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Research Article

THE CONTRIBUTION OF INDUSTRY 4.0 (4th INDUSTRIAL REVOLUTION) TO THE DIGITAL GAMES INDUSTRY

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ABSTRACT

The 4th Industrial Revolution, also known as Industry 4.0 (I.4.0), first emerged in industrial environments. Nowadays, it is increasingly present in all economic sectors, encompassing not only organizational environments, but also technological, economic and social systems. Thus, I.4.0 has strongly contributed to the digital games industry (DGI), which has grown significantly and has increased the participation in the economy. This article aims to identify the new I.4.0 technologies that are contributing to the DGI. The methodology used for the development of this article was an exploratory bibliographic research, in order to identify the main concepts of I.4.0 in the DGI. The study indicated that the principles, tools and techniques (PTTs) of I.4.0 have contributed strongly to the DGI, since the PTTs have a strong correlation with this segment, making it grow significantly. This growth allowed greater segmentation, new business opportunities with disruptive technologies[1] and strengthened its diversification with the emergence of new techniques, equipment and approach for the DGI.

INTRODUCTION

There is a silent revolution taking place no matter where, at work (factories or offices), in transportation or at home. Due to the internet, sensors and embedded systems, new opportunities are created and these enable new combinations of physical and mental work. The last phase of Pervasive Computing1, the long-range integration of Information Technology (IT) and Operational Technology (OT) have opened up a new universe of possibilities for new operations, which are also happening in the DGI. The integration of new technologies with the DGI is due to the fact that I.4.0 has been creating more and more PTTs, which established new opportunities for connections and possibilities of technological arrangement never imagined before. These connections exist in many forms and produce competitive advantages in numerous ways: decreasing operational costs, such as predictive maintenance, production controls, customer and supplier interaction, etc.; with more speed and intelligence, due to the communication and interaction between machine to machine (m2m), machine to human (m2h) and human to human (h2h) (BOLOEM *et al*., 2014).

The great cultural, social, political, economic and technological transformations that are happening today, demand new techniques (material and intellectual), practices, attitudes, thoughts and values from the cyber culture participants (LÉVY, 1999).

According to Oliveira (2016), the entertainment and media sector will grow more in Brazil than the rest of the world by 2020. This sector will grow by 6.4% per year in Brazil and it is expected to reach an annual turnover of US$ 48.7 billion in four years. In the same period, the sector will grow by 4.4% per year globally.

This article aims to identify new I.4.0 technologies that are contributing to the DGI. The text is structured in five parts: Introduction (section 1); Literature review, which discusses the main concepts and approach (section 2); Methodology (section 3); Data processing and analysis (section 4); Final considerations and work limitations (section 5).

[1] *Disruptive Technologies*: The term "disruptive technology" has been used as a synonym for "disruptive innovation", which nowadays has been considered more appropriate because the market disruption is not caused directly by technology, but by the way it is applied. These terms have been uses for decades (CALLAWAY and HAMILTON, 2006).
[2] *Pervasive Computing*: The main point is the creation of saturated computing environment with the ability to communicate and interact with users in an easy and agile way (SATYANARAYANAN, 2001).

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LITERATURE REVIEW

Industry 4.0

In the last three hundred years, society has gone through 3 industrial revolutions. Generally, these revolutions, despite having a strong impact on the production system, generated strong transformations and reached beyond the limits of companies, impacting also society and the economy. This transformation, that must be seen more broadly, indicates that the 4th Industrial Revolution is already happening.

The term "industrial revolution" refers to the alteration of the technological, economic and social systems in industry, especially in the working circumstances, living conditions and wealth distribution (DOMBROWSKI; WAGNER, 2014).

The first Industrial Revolution occurred in 1784, with the first mechanical loom and the introduction of hydraulic and steam energy. The second happened in 1870, with the first production line introduced at Cincinnati slaughterhouses, which was a mass production, using electric power. The third was in 1969, when was born the first Programmable Logical Controller (PLC) with the application of Electronic Systems and Information Technology together with Manufacturing Automation. The 4th Industrial Revolution is taking place today and it is based on the Cyber-Physical Systems (CPS) (KAGERMANN *et al*., 2012).

