data, with the objective of answering the central question of the study: "How is characterized the use of the tool of educational robotics in health?". From the central question, we split for four sub items that will also guide this research:

- Q1 - Which countries are involved in this study area?
- Q2 - What health areas are taking advantage of this tool?
- Q3 - How many works are reflections, how many are proposals and how many experiences?

After defining the central theme of this systematic review, we began to survey the published papers. The searches were restricted to national and international papers, written in English and Portuguese and published between 2000 and 2017.

With the appropriate previously selected papers, some criteria were used to determine which documents would be included or excluded, in fact, in the review. Among the inclusive criteria, we can cite:

1) The paper reports the application of educational robotics as a tool for health assistance;
2) The article presents educational robotics in a health context;
3) It involves the use of physical robots.

As well as the inclusion criteria, it is important to get more filtered jobs to add exclusion criteria. Exclusion criteria are also valid, since they eliminate any work that would not be useful for this research. For this, we identified some issues such as:

1) Educational robotics is not used in the context of health;
2) Aiming at the general area of robotics and not for educational robotics.

At beginning, an initial search yielded 102 papers, using keywords as *health* and *educational* and *robotics*. In the next step, we quickly reviewed the titles and abstracts in relation to the inclusion and exclusion criteria mentioned above. However, due to the specificity's of the criteria, it was difficult to exclude articles based only on the abstract. Therefore, we decided to seek the necessary information in the full text, basically by reading the introduction and conclusion of each selected work.

Thus, it was possible to select the article or delete it (by fitting it into one of the criteria). Approximately 60% of articles were excluded because they were not in the context of this research.

III. Results and Discussion

After the systematic review of the robotic educational methodology in the health area, we compiled the results with their respective observations. These will be presented through subtopics, answering the questions raised in Section II-A.

A. Q1 - Which countries are involved in this study area?

After compiling the data obtained by the systematic review proposed in this paper, we conclude that the countries most involved in research in this area are:

- United State with 10 publications;
- Italy with 6 publications;
- Netherlands with 3 publications;
- Japan with 3 publications;
- United Kingdom with 2 publications;
- Austria, Canada, Luxembourg, Portugal, Israel, Slovak Republic e Malasya with 10 publication each.

These publications were distributed as shown in the map chart presented on the Figure 1, which can be used for better visualization. The interpretation of the map chart is aided by a bar of intensity of colors. The regions identified by red color represent the countries with only one publication and the regions identified by the green color have ten published papers. The variation from 1 to 10 was determined by the color intensity bar and the countries that do not have publications in this area are identified by the color gray.

Among the countries mentioned, the publications are well distributed in several universities and research lines. In spite of the great distribution of the works, we found two publications submitted by the University of Nagoya in Japan, one being published to the International Conference

