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Embodied Cognition and Its Implications in Education: An Overview of Recent Literature

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***Abstract*—**Embodied Cognition (EC) as a learning paradigm is based on the idea of an inseparable link between body, mind, and environment. In recent years, the advent of theoretical learning approaches around EC theory has resulted in a number of empirical studies exploring the implementation of the theory in education. This systematic literature overview identifies the mainstream of EC research and emphasizes on the implementation of the theory across learning environments. Based on a corpus of 43 manuscripts, published between 2013 and 2017, it sets out to describe the range of topics covered under the umbrella of EC and provides a holistic view of the field. The aim of the present review is to investigate the main issues in EC research related to the various learning contexts. Particularly, the study addresses the research methods and technologies that are utilized, and it also explores the integration of body into the learning context. An important finding from the overview is the potential of the theory in different educational environments and disciplines. However, there is a lack of an explicit pedagogical framework from an educational perspective for a successful implementation in various learning contexts.

***Keywords*—**Embodied cognition, embodied learning, education, technology, schools.

I. Introduction

THE increasing dependence on technological tools for enhancing learning has brought to light new dimensions in the research area of educational technology, gaining more attention in pedagogical implications of different emerging technologies. In contemporary educational discourse, renewed interest in EC and Embodied Learning (EL) has emerged, in conjunction with the exploitation of technologies, which provide new teaching approaches and interactions. Simply stated, EC is a theory that takes into consideration that the human body can play a significant role in the cognitive process, in thinking and in acting in the world [1], [2].

In recent years, the theory of EC has brought in the light the involvement of physical body and activity into the learning process, changing the way of learning and creating questions about the role of body in cognitive processes. So far, the implication and the dynamic presence of EC in many different disciplines such as psychology, cognitive science, education, neuroscience, and HCI, indicates the great potential of this theory across many disciplines [3], [4]. It bears mentioning that studies around EC rose very fast in prominence towards the end of last century and it seems to be a trend in the research area of the abovementioned fields [5]. This orientation around EC that argues that mind and body are closely interlinked [1], has obviously many influences on the way we learn and teach. From this perspective, EC is one contemporary learning paradigm with a potential impact in educational settings.

This manuscript explores the development in the field of EC, by building a map of existing research work in the field. Based on a corpus of 43 manuscripts, published between 2013 and 2017, it sets out to describe the range of topics covered under the umbrella of EC and provides a holistic view of the field. In particular, the present review addresses: a) The research methods used in educational settings for EC research, b) the learning subject/content and technological tools are utilized for the implementation of EC, and c) the integration of body into the learning process.

In the sections below, first an overview of EC theory is providing, and related theoretical approaches are explaining. Subsequently, the method of the review is detailed, followed by major results and implications for future research and practice in the area of EC.

II. EC Theory

The theory has a relatively short history in the academic research and it has only been studied empirically in the last decades. Since 1990, talking about embodiment has become increasingly frequent in philosophy [6], psychology [7], neuroscience [8], education [9], [10], linguistics and language learning [11]-[13], and in dynamical systems approaches to behavior and thought [14]. The beginnings of EC in the 1980s, conducted by philosophical work in phenomenology [15], theoretical approaches in biology [16], and advances in cognitive psychology [17] and cognitive linguistics [18], among others, emerged as the idea of the mind as embodied and situated.

EC has now been proved to be a significant part of contemporary theories of cognitive sciences. The fascinating insight of the *EC* theory is that behavior is not simply the output of someone's isolated brain [2], [19]. The embodied approach, as a learning theory, is based on the idea that cognitive mechanisms are deeply linked with the human's interactions with the environment [1]. Consequently, in this theory, the body plays a central role in shaping the mind. Along the same lines, on this perspective, the mind is not only connected to the body, but the body influences the mind; as Atkinson [20, p.599] stated, "we experience, understand, and act on the world through our bodies".