Figure 1 shows the 4 stages of Industrial Revolutions; it is important to emphasize that the obtained knowledge in each stage is cumulative. The current evolution received significant contribution from authors, entities and society.

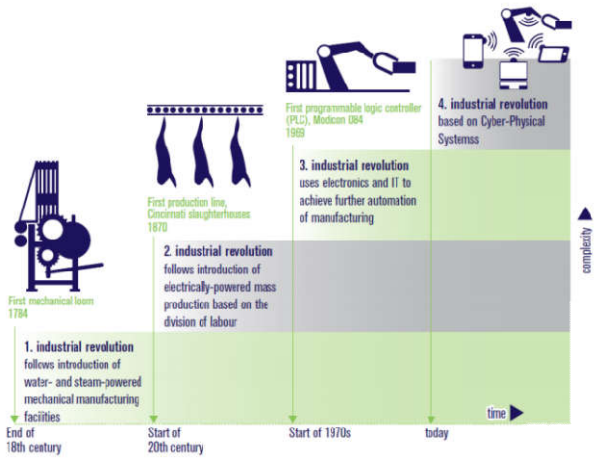

Figure 1: The Industrial Revolutions

Source: Adapted from Kagermann *et al*. (2012)

The 4th Industrial Revolution will create a world in which virtualization and the physical systems of global manufacturing will flexibly cooperate with each other (SCHWAB, 2016).

Shafiq *et al*. (2015), defines I.4.0 as the combination of intelligent machines, production, processes and system that create a sophisticated interconnected network. Furthermore, it emphasizes the idea of coherence, digitalization and linkage of all production units in an economy, creating real-world virtualization in a large information system. Industry 4.0 comes to be the integration of isolated concepts, such as: *Internet of Things* (IoT), *Internet of Services* (IoS), *Internet of Data* (IoD), *Cyber-Physical Production System* (CPPS), smart products, etc.

The development principles of I.4.0 presented by Hemann *et al* (2015) are: Interoperability – the ability of a system to communicate clearly with another system, similar or not; Virtualization - the ability of a system to monitor physical processes in a virtual way; Decentralization - the ability of a system to make its own decisions, through embedded computers talking to CPS system; Real-Time Work - the continuous operation tracking and analyzing, at the same time avoiding any kind of deviation; Service Orientation - the availability of a company service to other participants of the process, internally and externally, through IoS (Internet, Production Technology, Personalization, etc.); Modular System - flexibility in adapting to requirement changes, replacing or expanding individual modules, easily adapted in cases of seasonal fluctuations or changes in product characteristics, based on standardized software and hardware interfaces.

Principles, Tools and Techniques related to Industry 4.0

The principles related to I.4.0 were addressed by Hermann and Petek (2015), and are demonstrated below:

Table 1: Industry 4.0 principles

Principles	Definition
Interoperability	The ability of a system to communicate clearly with another system, similar or not;
Virtualization	The ability of a system to monitor physical processes in a virtual way;
Decentralization	The ability of a system to make its own decisions, through embedded computers talking to CPS system;
Real-Time Work	The continuous operation tracking and analyzing, at the same time avoiding any kind of deviation;
Service Orientation	The availability of a company service to other participants of the process, internally and externally, through IoS (Internet, Production Technology, Personalization, etc.);
Modular System	Flexibility in adapting to requirement changes, replacing or expanding individual modules, easily adapted in cases of seasonal fluctuations or changes in product characteristics, based on standardized software and hardware interfaces.

Source: Hermann *et al* (2015)

According to Holanda (2010), the tools are a set of instruments and utensils applied in an activity. For Basu (2009), a tool is a resource that has a clear and well defined function, being restricted to its function. The main tools related to I.4.0 have been highlighted and are shown in Table 2.

