A comprehensive approach to environmental and human factors into product/service design and development. A review from an ergoecological perspective

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ABSTRACT

This article presents the results of a documentary-exploratory review of design methods and concepts associated with human and environmental factors, based on a qualitative-quantitative analysis of co-incidences with the fundamentals of ergoecology and in line with sustainable dynamics, with a view to putting the principles of ergoecology into practice in product/service design and development. 61.6% of 696 documents found represent work on conceptual developments, while the remaining 38.4% refer to design methods. Searches were refined using Nvivo-10 software, and 101 documents were obtained about theoretical aspects while 17 focused on the application of methods, and these formed the analysis universe. The results show how little concern there is for working comprehensively on human and environmental aspects, and a trend toward segmentation of human and environmental aspects in the field of product/service design and development can be seen, at both concept and application/methodology levels. It was concluded from the above that comprehensive, simultaneous work is needed on human and environmental aspects, clarity and conceptual unity, in order to achieve sustainability in practical matters and ensure that ergoecology-compatible design methods are applied.

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1. Introduction

The need to expand the vision of Human Factors and Ergonomics (HFE) and include environmental aspects more directly has been pointed out by various authors since the 90s (Nickerson, 1992; Moray, 1995; García-Acosta, 1996; García-Acosta et al., 1997), but has gained interest during the last decade due to the proposals of Eco-Ergonomics (Brown, 2007); green ergonomics (Thatcher, 2013); HFE and Sustainability (Zink and Fischer, 2013; Zink 2013 iFirst); and Ergoecology (Garcia-Acosta et al., 2012; García-Acosta et al., 2012 iFirst). In addition to offering an overall alternative toward this end, ergoecology provides a validated, evolved method for applying its fundamentals in production processes (García-Acosta et al., 1999; Saravia, 2005; Barrero et al., 2006; Saravia and Rincón, 2006).

Continuing with this line of research, aiming to take ergoecology to be applied practically in product/service design and development with a symmetrical human-environmental perspective, a research project was proposed for examining progress made in terms of the state of the art on matters relating to ergoecology. Within the context of this research project, the present article presents the results of a systematic review between 1996 and 2013, about design concepts and methods associated with human and environmental factors.

Ergoecology seeks going beyond the hegemonic notion of 'sustainable development' (WCED, 1987) and to orientate itself towards true sustainable dynamics between systems; in other words, system co-existence or co-dependence.

Ergoecology is based around three principles: the anthropocentric approach, the systemic focus, and sustainability. Under sustainability, it proposes that two postulates be achieved: eco-

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productivity and *eco-efficiency*. *Eco-productivity* is to be construed as the ability of systems to transform energy, matter and information without generating waste or producing negative impacts on others systems. *Eco-efficiency*, meanwhile, can only be achieved when any type of negative impact can be generated between human-technological and terrestrial-natural systems (García-Acosta et al., 2012 iFirst). Finally, three axioms have been proposed: *energy*, *matter*, and *information*. These axioms can quantify interactions between built systems − which use resources − and natural systems − from which those resources come −, (García-Acosta et al., 2012). These concepts have also been addressed in other areas related to the economic sciences (Abukhader, 2008; Barbiroli et al., 2008; Dyllick and Hockerts, 2002; Kobayashi et al., 2005; Mauerhofer, 2008; Schaltegger et al., 2012; Villarroel Walker et al., 2009; Wang and Côté, 2011).

Previous design-related research aimed at human beings/users/customers (García-Acosta et al., 2011; Puentes et al., 2013) set out to embrace conceptual and methodological trends associated with product design and development, with relation to life cycle, human factors, and context-surroundings. Seven trends were identified, and it was established that while some of them have gradually established their own methods, certain methods are common to some of these seven trends. No proposals were found in the said reviews that were directly related to the fields of environmental management or ergonomic and quality studies.

Another systematic review used *sustainability*, *design*, and *ergonomics* as queries (Martin et al., 2013). Only 14 papers were obtained. This study didn't include other environmental aspects, such as ergoecological postulates i.e. eco-efficiency and eco-productivity. Therefore, proposals like ergoecology, take on importance as an innovative vision that can both evaluate processes and intervene in product and service improvement and innovation.