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Lakoff [11] explains the EC as cognition depending on the body with all its sensorimotor capacities and characteristics and its experiences in that way in which the body is inseparably connected to the mind. In doing so, humans' cognition is influenced by their experiences in the physical world. In the literature, there are many definitions regarding EC. Researchers try to connect the theory of EC with different disciplines and fields. The common idea about the theory of EC is that the body plays a significant role in shaping the mind. Wilson [1], trying to determine the general thesis of EC, gives the following definition: "Many features of cognition are embodied in that they are deeply dependent upon characteristics of the physical body of an agent, such that the agent's beyond the brain, body plays a significant causal role, or a physically constitutive role, in that agent's cognitive processing".

The most common theoretical aspect in literature, with the EC theory is "embodiment". As some researchers [4] state, theories of embodiment within cognitive science generally sit under the umbrella of EC. Embodiment theory, like EC theory, views the body inseparable from the mind and emphasizes the role of external environment in cognitive processes. Dreyfus [15], discussing about the work of Merleau-Ponty, points out three different meanings of embodiment. The first is the physical embodiment of a human subject; the second is the set of bodily skills and situational responses that we have developed; and the third is the cultural abilities and understandings that we responsively gain from the cultural world in which we are embedded.

During the last decades, the embodied view has accepted a lot of criticism from the theorists and cognitive researchers [21]-[23]. The close relation between body and mind has revolutionized in the field of cognitive sciences because this theory is coming to shake down the fundamental theories about the development of human cognition. The big difference from traditional view is that the EC gives attention to the dynamic interplay between bodily shapes and experiences with the whole brain system and their interaction in a real-life context and environment [7].

As Anderson [19] mentioned, a criticism is that EC cannot be true because the physically disabled are obviously able to learn, communicate and acquire concepts. The answer to this claim is that everyone is able to understand and comprehend things, which they have not experienced at all, through imagination, demonstration, and testimony. In that way, the physically disabled are in this regard no different from other people [19].

According to the theory of EC, the body and mind are dependent of each other. About this dualism, standard cognitive scientists claim that the brain is the only producer of cognition and completely ignore the role of the environment and the dependence of mind on the body [1]. Contrary to this statement of standard cognition principles, the EC theory argues that cognition can occurs as a continuous interaction between a mind, a body and a world.

III. EC as A Learning Paradigm

A. Embodied Learning

EL is coming into vogue during the last decade, seeking for the ways in which EC theory can help the educational field to benefit from it. For learning scientists, the meaning of EL is the understanding and retention which are affected by sensory input. While new digital content is constantly being designed, designers and learning scientists should take into account EL approach when designing mediated content [5].

In the EL environment, as Nguyen and Larson [24] noted: "Learners are simultaneously sensorimotor bodies, reflective minds, and social beings"; as well, according to researchers [24, p. 342], EL "provides a way through which alternative forms of teaching and learning can be integrated and accepted into the classroom".

B. Kinesthetic Learning

In the EC literature, some studies and papers refer to kinesthetic learning, except of EL. Kinesthetic is the learning environment in which the learner physically interacts with the learning experience. In the previous century, Montessori education used to promote learning through kinesthetic engagement [25]. The word "kinesthesia", proposed by Merleau-Ponty, is the movement sense and in that way the body is the perceiver and human's perception involves both sensory and motor processes [26].

Per scholars [27], kinesthetic learning offers new experiences in education, allowing more clear understanding of concepts, and gives the opportunity to the learner to take action in the learning procedure. The combination of different senses in order to gain new experiences and ideas of interaction and learning offered by the human body and senses, and kinesthetic perception and sensorimotor experiences, are tools to facilitate learning and teaching [28]. Furthermore, motion-based learning activities may facilitate kinesthetic practices for students who learn better when they are physically involved in learning [29]-[31].

C. Embodied Interaction

EC theory became prominent issue around the field of Human Computer Interaction (HCI) with the work of Dourish [32], who suggested the term "embodied interaction". Research in the HCI area aims to explore the role of the body in learning technologies in order to create appropriate design methodologies and strategies for developing interactive experiences in the service of EL.