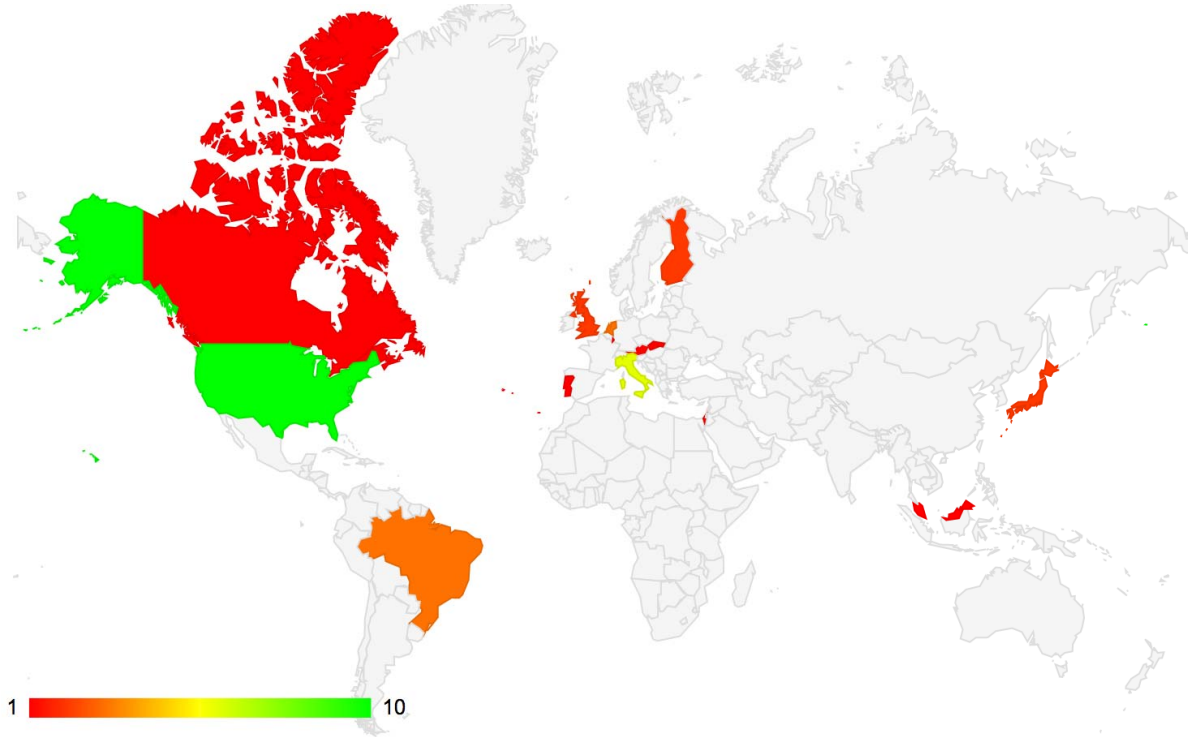

Figure 1. Distribution of Publications in the Global Scenario

on Soft Computing and Intelligent Systems (SCIS) and 17th International Symposium on Advanced Intelligent Systems (ISIS) in 2016. The extended version of the same work was submitted to the IEEE Symposium Series on Computational Intelligence (SSCI) in 2017.

Another case such as the last one occurred in the United States Automation and Interventional Medicine (AIM) Laboratory in the Department of Mechanical Engineering at Worcester Polytechnic Institute. The same authors published papers in the same area and at the same conference in different years, 2011 and 2014.

B. Q2 - What health areas are taking advantage of this tool?

From the selected papers, we include in a single file all the keywords and assembled a word cloud that is arranged as seen in Figure 2. This word cloud model gives a greater prominence to words that appear more frequently in the source texts.

According to the Section II-A and based on the inclusion and exclusion criteria as a parameter, we can observe through the highlighted words (larger dimension) that all of the criteria have been satisfied. All selected papers are part of the scope of the systematic review proposed in this article. We note that highlighted words, such as: Robotics, Education, and Educational, satisfy the first part of the first item of inclusion. The second part of the first and second inclusion items are evidenced through the words: Disorder, Autism, Pediatrics, Assistive Robotic, Therapy, Rehabilitation, Special, Needs and Medical. These words appeared in less recurrence, because their use depends on the approach of each paper.

This analysis allowed us to give an overview of what is being researched about educational robotics applied to health in order to categorize the articles so that we could compare them and know the main benefits of using this tool. Although we notice in the word cloud that some themes are in greater prominence such as: Autism, Disorder, Pediatrics, Assistive Robotic, Therapy, Rehabilitation, Special, Needs and Medical these subjects by themselves can not be considered categories. Considering that, if we take as an example the Autism, which in the area of health has a greater number of related papers, there are several approaches to this theme such as the use of a humanoid robot to aid classroom socialization or a tool for inclusion for students with this type of disorder. These works, although they have a common theme, are not considered related works in relation to their proposal.