Table 2: Tools related to I.4.0

Tools	Definition
Tags RFI/NFC/BLUE	(*Radio Frequency Identification*): The tags used to identify and track objects of interest. In addition to the identification ability of a level/item, they enable local storage and retrieval of relevant characteristics associated with each item (ZHOU; PIRAMUTHU, 2011).
Augmented Reality	The enhancement of human perception through the use of virtual objects. With Augmented Reality (A.R.), the relevant information can be added directly to the worker's field of vision. This is possible with mobile devices, such as smartphones, tablets and smart glasses (GORECKY, 2014).
Virtual Reality	The interface technology capable of deceiving user's senses, through a virtual environment created by a computer system. The virtual reality allows full immersion in a simulated environment, with or without user interaction, by inducing visual, sound and even

	tactile effects (TECHTUDO, 2017a).
Big Data / Warehouse	A term used to describe the huge amount of data – structured and unstructured – that impact business on a daily basis. The most important is not the amount of data, but what the companies do with it. Big Data can give insights that lead to better decisions and strategic business directions (SAS, 2017).
Data Mining	The analytical process designed to exploit large amount of data (typically related to business, market or scientific research), searching for consistent patterns and/or systematic relationships among variables and then validating them by applying the detected patterns to new subsets of data. The process consists basically of 3 steps: exploration, model construction or standard definition and validation/verification (CARLOS, 2014).
Cloud Computing	The use of computing as a service rather than a product, through which shared resources, software, and information are provided, allowing access to any computer, tablet, or mobile phone connected to the internet (TECHTUDO, 2017b).
3D Printer/ Additive Manufacturing	A technology that uses 3D-CAD data to conduct a manufacturing process (printing) layer by layer (ANDERL, 2014).
AGV (Autonomous Guided Vehicle)	Mobile robot that follows markers or wires on the ground or uses vision, magnets or lasers for navigation. They are most often used in industrial applications to move materials around a factory or warehouse (WIKIPEDIA, 2017).

According to Holanda (2010), the techniques related to I.4.0 are a set of methods, practices and processes essential to the perfect execution of an art or profession; Basu (2009) highlight that the technique requires a greater intellectual process, more ability, knowledge, understanding and training in order to be effectively used. The main techniques are shown in Table 3.

Table 3: The main techniques related to I.4.0

Techniques	Definition
CPS Cyber Physical Systems	The fusion of physical and virtual systems (KAGERMANN *et al*., 2013), so that sensors provide indicators to actuators to modify the environment (physical and virtual) in which they operate (ZANNI, 2015), designing them to represent their behavior in time (ANDERL, 2014).
IoT Internet of Thinks	The communication of intelligent systems using IP (ANDERL, 2014). IoT is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers and have the ability to transfer data through a network without the necessity of human-human or human-computer interaction.
IoS Internet of Service	New paradigms of services, such as service-oriented architecture (ANDEL, 2014). IoS is a system that allows providers to offer their services through internet. It has participants, many providers connected with their users and consumers. It is connected through multiple channels, service infrastructure, business models and own value added services.
IoD Internet of Data	The large amount of mass data, generated by IoT and its management: how to transfer and store them properly and the technologies for analyzing these data (ANDERL, 2014).
Vertical Integration	The network integration of manufacturing systems (KAGERMANN *et al*., 2013).
Horizontal Integration	The integration through the value chain of a company (KAGERMANN *et al*., 2013).
Artificial Intelligence	The set of programming techniques and methodologies used to try to solve problems more efficiently than algorithms, making it as close as possible to the human brain.
Automation System	A system that makes use of computerized or mechanical techniques with the purpose of optimizing all the productive processes of the most diverse sectors of the economy. The idea of automation is directly linked to the idea of machines, which speed up tasks usually without human interference.
Robotics	An area of science and technology that involves computers, mechanisms and systems. It replaces motorized mechanical systems controlled manually or automatically by electrical circuits to systems composed of automatic mechanical parts controlled by integrated circuits.
Traceability	The place where a product is in the logistic chain. It is also very used in quality control. In practical terms, tracking is the way to know: "what" (product or good), "from where" came (origin) and "where" is going (destination) (WIKIPÉDIA, 2017).
Big Data Analytics	The process of examining big data to discover hidden patterns, unknown correlations and other useful information that can be used for better decision making. With big data analysis, data scientists and others can analyze large volumes of data that conventional analytics and business intelligence solutions cannot do (SAS, 2017).
Pallet Management System	A key component of any platform of supply chain management solutions within pallet industries. It shares many of the same elements of other systems, such as the use of bar codes or RFID, mobile devices for automatic identification, data collection (AIDC), location tracking and potentially functional elements such as receiving, depositing, picking etc. (RADIANT WAVE, 2003).
Preventive Maintenance	The operation performed based on the modification of condition or performance parameters, whose follow-up is systematic. Its objective is to prevent failures in equipment or systems by monitoring various parameters, allowing the continuous operation of the equipment for as long as possible (KARDEC, 2009).
Smart Factory	Factories that have intelligent production systems capable of managing the complexity of a production system in an autonomous way in which men and machines naturally interact (Kagerman *et al*., 2013). They have cyber-physical systems that communicate through the Internet of Things, helping people and machines to perform tasks optimally (HERMANN; PETENK, 2015).
Smart Products	An entity (physical object, software, or service) designed and made to self-organize, to incorporate different environments (intelligent) throughout its lifetime, providing greater simplicity and interaction and taking a proactive behavior with natural interfaces (MUHLHAUSER, 2008).
Smart Building	Any structure that uses automated processes to control the operations of a building, including heating, ventilation, air conditioning, lighting, security and other systems. A smart building uses sensors, actuators and microchips to collect and manage data according to a company's functions and services (TRACY, 2016).
Smart Grids	Electricity distribution and transmission systems that have been equipped with Information Technology (IT) resources and a high degree of automation in order to increase substantially their operational efficiency. Thanks to the high level of aggregate technology, Smart Grids are able to respond to various demands of modern society, both in terms of energy needs and sustainable development (CPFL, 2017).
Smart Mobility	One of the options for more sustainable transport systems. It could also be a set of coordinates aiming to improve the efficiency, effectiveness and environmental sustainability of cities (BENEVOLO, 2017).
Smart Logistics	The ability to develop all traditional logistics services using the new technologies, in order to save time and cost (ID LOGISTICS, 2013).