Embodied theory has brought in the light essential considerations for how we can design for the interactions between people, objects, and spaces [33]. Dourish [32] coined the term "embodied interaction" in order to describe and understand the role of embodiment in HCI. As Dourish [32, p.3] points out, "Embodiment is the property of our engagement with the world that allows us to make it meaningful", and thus, "Embodied Interaction is the creation, manipulation, and changing of meaning through engaged interaction with artifacts".

Last, Dourish [32] states the need of creating new ways of

interacting with digital realty, ways that can better satisfy the people's needs and abilities. According to Garg [34], the application areas of embodied and HCI are: a) Educational and online systems, b) Cognitive design and robotics, c) Autonomous Agents and, d) Cognitive Interfaces.

IV. Methodology

The purpose of this review is to map the current research issues and directions in EC through a systematic literature review. Following the similar methodology described in previous systematic overviews [35], [36], this is characterized by initial selection, filtering and classification processes. The review includes studies published in scientific journals, proceedings of conferences and book chapters. The methodological procedure followed for this review (see Table I) consists of three phases:

In Phase 1 (first database search), the initial search was based on searching terms "embodied cognition" and "embodied learning", with the keywords: education, embodied interaction, embodiment, technology, full-body interaction, kinesthetic learning, multisensory, motion-based interaction, school, classroom. From this initial database research, the total number of papers was 147.

In Phase 2 (selection of papers), the selection was based on the following criteria: 1) Containing an EC theoretical orientation such as "embodiment-based learning", "embodied interaction", "kinesthetic approach", whole-body interaction", "gesture-based learning", "situated cognition" and other relevant theoretical approaches. 2) Containing technological tools and devices such as "gesture-based devices", "motion-based devices", "embodiment technologies", and other "multi-sensory tools". In this selection of the corpus of 147 papers, only 82 papers remained in the pool after applying the above two rules.

In Phase 3 (final selection of papers), the final selection was made by focusing on empirical work in learning contexts and environments. Only empirical research papers conducted across learning settings were included. During the final selection, other types of papers were excluded such as papers that provided "product reviews", "introductions to special issues", "theoretical/position papers", "reports", and "commentary sections". This resulted in a final list of 43 papers published between 2013 and 2017.

TABLE I
Methodological Procedure

		No of Manuscripts
Phase 1	Database search	147
Phase 2	Selection of related papers	82
Phase 3	Final Selection	43

V. Findings

The overview of EC literature shows that theory has many implications in different fields and contexts, specifically in context related to learning comprehension and process. The results of this systematic literature review have revealed some important themes/ topics which are discussing in the following sections. These themes are the research methods used in these studies, the learning subjects, tools and learning outcomes acquired, and the effective integration of body in learning context.

A. Research Methods

The design of the research and the methods that were used in reviewed studies are categorized and analyzed. The majority of papers used experimental research (24) and design-based research (15). The rest of the studies focused on case studies, qualitative research and location-based research. Research methods used for data collection were also analyzed. It should be noted that each type of research addresses different purposes. In almost all the studies, the main purpose was to examine the hypothesis that embodiment technologies may have an impact on learning process, and indeed all reviewed studies show a positive impact related to learning outcomes. In addition, the aim of some other studies was to explore relevant issues, to gain better understanding, and to promote design guidelines for developing learning conditions involving EC theory and related technologies.

Many different methods are utilized in order to accomplish the abovementioned goals and respond to those research questions. A combination of methods was utilized including usability tests, user studies, pre- and post-tests, questionnaires, and traditional qualitative strategies such as interviews, video and audio recording, and observations.

Depending on set research purposes, some researchers focus especially on user studies adopting related techniques like usability tests, and observations protocols in order to evaluate the interaction with the devices and technologies. Some others adopt particular approaches, such as grounded theory and action research.