In this way, we divide the papers into the following categories according to their proposal:

1) Educational Robotics as an Assistive Technology: Use of educational robotics methodology to promote functionality related to the activity and participation of people with disabilities, reduced mobility, aiming at their autonomy, independence, quality of life and

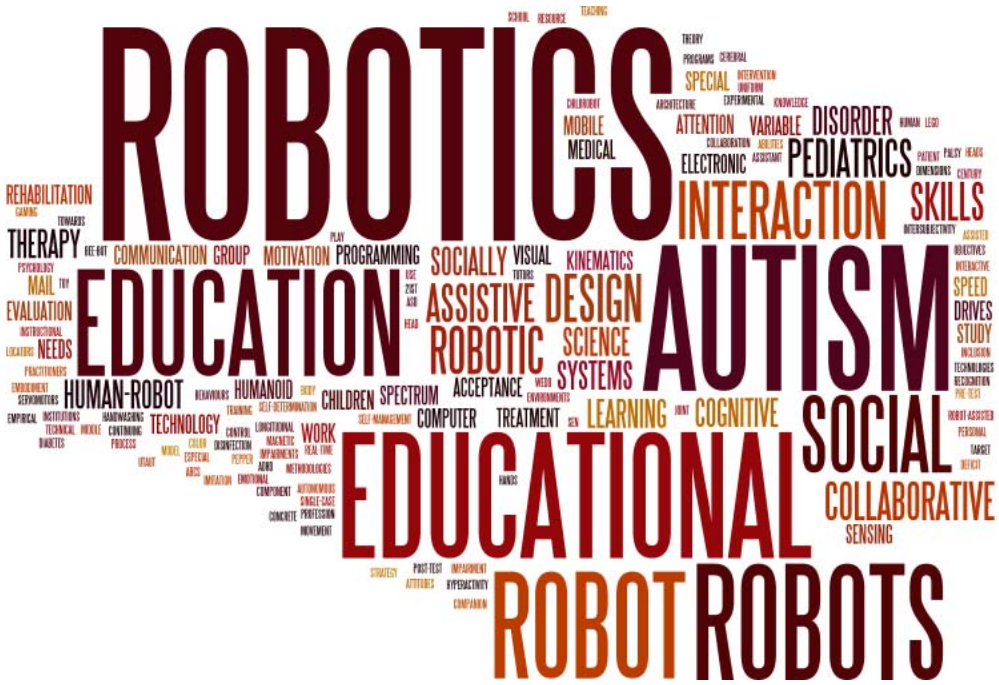

Figure 2. Word cloud from paper's keywords

social inclusion [15].

2) Educational Robotics For Inclusive Learning: Use of educational robotics as a means of educational inclusion, providing the individual necessary conditions for their development and use of their skills in a regular environment [16].
3) Methodology Proposal or Research Methodology for Assessment of Impact of Educational Robotics Activities with People with Health Issues or Disorders: Prosposta/pesquisa de motodologias
4) Social Robotics: The works that approach this theme use the social robots as tools to teach skills, to play and to extract certain desired behaviors [17].

We can see from the graph shown in Figure 3 that most of the papers, 16 of them, present a Research Methodology for Assessment of Impact of Educational Robotics Activities with People with Health Issues or Disorders. In this category, the authors presented approaches and benefits of the use of Educational Robotics in health. Social Robotics and Educational Robotics as an Assistive Technology corresponded to 10 and 6 papers respectively. Only two of the articles have submitted proposals in Educational Robotics for Inclusive Learning. So we believe that this type of proposal is still an open topic in Educational Robotics because of the difficulty of producing technologies that are usable by people with or without Health Issues or Disorders without the need for adaptations [18].

C. Q3 - How many works are reflections, how many are proposals and how many experiences?

In relation to these issues, we evaluate the approaches that the works are directed to. For this, we divided the subjects into three categories of approaches:

- Reflections: Works in which the main point is related to concepts, facts and circumstances. The author makes an investigation of the proposed subject and discusses it;
- Proposals: Works that propose some type of intervention or methodology;
- Experiences: Works that accurately describe a given experience that can contribute in a relevant way to your area of expertise.

In Figure 2 we can see the distribution of the selected works in the categories mentioned in Subsection III-C. Among the 35 articles selected, 19 deal with the theme of *Experiences* corresponding to 54% of the papers. For the subject of *Reflections* we obtain 11 papers, referring to 32%. Finally, we found the approach of the *Proposals* with 5 papers, which gives a total of 14%. We include in the graph the total number of publications that involve Autism alongside the total of each category, since this subject was the most recurrent one.

