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# Exploring gamification to support manufacturing education on industry 4.0 as an enabler for innovation and sustainability

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## Abstract

The issue of sustainability in productive processes has become one of the main challenges industries faces in the contemporary era. New industrial paradigms such as the Industry 4.0 point towards the creation of more sustainable processes. The transition process from traditional manufacturing to the Industry 4.0-ready manufacturers, however, presents a range of barriers which organizations must overcome. In this context, we look to the concept of gamification and the opportunities provided by this approach to help tackle such obstacles. In this paper, we expand the discussion on how gamification can be articulated to the Industry 4.0 transition context, aiming to develop a conceptual framework for gamification implementation tackling sustainability awareness issues. We argue that these gamification mechanics can contribute to support manufacturing education on Industry 4.0, enabling innovation and sustainability. Based on a systematic analysis of relevant literature, we verify that the sustainable manufacturing and Industry 4.0 topics were the least reported on having employed gamified applications. The proposed framework articulates gamification elements and sustainability requirements in the Industry 4.0 transition. This contribution may help companies on developing gamified applications to overcome some of the challenges they face regarding the sustainability aspect in the transition towards Industry 4.0.

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## 1. Introduction

Disruptive technological and industrial developments increasingly point toward a new industrial revolution referred as the “Industry 4.0” paradigm. The issue of resource efficiency and consumption in the context of Industry 4.0 is discussed by [1–4] appearing as an inextricable feature of this new paradigm thus being important to consider its relationship with sustainable manufacturing practices. Sustainable development has been increasingly central to world’s economies policies due to the several challenges related to limited resources, rapidly growing population, industrialization and globalization faced by humankind. In this context, the role manufacturing companies play in the depletion of natural resources and the environmental impact of their products and services has come under closer scrutiny. The concept of “sustainable manufacturing” defined by [5] aims to create manufactured products that fulfill their designed function throughout their lifecycle causing manageable amount of impacts in society and nature while delivering the proposed socio-economic value. Several studies focus on sustainable manufacturing practices and frameworks [6–10] highlighting their challenges and opportunities.

Nonetheless, challenges arise for the education of both sustainability & sustainable manufacturing practices [11–13] and Industry 4.0 concept and requirements [1,14]. Novel approaches for education and learning such as game-based learning [15] and gamification [16–18] can be of assistance in this context. This paper focusses specifically on how gamification mechanics can be articulated to the sustainability in manufacturing education. In this first section, we provided a brief overview of the background of this contribution (1), the following section will provide a more robust theoretical basis on the topics approached (2), followed by a methods section where we detail the literature review process (3) which we subsequently synthesize (4), finishing up with concluding remarks (5).

## 2. Theoretical Background

### 2.1. Industry 4.0

Industry 4.0 has recently become a well-discussed term among researchers and companies alike. The idea of a fourth industrial revolution driven by smart technologies was put forward mostly by Germany and its highly developed industry made the concept achieve a relatively undisputed acceptance [1,3,19]. However, there is still no consensual, widespread definition that may characterize the concept of Industry 4.0 and its various facets, which include issues of resource efficiency and new paradigms for factories, businesses, product development and customer management [1,3]. The Industry 4.0 concept usually comprises a range of concepts and technologies related to value chain organization. A core concept to the industry 4.0 are the Cyber Physical Systems (CPS), which enable the monitoring of physical processes in the factory in a virtual environment, through the digitization and creation of a digital clone of the factory adding value to the computing, communication, control and coordination processes [1,2,19]. Internet of Things (IoT) fosters the communication in a uninterrupted fashion, among not only humans, but also machines [20]. The equipping of manufacturing with sensors, actors and autonomous systems to the point of achieving real time, self-organization, is central to the smart factories and to industry 4.0 [1,2].

One of the cornerstones of industry 4.0 is sustainability and resource efficiency [1,5,20], focusing mainly on the environmental aspect of sustainable development. Research by [19] states the need for the production facilities, processes and the product itself to be less aggressive towards the environment and [2] points out energy management systems can be used in the context of the transition towards industry 4.0. Due to its intrinsic consideration for resource efficiency industry 4.0 can be seen as an enabler of sustainable manufacturing since the articulation of these concepts put forward a strategy to produce better consuming less [1,2,5,19]. These concepts significantly change the current manufacturing landscape and to achieve them is necessary to establish learning and education programs accordingly [19,20].

### 2.2. Sustainable Manufacturing

The sustainable development concept emerged in the 1980’s amid growing concern on Earth’s resources depletion and environmental issues such as global warming, deforestation and desertification [21]. The Brundtland Report [21] presented sustainable development as ensuring humanity present needs are met without compromising

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