It should be stressed that all the aforementioned studies are based on documents that have been published and are accessible in databases. In other words, it is information and knowledge that has been made public. However, when products and services are being designed and developed, much of the knowledge that is developed, including methods and procedures, is classified information that companies treat as a jealously kept secret, as they consider it to be part of the technology that gives them competitive advantages. Any systematic study based on published sources (including this one) will therefore take into account only knowledge that is in the public domain, and which accordingly does not reflect the latest developments in product design and development.

2. Methodology

The research is of the documentary-exploratory type, investigating possible coincidences with the basic fundamentals of ergoecology (postulates, principles and axioms) that could support product/service design and development processes in line with sustainable dynamics. The methodological approach is divided into enquiring into concepts and methods, construction of search equations, and qualitative-quantitative analysis.

2.1. Enquiring into concepts and methods

Under this premise, an analysis matrix was constructed which established the notions of *design* and of *product/service development*, *human aspects* and *environmental aspects* as *macro-concepts*. These *macro-concepts* were cross-checked in this matrix against the three principles of ergoecology: *anthropocentric posture* (human aspects, in the first two columns), *sustainability* (environmental aspects, in the next two columns), and *systemic focus*, which was

assumed for all categories. The *macro-concepts* were grouped together as follows: (1) *design and product development*, (2) *environmental and sustainability*, and (3) *ergonomics*. The descriptors (key words) that were used for constructing the search equations and refining database findings were taken from this matrix (see Table 1).

In order to guide the search and guarantee its relevance, two groups of differentiated equations were produced. The first group concentrated on *conceptual developments* and was given the name Search 1 (henceforth S-1), while the second group looked at *design methods* and was called Search 2 (henceforth S-2). This grouping was designed allowing each group to be analysed independently and, at the same time, to be related to each other, in order to establish the extent to which they converged. Each step described below adheres to this division.

2.2. Construction of search equations

From a universe of 56 databases that were available across the three participating universities, 13 were chosen, based on robustness and coverage criteria. Finally, a categorisation of academic articles was made, and a selection process by relevant subject covering product/service design and development was performed, and from this, six databases were selected: Scopus, IEEE, Compendex, ScienceDirect, Proquest, and EbscoHost.

Three terms were used for constructing the S-1 equations. *Design* and *ergonomics* were the constants, while the following variables were used: (1) *sustainability*, (2) *eco-productivity*, (3) *eco-efficiency OR eco-effectiveness*, (4) *ecology*, and (5) *sustainable development*. The following terms were also used independently: (6) *eco-efficiency*, (7) *eco-productivity* and (8) *eco-effectiveness*, making a total of eight search equations (see Fig. 1a).

A single term was used as a constant when producing the S-2 equations: *design method*. Variable terms came into two categories. The first category of descriptors was obtained from trends deduced by García-Acosta, (2009) and García-Acosta et al. (2011), with six concepts associated with the human aspect and ergonomics being selected: (1) *user-centred design*, (2) *usability*, (3) *participative design*, (4) *universal design*, (5) *emotional design*, and (6) *cross-cultural design*. The second category of descriptors came from the eight concepts associated with the environmental aspect: (1) *sustainable design OR eco-design*, (2) *environmentally friendly design*, (3) *design for the environment*, (4) *restorative design OR design for recovery*, (5) *design for reuse*, (6) *clean production OR design for reducing emissions*, (7) *design for disassembly OR design for waste minimisation*, and (8) *vernacular design*. The result was 48 search equations (See Fig. 1b).

As a result of performing the two searches, almost 1900 documents were obtained. Refinement criteria were applied such as robustness, publication date, author name verification, etc., as well as the expression '*product design*' and relevance to product/service design and development, significantly reducing the database. Repeated documents were eliminated and access to each complete document was verified. The figure was thus reduced to 696 documents, with 429 corresponding to S-1 and 267 to S-2 (see Fig. 2a).

2.3. Qualitative-quantitative analysis

Two tools were employed for performing a deeper analysis. Firstly, NVivo-10 software was used to determine the number of references to the concepts in question in each text, and in the documents found as a whole. Secondly, a Delphi study of methodological developments in the documents was conducted, with a view to (a) deducing what international experts understood about different concepts relating to sustainability, (b) drawing up a