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The modern pillars of Circular Economy

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ABSTRACT

Relationship between industry and environment is crucial for industrial business performance. Environmental impacts have incrementally increased pressure on industrial businesses. Looking back to the beginning of the industrial revolution, mass production of goods was enabled by new manufacturing methods resulting in products with high availability and low costs. Consequently, due to new consumer societies and staggering growth in industrial activity, emissions to environment, solid waste generation and landfill have become increasingly severe. In addition, due to a growing world population and especially strong middle-class growth the demand for resources is expected to rise rapidly indicating a rising consumption of natural resources. This paper shows the modern concepts of the circular economy and industrial ecology, emphasiyng the benefits of industrial symbiosis.

Keywords: circular economy - industrial ecology -industrial symbiosis and metabolism

INTRODUCTION

. Since planet earth's resources are limited the requirements of exponential economic and population growth cannot be met [1].

Over the last decade growing attention has been paid worldwide to the new concept and development model of Circular Economy, CE, with the aim to provide a better alternative to the dominant economic development model, so called “take, make and dispose” [2-3]. The concept of circularity, especially in terms of closed material loops, is not a concept of novelty originating from recent developments but has been emerging now and then throughout the history.

The concept of a circular economy – currently widely promoted in Asia – has its conceptual roots in industrial ecology, which envisions a form of material symbiosis between otherwise very different companies and production processes. Industrial ecology emphasizes the benefits of recycling residual waste materials and by-products through, for example, the development of complex interlinkages, such as those in the renowned industrial symbiosis projects [4]. However, in more general terms, it promotes resource minimization and the adoption of cleaner technologies [5-6].

Every firm operating in the field of the circular economy should adopt an industrial approach based on resource efficiency and the use and supply of sustainable raw materials, which can be achieved through innovative technologies, innovative methodologies and new business models [7]. This first chapter introduce and explain the main theme which is at the base of the process of extraction and reuse of metals from ashes: the circular economy, whose main concept is to use waste for a certain production cycle as an input for a different production cycle. The reuse and recycling of materials are two of the key features that characterize the concept of the circular economy. The chapter is divided into six paragraphs, the first one introducing better the concept, explaining his importance and newness; in the second one it is better analysed the definition of circular economy thanks to international biography and then all the historical

steps which lead to the actual concept of circular are recalled. Another fundamental term, which is firmly connected with circular economy, and which is widely defined in the fourth chapter, is the one of circular raw material, which is considered to be an input for another production cycle, source of direct or indirect profit. The fifth paragraph is about advantages, which can be either economic, environmental or social, of the concrete application of circular economy's principles. Finally, the sixth paragraph focuses on the future, hypothesizing abut next evolution of the concept of circular economy, with the hope of an extension of all the innovative techniques to other firms of the environmental management sector.

IMPORTANCE AND ACTUALITY OF CIRCULAR ECONOMY

The literature on industrial ecology (IE) is concerned at the macro level with bringing the industrial economy and the environment, or the economy and its natural limits, into some form of harmony; at the micro level it is concerned with the identification and analysis of a wide variety of "eco-industrial initiatives" that reduce the energy and resource intensity of industrial activities, largely through converting wastes from one process into inputs to another industrial process [8-9].

There have long been calls from industry for guidance in implementing strategies for sustainable development [10]. The Circular Economy represents the most recent attempt to conceptualize the integration of economic activity and environmental wellbeing in a sustainable way [11]. The concept of a circular has its conceptual roots in industrial ecology, which envisions a form of material symbiosis between otherwise very different companies and production processes. Industrial ecology emphasises the benefits of recycling residual waste materials and by-products through, for example, the development of complex interlinkages, such as those in the renowned industrial symbiosis projects [12]. In the last few years Circular Economy (CE) is receiving increasing attention worldwide as a way to overcome the current production and consumption model based on continuous growth and increasing resource throughput. By promoting the adoption of closing-the-loop production patterns within an economic system CE aims to increase the efficiency of resource use, with special focus on urban and industrial waste, to achieve a better balance and harmony between economy, environment and society [13]. It is widely acknowledged that economic miracles have been achieved at the expense of its natural capital and environment. In order to deal with this problem, the circular economy (CE) has been chosen as a national policy for sustainable development. National laws and regulations have been enacted to facilitate the implementation of CE and national CE demonstration projects have been initiated such that national benchmarking activities could be completed. It incorporates myriad strategies to achieve greater efficiency through economies of systems integration. Partnerships amongst businesses to meet common service, transportation and infrastructure needs are encouraged. The policy potentially adds value to businesses and communities by optimizing the use of energy, materials and community resources [14]. Since planet earth's resources are limited the requirements of exponential economic and population growth cannot be met. In this scenario, it is not only the challenge of environmental pollution that is becoming acute but the challenge of global resource scarcity as well. These circumstances confront manufacturing industry to simultaneously cope with the pressure of environmental regulations, challenges of resource price volatility and risks in resource supply, in addition to their daily business. As individual competitiveness is thereby influenced fundamentally, manufacturing companies find themselves in a progressively uncertain position when it comes to resource supplies.