Contextualization of Digital Games

An electronic/digital game is a playful activity formed by actions and decisions for a particular purpose (SCHUYTEMA, 2008). In such environment, actions and decisions are delimited by a set of rules that are in a universe governed by a computer program. This universe contextualize the player's actions and decisions, which provides an appropriate environment to the narrative of the game; on the other hand, the rules define what can and cannot be done, as well as the consequences of the player's actions and decisions. In this environment, the rules provide challenges in order to hinder or prevent the player from achieving the established goals.

According to Battaiola (2000), electronic/digital games are composed of three bases: story, motor and interactive interface. The story defines the theme, the plot, the goals of the game, and the sequence in which events occur. The motor is the mechanism that controls the reaction of the environment to the player's actions and decisions, effecting the changes of state in that environment. Finally, the interactive interface allows communication between the player and the motor, providing an input path for the player's actions and an exit path for the audiovisual responses regarding changes in the state of the environment.

There is no consensus in the literature regarding the classification of digital games. Each author uses different criteria. For our study, we used Crawford's (1982) division, which suggests the division into two broad categories of digital games: action and strategy, as shown in Figure 2.

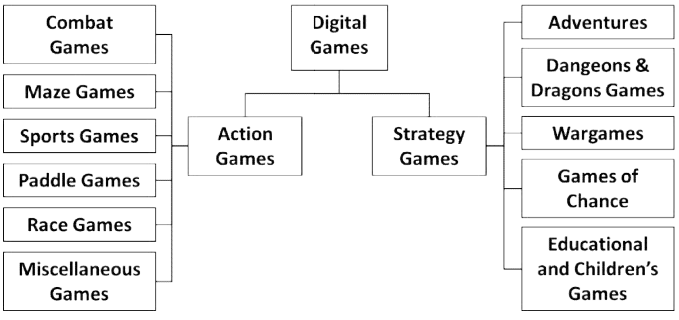

Figure 2: Digital Games Classification

Source: Adapted from Crawford (1982)

According to Crawford (1982), action games are those that challenge the player's motor skills most of the time, that is, the

player's ability to react to audiovisual stimuli. They are detailed in Table 4.

