Impact of Learning Factories over sustainable production

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Abstract: In recent years the macrotrend of sustainability has experienced an impressive rise in the scientifical debate aided by the correspondent uprising of the green economy macrotrend. Following the directions given by the environmental dimension of the Triple Bottom Line approach, companies are manufacturing goods considering additional factors such as their End of Life, the energy consumption needed for their production and the overall environmental footprint. For this reason, research laboratories and academia are nowadays asked to provide the knowledge needed to assess this impact. The so-far obtained results and the current state of the art are described in this work, thanks to a systematic literature investigation and a bibliometric analysis

Keywords: Sustainability, Industry 4.0, Learning Factory

I. INTRODUCTION

After the advent of the so-called "Industry 4.0" (Kagermann, 2011), several companies had to face a radical transformation towards new models of production. This "revolution" aims indeed at addressing the digitalisation of manufacturing companies, through the renovation of the revamping of existing assets with new or modified ones able to produce clean and structured data, enabling the informative systems to get a deeper knowledge of the production status and an easier way to retrieve the desired information from the collected data [2]. The internal organisation of the same manufacturing SMEs is supposed to be remodelled too, in order to fit closer to the paradigms stated by pre-existing standards such as IEC 62264 [3], relying on turn on the previous Purdue Enterprise Reference Architecture [4].

Among the different studies which reported the benefits of the adoption of the "Industry 4.0" adoption on the holistic manufacturing sector [5], several works addressed also the specific technological areas this "revolution" impacted, such as material handling and internal logistics [6], maintenance and asset management [7], supply chain [8] and decision making [9].

These benefits have been realised mainly exploiting the potentialities of the so-called "Cyber-Physical Systems" [10], sensors, actuators and devices able to gather data signals from the field and to deliver them to the interested software components in a structured and reliable way.

This technology and the centrality of data in the modern production paradigm, introduced however a series of challenges for manufacturing companies, whose first is the training of workers and technicians [11], who are required to exploit the potential of "Industry 4.0" in their daily operations, when not to master the data production and consumption [12]

Several strategies have been formalised to mitigate this barrier [13], but one of the most considered is the new paradigm of Learning Factories [14]: an existing educational approach relying on physical facilities to train professionals for the future of manufacturing [15], but revisited in recent years to face the new challenges of the Industry 4.0-revised manufacturing [16], [17].

This approach is being successful in solving the problem it has been designed for [18], but the Industry4.0 theme is not the only one actively characterising the manufacturing landscape.

As noticed in particular, by Worthington and Patton (2005), a profound change in terms of business perspective has been experienced in several business: companies have indeed shifted from a profit-oriented vision (Friedman, 1970) to a framework influenced by sustainability sensitivity (Holliday et al., 2017).

The sociological reasons of this framework-shift have been widely studied in other disciplines, being referred to the so-called ""macro-trends" or "game-changers" [20], where the ecologic or environmental sustainability is usually targeted as the main actor, but which is actually "only the tip of the iceberg", and hiding a "societal transformation towards sustainability" [21].

Despite the pure sociological aspects, several works have been published about the sustainability in the last years, inflecting this topic into a business/company perspective, to understand the bigger picture. A well-known approach has been introduced by the Brundtland Report [22], which brought in the years after to the statement of the the so-called Triple Bottom Line [23], but other models and interpretations have been framed about the sustainability, as the so-called 3P (Profit, People, Planet)

and CSR (Corporate Social Responsibility) relationship that insists more on an ethical aspects [24]. However, Van Marrewijk (2003) clarified that no universal meaning can be provided to describe the sustainability topic.

However, despite the different framework to address the sustainability macrotrend, the topic is international recognised as a priority one for the industrial world, as the United Nations Sustainable Development Goals initiative witnesses [25].

Given the importance of the sustainability and the ongoing best practice of the Learning Factories, the authors want to investigate the possible relationships between Learning Factories and sustainability.

This work is hence structured like this: Section 2 describes the methodology developed to conduct the work, Section 3 collects the results and Section 4 contains the conclusions and some cues for future works.

II. Methodology

In order to investigate the topic, the work has been structured as a systematic literature review: as first, a search query has been formulated and inserted into the scientific database Scopus, as addressed as reference database for the engineering community [26].