Increased competition for access to scarce or critical resources has become another major concern for manufacturing industry, in addition to fulfilling obligations on environmental legislation at minimum cost [15]. In order to implement the CE, the 3R principles (Reduction,

Reuse, and Recycle) have been embedded in production and consumption since the flow of materials and energy penetrates in both areas. Reduction refers to minimize the input of primary energy and raw materials through the improvement of production efficiency. As for consumers, a more frugal way of consumption has been encouraged. Reuse suggests using the by-products and wastes from one firm as resources for other firms or industries. It also refers to use products to its maximum capability with frequent maintenance and reclamation to prolong its endurance. Recycle encourages processing the recyclable materials into new products so that the consumption of virgin materials can be reduced. These principles, as parts of the whole process, have different hierarchical importance, with the reduction of resources used as the leading principle within a circular economy system [16]. Governmental organizations as well as business representatives report an increasing pressure on our global resources and the climate due to human activity. The circular economy is viewed as a promising approach to help reduce our global sustainability pressures. The Ellen MacArthur Foundation has helped popularize the move to a circular economy with businesses [17]. Europe and China have adopted Circular Economy principles as part of their future strategies. For example, the European Commission associates the move to a more circular economy with strategies such as: boosting recycling and preventing loss of valuable materials; creating jobs and economic growth; showing how new business models, eco-design and industrial symbiosis can move Europe toward zero-waste; and reducing greenhouse emissions and environmental impacts [15]. Organizations such as the Ellen MacArthur Foundation, working in partnership with the consultants McKinsey, have also championed the potential of the circular economy for EU economies, through a series of reports [18-19] and through the medium of the Circular Economy Platform, a knowledge exchange network which seeks to bring together leading companies, innovators and regions. In academia the concept of the circular economy has gained purchase in a number of fields including sustainability science, environmental studies and a wide swathe of development studies shaped by low-carbon imperatives. It is not hard to see its appeal. The concept appears to decouple economic growth from increasing resource use as well as promoting waste reduction or minimization.

Hence, its use in both practitioner and academic literatures tends to be approbatory, uncritical, descriptive and deeply normative. Given its prominence, it is important that the circular economy be subjected to critique [20].

DEFINITION OF CIRCULAR ECONOMY

The Circular Economy as a concept has its antecedents in broader historical, economic, and ecological fields. Examination of these supports understanding of the subsequent application of the concept in practice. The circular flow of blood around the body was viewed as a useful metaphor for the flow of money through an economy. Of course, in terms of etymology, the word economy (οἰκονομία —household management), comes from the same ancient Greek origin as ecology (οἶκος, house -λογία, study of) meaning study of the household. This makes it all the more fitting that these concepts should come together. Indeed, the Circular Economy has, as its main concern, the management of the economy in such a way as to leave the house undamaged [11].

The term circular economy has both a linguistic and a descriptive meaning [21-22]. Linguistically it is an antonym of a linear economy, defined as converting natural resources into waste, via production. Such production of waste leads to the deterioration of the environment in two ways: by the removal of natural capital from the environment (through mining/unsustainable harvesting) and by the reduction of the value of natural capital caused by pollution from waste. Pollution can also occur at the resource acquisition stage. The term linear economy was brought into popular use by those writing on the Circular Economy and

related concepts. Thus, in many ways, the origin has been deliberately set, in framing the antonym, to promote the term circular economy. By circular, an economy is envisaged as having no net effect on the environment; rather it restores any damage done in resource acquisition, while ensuring little waste is generated throughout the production process and in the life history of the product. The circular economy from the environmental economics perspective is based on a material balance principle [23-24], which implies that all material flows need to be accounted for, although it will be the economic values, not the physical flows, that guide their management.

HISTORICAL EVOLUTION: FROM CIRCULAR ECONOMY TO INDUSTRIAL METABOLISM

As a concept, the circular economy has a longer history. This is located in the allied but distinct fields of ecological and environmental economics. The origin of the term 'Circular Economy' itself is debated and the idea behind a circular economy has existed for a long time. As early as 1848, Hofman, the first President of the Royal Society of Chemistry, stated "…in an ideal chemical factory there is, strictly speaking, no waste but only products. The better a real factory makes use of its waste, the closer it gets to its ideal, the bigger is the profit" [25]. Greyson [26] claims that Kenneth Boulding [27] was the originator of the term when he wrote: "Man must find his place in a cyclical ecological system which is capable of continuous reproduction of material form even though it cannot escape having inputs of energy". The first use of a circular economy concept was in China and occurred in an unreferenced 1998 paper by Zhou [28-29- 30], inspired by German and Swedish loop-closing, and arising from the Industrial Ecology paradigm which models industrial processes using the flow of material and energy through them [31-32]. The inclusion of Sweden is interesting here, as most literature attributes the inspirations as stemming from Germany and Japan [33]. Pearce and Turner (1990) claim that the term 'circular economy' was first used in western literature in the 1980s, to describe a closed system of economy-environment interactions [34]. It was Stahel and Reday-Mulvey [35] who first referred to a closed-loop economy: "I suspect that we have underestimated, even in our spendthrift society, the gains of increased durability" [36].