Table 4 Action games

Combat Games	Games characterized by direct and violent confrontation, in which the player must fight against enemy entities, controlled by the computer or other players, defending and attacking their opponents;
Maze Games	Games that have an environment composed of several paths, in which the player needs to eventually face enemy entities so that he can reach a specific place;
Sports Games	Games based on sports, such as soccer and basketball;
Paddle Games	Games where the player uses a paddle to hit one or more objects. In general, they refer to *Pong* style games, which are an electronic version of ping-pong game, and *Breakout*, in which the objective is to hit a ball so that hits colored blocks, destroying them;
Race Games	Games in which the fundamental element for victory is speed and the ability to manipulate entities through a path;
Miscellaneous Games	Games that have the characteristics of action games, but do not fall into the previous groups.

Source: Adapted from Crawford (1982)

According to Crawford (1982), strategic games emphasize the use of cognitive abilities and normally require more time and effort to be completed. They are detailed in Table 5.

Table 5 Strategic Games

Adventures	Games in which the player must move his/her character through complex worlds, accumulating tools and necessary items to resolve problems and overcome obstacles, in order to reach the final goal. Initially, these games were based on actions provided by textual descriptions. Later, graphic interfaces appeared;
Dungeons & Dragons Games	Games of cooperation and exploration in medieval environments. In general, it based on non-computerized Dungeons & Dragons game, created by Gary Gygax;
Wargames	Games in which the player makes use of strategies for his army to defeat the enemy. Board games are examples of war games; the army, in this case, is the pieces;
Games of Chance	Games based on traditional gambling games, such as poker, blackjack and slots games.
Educational and Children's Games	Games that the fundamental objective is to educate.

Source: Adapted from Crawford (1982)

Even though, this classification was proposed by Crawford (1982) in the early 80's, when digital games had big technological limitations, it is still very interesting. The classification divides the game function into necessary abilities, that is, psychomotor for action games and cognitive for strategic games. This classification is useful until the present (LUCCHESE; RIBEIRO, 2009).

Digital Games Industry

In its 17th edition, *Global Entertainment and Media Outlook 2016-2010* (OLIVEIRA, 2016), analyzed 13 media and entertainment segments from 54 countries. The study pointed to the strong growth of internet access, as shown in Figure 3.

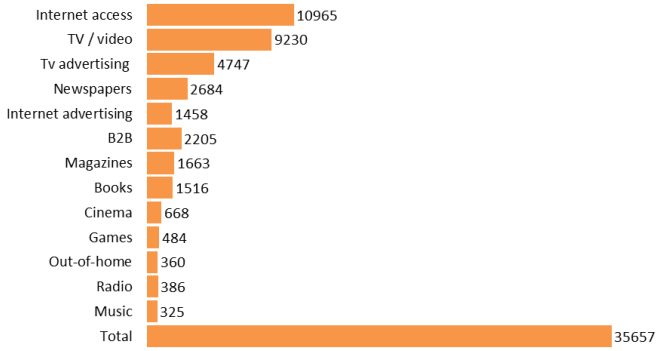

Figure 3: Average growth of media over the next 5 years

Source: Adapted from Oliveira (2016)

One of the most important DGI factors is the vocation to promote the technological innovation, in addition to the ability to create employment and income. These factors affect other different economic sectors, such as architecture, advertising, marketing, health, education, defense, training, etc. (FLEURIY *et al*., 2014).

According to Fleuriy *et al*. (2014), one of the reasons for the growing importance of the DGI is that this industry is not only consumed by young men, but also by children, women and the elderly. In addition, the use of Digital Games and the technologies that this sector develops have surpassed the entertainment sector, acquiring a "serious" character, being incorporated into education activities, scientific research, training (from corporations to the National Defense).

Asia is the biggest market in the global sales, followed by Europe and USA. In this scenario, Latin America has a modest market share of only 2%, according to Figure 3.

Studies conducted in England show that in the perception of analysts the Massively Multiplayer Online (MMO) games market by subscription, consoles and PCs (the older ones) are more mature and in equilibrium. On the other hand, online social games, free-to-play MMOs, are at the end of their consolidation curve, while mobile (including social mobiles and OT - Over the Top Content) are still at the beginning of this phase (DIGI-CAPITAL, 2014).