A second step, consisting a bibliometric analysis, consists in a co-citation analysis [27], performed via software tools [28].

III. Results

A. Research protocol

The scientific database Scopus has been queried with the string:

TITLE-ABS-KEY ((teach* OR learn*) W/5 factor* AND sustainability) AND (LIMIT-TO (SUBJAREA, "SOCI") OR LIMIT-TO (SUBJAREA, "ENVI") OR LIMIT-TO (SUBJAREA, "ENER") OR LIMIT-TO (SUBJAREA, "ENGI") OR LIMIT-TO (SUBJAREA, "COMP") OR LIMIT-TO (SUBJAREA, "BUSI") OR LIMIT-TO (SUBJAREA, "AGRI") OR LIMIT-TO (SUBJAREA, "DECI") OR LIMIT-TO (SUBJAREA, "ECON") OR LIMIT-TO (SUBJAREA, "MATE") OR LIMIT-TO (SUBJAREA, "CENG") OR LIMIT-TO (SUBJAREA, "CHEM") OR LIMIT-TO (SUBJAREA, "MULT"))

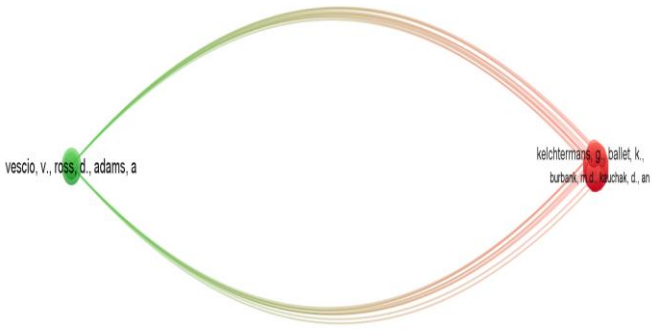

Fig. 1. Co-citation analysis

The reason behind the inclusion of the root "teach" relies in the often co-occurrences of the concepts of teaching and learning factories: despite being here a sub-category of the learning factories, teaching factories have been included given the missing agreement about the difference between teaching and learning factory in the scientific community [17].

Filters on subject area have been also applied to discard false flags mainly related to life sciences.

The query returned an outcome of 377 scientific papers, which have been downloaded in their bibliographic and reference data for the bibliometric analysis as a comma-separated-value file.

B. Bibliometric analysis

The so-obtained database has undergone a mapping by VOSviewer software [28]. The number of papers corresponding to each number of occurrences is displayed in Table 1.

TABLE 1
CO-CITATION ANALYSIS PRELIMINARY RESULTS

Threshold	Number of works
5	6
4	12
3	26
2	355
1	17594

The threshold has been set to 2, given the reasonable number of occurrences to visualise and the analysis has been purged from the isolated items and clusters. After a filtering phase of badly formatted or wrong entries, a total number of 174 papers has been hence selected.

The software has clustered those works in 4 sets, among which a first clusters of 81 and 43 papers were connected, as displayed in Fig. 1. The most populated cluster (red) is related to pedagogic topics and contains work devoted to the effectiveness of training in di diverse grades of school [29]. The second cluster (green) contains works related to the sustainability topics [30]. The two clusters non-reported in Fig. 1 contain works related to sustainability in citizenship [31] and psychology applied to teaching [32].

IV. Conclusions

The co-citation analysis highlights a dual nature of Learning Factories experience applied to sustainability: if on one side it is quite clear that these entities rely on evidence matured inside the social and human science, it's not evident, from the literature the inductive approach which should have brought the academic institutions to include the sustainability in the areas of learning.

If, indeed, is quite evident that Industry 4.0, coming from companies' needs, brought to a new conception of Learning Factories [33], it's not equally evident how companies' sustainability impacted into Learning Factories paradigm. In this way, a proper bibliographic coupling analysis [34] conducted on the same database, could highlight, with a statistical degree of confidence and from a research point of view, the impact that Learning Factories reached through the teaching of sustainable development practices.

In this sense, this type of analysis could constitute a future work, with respect to which this one could be considered as a placeholder.

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