We can verify that the most discussed topics in the publications are related to the papers that describe their experiences and results using the proposed tool. Approximately 37% of the papers address experiences for children with

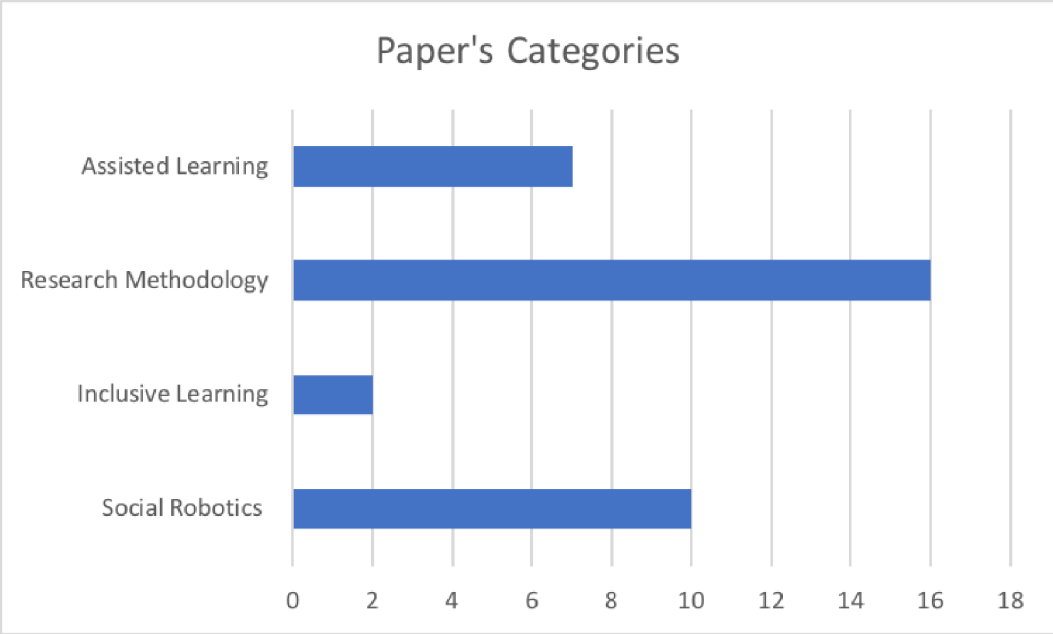

Figure 3. Distribution of Papers by Categories

autism spectrum disorders, reporting their results and how this tool was effective in educational and social interventions. Among the works that address this theme, the author Robins [19] evidences his experience with four children with autism who were exposed to a humanoid robot during a certain period and obtained significant results in relation to their social interaction skills.

In his work, Desideri [20] highlights the use of a humanoid robot with the goal of improving the effectiveness of educational interventions aiming to help children with autism. This analysis was performed with three kindergarten pupils and the results indicated that interaction with the humanoid robot facilitates the engagement and achievement of goals in educational activities.

The other works, still in the thematic *Experiences*, are randomly distributed in some styles of approaches as: works with seniors through the use of a communication robot; use of robots as a motivational aid for pupils with diabetes; effects of educational robotics on kindergarten in order to verify executive functions; educational robotics as a tool for inclusion of hearing impaired students suffering from schizophrenic, Asperger syndrome, and intelligence deficit; and the use of an autonomous and socially assistive mobile robot to help children with attention deficit hyperactivity disorder, encouraging attention and academic productivity of children.

We can highlight that among the 11 papers classified as *Reflections* 5 of them are also towards defining acting approaches to help autism. In order to specifically address the related therapeutic and educational goals through the design of a robot aimed at the autism-assisted play of children proposed by E. Ferrari [21]. Still on the autism theme we present the work of Ozcana [22] that proposes the development of socially assisted robots that stimulate the cognitive level and that can be engaged in social interactions with autistic children. The other works classified as Reflections are related to another themes, such as: robot-assisted therapy for diabetic patients; Educational robotics in teaching special students through the development of skills such as collaboration, cognitive skills, self-confidence, spatial perception and understanding; The use of robotic social assistance technology as an approach for the rehabilitation of children with cerebral palsy.