In the nineteenth century, industrialists had already developed the idea of industrial metabolism, wherein industry operates not as a set of independent inputs and outputs, but as a unified larger 'organism', and waste-is-food [37], both of which would inform Circular Economy thinking. By 1930, industrial symbiosis had appeared in the literature [38-39]. The largest recent sustainable economics movement, Industrial Ecology, IE, brought together these ideas and gathered considerable interest. It emerged in opposition to the current conception that environmental impacts of industrial systems should be studied by keeping separate the source "industrial system" and the receptor of the impacts, "the environment". Industrial Ecology introduced a different perspective by analysing the industrial system and its environment as a joint ecosystem characterized by flows of material, energy and information as well as by provision of resources and services from the Biosphere [40].

Experience suggests that material flow management (MFM) and related analysis tools such as material flow analysis (MFA) and life-cycle assessment (LCA) are good methods. In the 20th century, the MFA concept emerged in various fields of study at different times. It provides a method attractive as a decision-support tool in resource management and waste and environmental management. MFA is defined as the systematic assessment of the flows and stocks of materials within a system defined in space and time; it connects the sources, the pathways, and the intermediate and final sinks of a material, and the results of an MFA can be controlled by a simple material balance comparing all inputs, stocks, and outputs of a process [41-42].

The Circular Economy has been framed in an almost identical way as Industrial Ecology, with three levels of initiatives: At the micro or individual firm level, companies are either required or encouraged to conduct cleaner production , CP, auditing. For heavily polluting enterprises, CP is obligatory and single enterprise, involving a firm-level study of cleaner production, on eco-industrial initiatives at a smelter [43]; at the meso or second level, the main objective is to develop an eco-industrial network that will benefit both regional production systems and environmental protection. Approaches include but are not limited to energy cascading, sharing of local infrastructure, and exchanging by products and recycling wastes; inter-firm clusters at supply chain level, represented by eco-industrial parks (EIPs) and involving industrial symbiosis; finally, entire cities/municipalities, incorporating industrial metabolism [44-45-46-47].

A separate line of thinking began in the early 1970s, inspired by the OPEC oil crisis: Environmental Economics [48-49] with its emphasis very much on economics, sought to examine how the environment could be managed in order to allow economic growth to continue [50]. By the 1980s, frustration with progress led to a second school of thought, Ecological Economics, separating itself and developing a more ecologically centred approach [51]. From this group emerged a third school, who felt that the social aspects of sustainability were not sufficiently recognized. They called it Socioecological Economics [52-53]. The industrial symbiosis field is thus moving from analogies with natural ecosystems and turning to economic sociology and geography accounts of embeddedness for explanatory purchase [54].

In this context industrial metabolism is mentioned as study of material and energy flows through societies and the sources as well as causes of emissions including their connection to human activities [55]. Adjacent to studies of industrial metabolism ecological modernization theory focuses on rather sociological perspectives of industrial and environmental developments, in particular ecological risks that are associated with industrialism [56-57].

SECONDARY RAW MATERIALS

The uniqueness of the Circular Economy comes from two interconnected ideas, the closed-loop economy and 'design to re-design' thinking. The Circular Economy include 'low consumption of energy', 'low emission of pollutants' and 'high efficiency', using it as a generic term for an industrial economy which is, by design or intention, restorative and in which material flows are of two types- those which are biological nutrients, designed to re-enter the biosphere safely, and technical nutrients, which are designed to circulate at high quality without entering the biosphere. The aims are to 'design out' waste, return nutrients, and recycle durables, using renewable energy to power the economy [58]. The use of the word 'restorative' is important, as the Circular Economy is not merely a preventative approach, reducing pollution, but also aims to repair previous damage by designing better systems within the entity of the industry itself. Its concept of redesigning systems of manufacture and service supply focuses on achieving value from such redesign rather than simply improving resource utilization. Feng et al. (2007) [59] describe the Circular Economy as a mode of economic development based on ecological circulation of natural materials, requiring compliance with ecological laws and sound utilization of natural resources to achieve economic development.