B. Learning Subject/Content and Technological Tools

The majority of research papers were in the domain of math education (14 papers), followed by Higher Education topics (10 papers). This second category encompasses studies with different topics/ content applied all in university settings. Some of the topics include language learning, psychology, medicine, and communication. In science education (physics, chemistry) there were seven papers and in language learning and second language acquisition there were also five studies. Other subjects consist of different topics in school education. Three studies were conducted in Special Education on children with special needs, including physical disability, autism, blindness, and other impairments. The rest of the papers were from other fields such as environmental education, reading, manufacture, medicine, dancing, music, and behavior development. The papers which did not mention the specific content or field, were categorized in general education. Furthermore, the users and sample of these studies were categorized in two categories: 1) children (infants, K-12, high school), and 2) adults (over 18 years old). Most studies were conducted with children (30 studies) in the K-12 system. All the other studies utilized adults for their data collection.

The technology listed, as it appears in Fig. 1, includes the

devices used for the EL environment based on the reviewed papers. Most articles utilized Tangible User Interfaces (18 studies), including desktop computers, interactive tabletops, iPad, tablet, MoSO, gesture-based devices. The second popular technology is Microsoft Xbox Kinect, which was found to be the main device in 12 studies. Only one study in this category used the WBB (Wii Balance Board). There are five cases using some embodied artifacts or objects such as 3D pictures and objects, cameras, virtual reality objects, and Mathematics Imagery Trainer for Proportion (MIT-P). Three articles used biosensor technologies such as haptic glove interface, remote-sensing technologies and other related devices. Only two studies using embodied interaction video games like Second Life. The last category, as shown in Fig. 1, refers to studies using multiple devices (e.g. eye tracker, LEGO, and Embodied Mixed Reality Learning Environment-EMRLE).

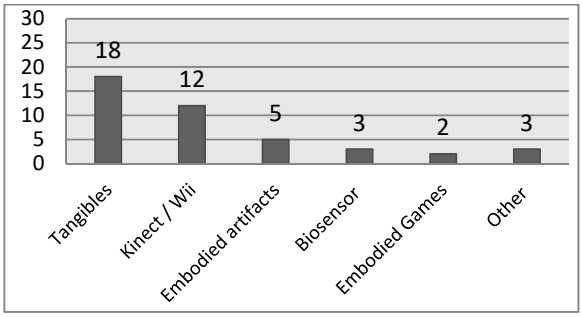

Fig. 1 Technologies for EC in Education

C. The Effective Integration of Body in Learning

Many empirical studies in the last two decades on learning and technology have shown that bodily movements and actions enhance learning in a positive way. One study [9] examined the learning effectiveness of a Kinect-based environment for college students' understanding of verbal information. The collected data indicated that the embodied approach facilitates students' cognitive learning outcomes and give opportunities for more active learning experiences. Along the same line, in other study [10], Kinect-based condition has positive effectiveness on encoding and later recall, providing better understanding of action phrases.

Moreover, applying EC theory in mathematics instruction has been prevalent in many studies in very recent years [37]-[41]. The general findings of these studies show that embodied approach and methods provide not only better understanding of mathematical concepts, graphs and formulas [27], [42], but also help students in mathematical achievement [38], [41]. Some other studies with empirical evidence indicate that the involvement of the body in doing math help students to solve easier mathematical problems by improving their self-confidence [43].

Additional studies have examined embodiment from different academic perspectives. An important perspective is the role of embodiment in information processing. In one study [44], researchers applied Microsoft Kinect to capture gestures like hand rising, waving, and pointing, to facilitate conversational language learning for 39 non-English speaking college students.

The findings have shown that gestures attract attention from learners and stimulate their thinking. In addition, other study [45] showed that the embodied approach can result in language comprehension indicating that word meaning is linked to sensorimotor experience.

Synthesizing the discussions and findings of articles, it is obvious that motor and bodily activities can facilitate both learning processing and comprehension. Bodily movements also help to attract attention, encode information, and facilitate the communication and interaction between learner, technology and environment. To conclude, all the studies point out the effectiveness of integrating body movement and technology in various educational settings.

VI. Discussion

In the short presence of EC in research, a good deal of studies in various fields has shown the potential of the theory in different environments and disciplines, and for different purposes. However, the focus differs between areas.