Finally, the papers classified as *Proposals* corresponded to 5 articles, and 3 among them are on the subject of autism. Saskia van Oenen [23] proposes the development of an educational approach, where social robotics is used to increase the developmental opportunities of students with a certain type of autism. In another paper Charron [24] describes a methodology for the development of joint attention skills in students with autism spectrum disorder. The remaining articles address topics such as: new assistive educational technologies to enable the use of educational robotics among visually impaired or low vision; and topics to improve the use of robotics in teaching, with a new approach to Cognitive Science, in order to facilitate student learning.

IV. Conclusion

In traditional systematic reviews of the literature, several studies show that robotics can be used as an important

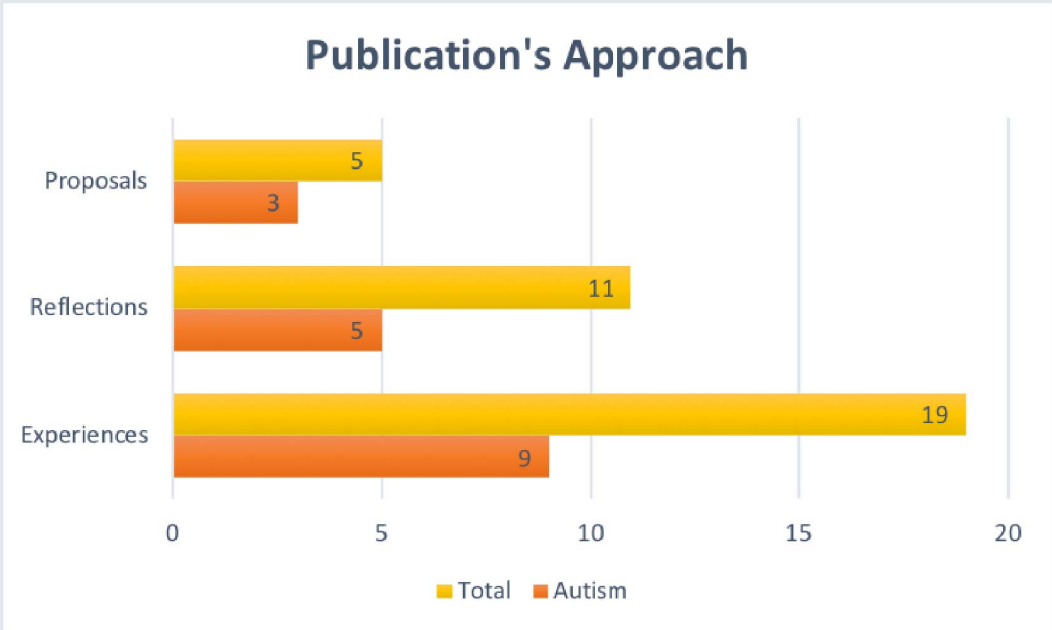

Figure 4. Distribution of Papers by Approach

educational tool, stimulating the learning and understanding of the knowledge inherent to the school curriculum. Another important feature of educational robotics is the accomplishment of group work, which stimulates collaborative work among students, as well as cognitive and motor development.

This work introduces a particular systematic literature review of the works related to educational robotics in health. The research was carried out based on articles that are dated from 2000 to 2017. The results show an increasing interest in the scientific community in the area, especially for treatment and improvement of the quality of life of people with autism, and it also highlights the works of authors in Europe and the United States responsible for much of the research found.

It is important to emphasize the presence of the works with autism in the initiatives of the use of educational robotics of health. Given that one of the great benefits of educational robotics is group work through collaborative learning, and this ability is fundamentally sought after by educators, health professionals, and family members who deal with people with this type of disorder. The benefits of using robotics as a support tool have been evidenced in 37% of the articles selected in this review for this subject. This indicates that educational robotics could be used, for example, in conjunction with other tools as augmented reality [25] in order to provided better responses to stimuli for these children.

Another factor evidenced in this work emerged from the popularization and dissemination of educational robotics. We note that 67% of the work that does not involve autism was published between 2014 and 2017. Finally, we infer that this area of research is still recent and has several open themes.

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