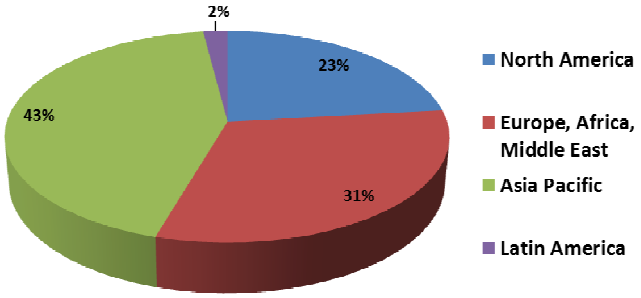

Figure 4 Regional participation in the global sale

Source: PwC (2014)

According to the above research, mobile and social games represent a market that has more opportunity for growth, as shown in Figure 5.

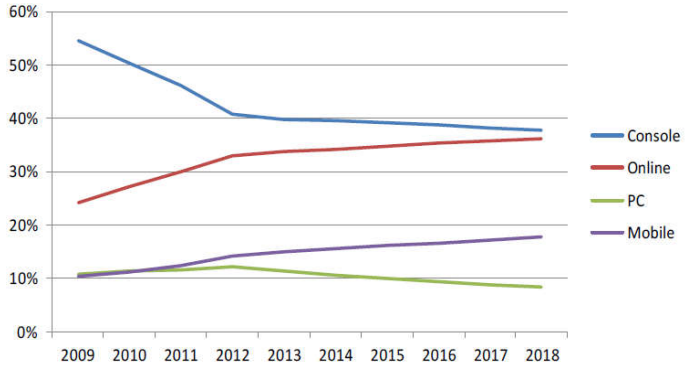

Figure 5 Participation evolution of the different platforms in the revenues

Source: PwC (2014)

According to Dantas (2016), The Brasilian Digital Games Industry (BDGI) is new and composed by just over a hundred companies with high economic potential. In 2007, this industry earned BRL 7.51 million with game development alone; of this total BRL 5.38 million came from exports, which represents 0.16% of global digital games revenues (ABRAGAMES, 2008). The BDGI is part of a broader international market. Comparatively, the International Digital Games Industry (DGI) is in a more mature stage compared to the national, which is mainly focused on the development of digital games for video game. In order to have a perception of the size of the DGI, only the Digital Games segment (DG) achieved a result of US$ 39 billion in 2009 (DATAMONITOR, 2010). In the United States in 2014 consumer spending on games for video games, PC and other platforms were evaluated at US$ 15 billion (ESA, 2014).
Another aspect that influences the Brazilian Digital Games market, highlighted by Fleury *et al*. (2014), was the growth of cell phones and, in particular, of the smartphones, devices that allow access to a great variety of games. In 2001, 31% of the households had cell phones, and 51% had a landline. This picture was reversed in 2004. In 2009, 78.5% of Brazilian households had cell phones, and 43.1%, landlines, according to the Brazilian Institute of Geography and Statistics - National Survey by Household Sample (IBGE - PNAD, 2009). This means that the cell phone has become the preference in homes that have only one phone. Another more recent change is the growth in the share of smartphones in the domestic market. While in the first six months of 2012, 6.8 million smartphones and 20.5 million feature phones were sold (according to IDC data - www.idc.com), in the third quarter of 2013, 10.4 million smartphones and 7.5 million feature phones were sold, that is, the sale of smartphones far exceeded that of feature phones, confirming the trend verified in the second quarter. On the demand side, these data show the strength of the domestic market and its growth prospects.

Table 6 shows the first sense of digital games made in 2014 by GEDIGames (2014) in 133 companies in different states of Brazil.