The EC field provides compelling evidence that cognition is affected from different systems and should clarify these cognitive areas as separate from one another [46]. As Antle, and Wise [47] point out, embodied theory is largely empirically unexplored, especially in a way to identify how the design of mappings between activities, objects and digital representations in conjunction with embodiment approach may enhance learning and understanding of abstract concepts. Further research is needed to reach the limitations of the relationship between the body and more abstract representations [48]. More theoretical approaches also need to explain clearly the idea that the body can influence cognition and, thus, body is necessary in cognitive work [49]. Kirsh [50] says, as well, that this area needs theory and strong empirical support of what human bodies are capable of doing for cognitive purposes.

An extraordinary number of empirical studies have investigated many claims regarding the role of embodiment in learning using various methods, from gesture studies to psycholinguistic experiments [51]. Particularly, in education it is essential, according to researchers [52], to examine how embodied technologies could be integrated into classrooms and which is the best way to design and prepare learning environments that take full advantage of such tools. It is also important for the future research to show how these new tools can influence learners' attention and collaboration, and whole-classroom orchestration [52].

It is worth investigating, as some researchers [13] believe, which are the factors that may facilitate students' learning performance and retention, like gender, prior knowledge, and collaboration activities, and what might be the effect of Kinect's integration into collaborative problem-solving activities. Similarly, one study [10] proposes the examination of the educational implication of Kinect usage in the classroom enhancing students' engaging in a more active, physical and emotional way during the lesson. In addition,

theoretical research is limited about these applications with respect to the cognitive learning strategies and little research is published on the Kinect's effectiveness in gesture-based learning [35].

Osgood-Campbell [25] states that future research should show evidence about the link between sensorimotor action and cognition in classroom activities and, specifically, should examine the improvement of specific academic skills such as language comprehension, mathematics, and scientific thinking. More so, future work should investigate the impact of sensory-motor abilities on language acquisition and comprehension [53]. Studies should focus on teaching and learning investigating how designers can build new understandings of embodied mathematical cognition in learning environments [54]. Additionally, future research should explore the value added of EL in game-based environments. Some directions are the exploration of how embodied devices can support learning, and how the EL apps can influence the relation between learner characteristics and game features [43]. Due to the lack of a comprehensive design based on EC, it is suggested by a study [55] that more investigation is needed to demonstrate how games can be integrated in learning content along with the embodiment-based methodologies. Empirical research is limited also in the field of embodied interactive games for healthcare and special education [56].

All things considered, taking into account evidence and theories arising from EC and interaction, developments in computing technologies, and evidence from research, the future for education is set to change. Research effort and evidence is needed, exploring effective ways for teachers to know how to use and adopt technologies, which provide the body engagement and movement in learning environment [57]. A future research path is the promotion of educational methodologies and design guidelines, which are important for better system design, development, and implementation [36]. Therefore, it is confirmed that EL is an exciting and interesting area of investigation [58], because of many existing challenges in various aspects and because of many unanswered questions in accordance with the design, teaching, learning, and environment in EL context.

VII. Conclusion

This study focused only on EC theory applied in learning environments and for learning purposes. Nevertheless, there are applications of the theory in other professional areas which are also notable, such as in medical care. In some fields the implementation of EC is really complicated and often designed for higher level learning and that is why it might not be widely common in educational systems.

The study also focused on educational and computing databases. Since EC is also used for learning in other professional fields, it would be interesting to see future studies investigating the implications of EC in other professional fields as well, such as medical training, physical therapy, sports and exercise science.

Another issue is that the cost of technological applications and tools around embodiment, which reduce the possibilities of using them in the classroom or in other educational settings.

In this section, 43 empirical studies published from 2013 to 2017 were analyzed and categorized according to the topic, technology used and research method. To date, the study provides the distribution and trends in research methods, learning content, the technology used, and the theoretical framework. Generally, the results of the analysis show that EC research is a growing field in education.

In summary, this study may support and expand the promising research in EC or embodiment-based learning or gesture-based learning or kinesthetic learning. A future pathway can be an empirical investigation on the implementation and effectiveness of embodied approach in authentic learning contexts [59].

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