Table 6 Location of Brazilian developers

State	Companies	%
São Paulo – SP	54	36.24%
Rio Grande do Sul – RS	16	10.74%
Rio de Janeiro – RJ	12	8.05%
Santa Catarina – SC	11	7.38%
Pernambuco – PE	10	6.71%
Paraná – PR	8	5.37%
Distrito Federal – DF	7	4.70%
Minas Gerais – MG	6	4.03%
Paraíba – PB	6	4.03%
Bahia – BA	5	3.36%
Espírito Santo – ES	5	3.36%
Ceará – CE	4	2.68%
Amazonas – AM	1	0.67%
Goiás – GO	1	0.67%
Pará – PA	1	0.67%
Piauí – PI	1	0.67%

Source GEDIGames (2014)

In 2013, 133 companies produced 1.417 game titles. Table 7 shows them distributed by genre.

Table 7 Games developed in 2013.

Type of game	Number	Total
Entertainment	**698**	**49.3%**
Advergames	189	13.3%
Entertainment games for third parties (services for international clients)	188	13.3%
Entertainment games for third parties (services for national clients)	84	5.9%
Own Entertainment games	237	16.7%
Serious Games	**678**	**47.8%**
Training and Corporation games	52	3.7%
Educational games	621	43.8%
Health games	5	0.4%
Simulators with specific hardware	**23**	**1.6%**
Other Types of digital games	**18**	**1.3%**
Total	**1417**	**100%**

Source: GEDI Games (2014).

The most produced games are educational games (43.8%), entertainment (16.7%) and advergames (13.3%), as well as entertainment games for national and international clients (13.3% and 5.9%).

According to GEDI Games (2014), some companies can be highlighted within their respective sectors. For example, in the educational area, only one company produced 117 educational games; in the entertainment area, one company produced 58 games.

METHODOLOGY

In this work, it was conducted an exploratory bibliographical research concerning the innovation and the technologies that I.4.0 has provided to the DGI, in order to create greater familiarity with the problem and make it explicit. To conduct this work, it was observed the economic relevance of the DGI market and, in this sector, the implementation of new technologies by the advance of I.4.0 - which is being increasingly able to offer added value to the products.

As mentioned earlier, this is an exploratory bibliographic research. Exploratory, because explores a little-known subject, trying to describe it. Bibliographic, because the search will be done in articles available on databases.

The bibliographic research included the survey of references about the phenomenon studied on databases, including national and foreign periodicals. Due to the novelty of the subject, the research has been restricted to the last 6 years.

RESULTS

The exploratory bibliographic research aims to identify how much the PTTs of I.4.0 interact and collaborate with the DGI. The table 8 shows the degree of interaction between the PTTs of I.4.0 and the DGI.

Table 8 Interaction between the PTTs of I.4.0 and the DGI

	GAMES	Action games						Strategic games				
	Industry 4.0	Combat	Maze	Sports	Paddle	Race	Miscellaneous	Adventures	D&D	Wargames	G. of Chance	Educational
Principles	Interoperability	●	●	●	●	●	●	●	●	●	●	●
	Virtualization	●	●	●	●	●	●	●	●	●	●	●
	Decentralization	●	●	●	●	●	●	●	●	●	●	●
	Real-Time Work	●	●	●	●	●	●	●	●	●	●	●
	Service Orientation	●	●	●	●	●	●	●	●	●	●	●
	Modular System	●	●	●	●	●	●	●	●	●	●	●
Tools	RFI/NFC/BLUE	-	-	-	-	-	-	-	-	-	-	-
	Augmented Reality	-	-	-	●	-	⁎	⁎	⁎	●	-	+
	Virtual Reality	●	●	●	●	●	●	●	●	●	●	●
	Big Data	+	+	+	+	+	+	+	+	+	⁎	⁎
	Data Mining	-	-	-	-	-	-	-	-	-	-	-
	Cloud Computing	●	●	●	●	●	●	●	●	●	●	●
	3D Printer	-	-	-	-	-	-	-	-	-	-	-
	AGV	-	-	-	-	-	-	-	-	-	-	-
Techniques	CPS	⁎	⁎	⁎	⁎	⁎	⁎	⁎	⁎	⁎	⁎	⁎
	IoT	●	●	●	●	●	●	●	●	●	●	●
	IoS	●	●	●	●	●	●	●	●	●	●	●
	IoD	⁎	⁎	⁎	⁎	⁎	⁎	⁎	⁎	⁎	⁎	⁎
	Vertical Integration	-	-	-	-	-	-	-	-	-	-	-
	Horizontal Integration	-	-	-	-	-	-	-	-	-	-	-
	Artificial Intelligence	-	-	-	-	-	-	-	+	+	⁎	⁎
	Automation System	-	-	-	-	-	-	-	-	-	-	-
	Robotics	-	-	-	-	-	-	-	-	-	-	-
	Traceability	-	-	-	-	-	-	-	-	-	-	-
	Pallet Manag. System	-	-	-	-	-	-	-	-	-	-	-
	Preventive Maintenance	-	-	-	-	-	-	-	-	-	-	-
	Smart Factory	-	-	-	-	-	-	-	-	-	-	-
	Smart Products	●	●	●	●	●	●	●	●	●	●	●
	Smart Building	-	-	-	-	-	-	-	-	-	-	-
	Smart Grids	⁎	⁎	⁎	⁎	⁎	⁎	⁎	⁎	⁎	⁎	⁎
	Smart Mobility	-	-	-	-	-	-	-	-	-	-	-
	Smart Logistics	-	-	-	-	-	-	-	-	-	-	-

Note: Correlation: ● Strong; ⁎ Medium; + Weak; - Do not exist.

Regarding Table 8, it is important to make some considerations: it was built with the existing knowledge, which means that, with the evolution of technology, nothing prevents the PTTs from interacting more with the DGI. In this way, due to the dynamics of the technological advance, as well as the development of the DGI programs, this interaction will certainly change.

Research analysis

Analyzing Table 8, it can be observed that all the I.4.0 principles (Interoperability, Virtualization, Decentralization, Real-time Work, Service Orientation and Modular System), the tools (Virtual Reality and Cloud Computing) and some of the techniques (IoT, IoS and Smart Products) have a strong correlation with the DGI, because some of them are the basis, the "platform" of execution, or rather, the environment where the games are developed.

The tool, Augmented Reality, and the techniques, CPS, IoD, Smart Grids, have a medium correlation with the DGI.

We can highlight that the I.4.0 principles have a strong correlation with the DGI; practically most of the tools, 4 out of 8 (50%), have a strong and weak correlation with DGI; and few techniques, 7 out of 18 (39%) have any correlation with the DGI. Practically only 16 (out of 32) I.4.0 PTTs have a clear correlation with the DGI, due to the fact that the PTTs were developed for industrial application. But this relationship tends to increase with the dynamics, technological evolution and related knowledge.

The DGI analysis was based on Crawford (1982). For the PTTs analysis were used several authors, but mainly Hermann *et al* (2015), especially in relation to the principles.

With the technological advances, new habits are emerging not only from children, but also from adolescents and adults. These habits are bringing people closer to teaching and learning world. When we look at the DGI we cannot forget that education and training are part of this industry. Their products are often referred as "Serious Games", which are becoming increasingly essential as educational material. Those games use contexts and develop processes that are rethought both in terms of their roles and their concept, content and interactive possibilities. In this universe, it is not possible to imagine the limit, not only of its application, but also for the benefit it will bring to society.

Final considerations

This article presented an exploratory bibliographical study of the existing literature on the interaction between the PTTs of I.4.0 and the DGI, and a comparative analysis of this interaction. It was observed that all principles have adherence to the DGI, showing that the DGI are an important part of the digital revolution and I.4.0.

Through the existing technological resources, digital games are bringing users to a fictional world very close to the real, due to virtual reality. This shows the technology evolution with the active and interactive participation of users, the features of digital games and their environments. New technologies allow the fantasy world to become ever closer to reality. In this way, serious games, collaborate with training and learning, and enable the development of practices and techniques in the areas of medicine, engineering or aviation, etc., in a much faster and much less onerous way.

During the analysis and development of this work, it was possible to understand the impact and the transformation that I.4.0 is causing in the DGI, and also in the educational environment. Nowadays, digital games are creating possibilities to explore knowledge and learning in a more active way.

Finally, as a result, this study proposes new researches about the collaboration of the PTTs to the area of teaching and learning, whether academic or corporate. In addition, wonder how these new technologies can become strong allies in the relations of teachers and students to formal education through the improvement of educational environments.

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