Recycling has been a significant part of sustainable practice for many years, and it is fundamental to the Circular Economy. These ideas are further developed in industrial symbiosis, where firms use each other's waste as resources, and in the service economy, where work is done to slow down cycles of use, in order to delay waste output. By increasing longevity of products through better manufacturing and maintenance, the rate of replacement

decreases, and so resource use is reduced. Thus the 'waste-as-food concept', wherein unwanted outputs of one industrial process are used as raw materials in another industrial process, and the three Rs of Reduce, Reuse, and Recycle have become central to the concept of the Circular Economy. So, there is a feedback process of resource —product—renewed resource, and that the ultimate objectives of optimum production, optimized consumption, and minimum waste can be achieved in production [60]; recently, there is a major stress on focus of the Circular Economy is on resource productivity and eco-efficiency improvement, and they adopt the 4R approach: reduce, reuse, recycle, and recover. The Reduction principle aims to minimize the input of primary energy, raw materials and waste through the improvement of efficiency in production (so called eco-efficiency) and consumption processes e.g. introducing better technologies, or more compact and lightweight products, simplified packaging, more efficient household appliances, a simpler lifestyle, etc. [61]. Recycling of waste offers the opportunity to benefit from still usable resources and reduce the quantity of waste that need to be treated and or/disposed of, thus also decreasing the related environmental impact [62-63-64-65]. However, if a company or the society is able to recycle all its waste, it may not be interested in reducing the amount of waste [66]. Although Circular Economy is often identified with the recycling principle, it must be underlined that this may be the least sustainable solution compared to the other CE's principles (Reduction and Reuse) in terms of resource efficiency and profitability [67-68].

In closed-loop supply chains the entire flow of material from suppliers to manufacturers, distributors, retailers and finally consumer is considered (forward supply chain) as well as the reverse flows of used products (reverse supply chain) [69]. In focusing attention on exchanges of by-products and wastes in planned complexes of co-located manufacturing plants, the industrial symbiosis approach to the circular economy is to increase the intensity of localized resource use; literally squeezing more value from the same initial inputs through co-located manufacturing processes. This contrasts with the extended product life approach. Here the circular economy seeks to stretch the economic life of goods and materials by retrieving them from post-production consumer phases. This approach too valorises closing loops but does so by imagining object ends in their design and by seeing ends as beginnings for new objects. Unlike industrial symbiosis, the aim is to re-use or repurpose products at a later date after their consumption [70].

ENVIRONMENTAL AND SOCIAL ADVANTAGES

In industrial ecology, it is implied that a circular economy will be beneficial to society and to the economy as a whole. Benefits will be obtained, not only by minimizing use of the environment as a sink for residuals but – perhaps more importantly – by minimizing the use of virgin materials for economic activity.

Various studies on CE have been conducted during the last decade and it is clear that CE provides a way to ease the tension between economic development and carbon dioxide emission; addresses the urgent pollution and resource scarcity problems; and helps enterprises and industries to improve their competitiveness and remove green barriers in the international trade.

Our review results show that current practices are being carried out at the micro, meso and macro levels simultaneously and cover the areas of production, consumption, and waste management.

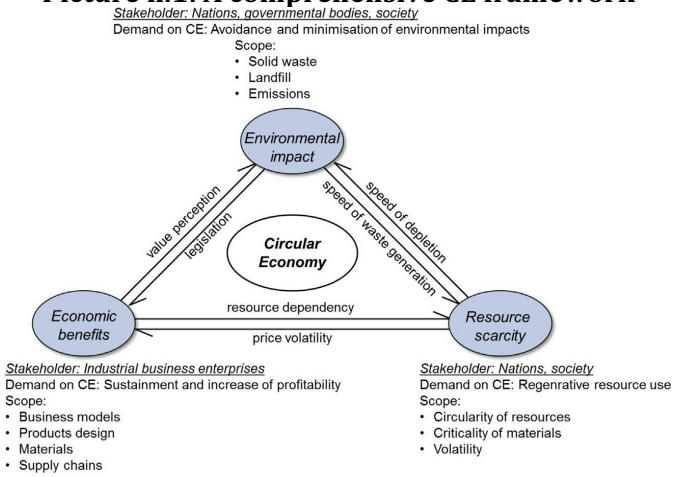
Other supports, from government and non-governmental organizations, help to promote, regulate and monitor the CE implementation.

In the interest of taking the study of ecoindustrial initiatives further and placing those initiatives within an economic and evolutionary setting, there are two criteria in examining the success of each such initiative and its evaluation: It must improve the eco-efficiency of the group of firms as a whole while improving the profit position of at least one firm without damaging the profit position of the others. The first criterion of eco-efficiency has been intensively discussed in the literature [19;71-72], and a number of measurements for eco-efficiency have been developed and applied in previous studies, such as a tangible reduction in material throughput; in energy released; in carbon dioxide released; or in some biological measure, such as basic oxygen demand (BOD) of watercourses [73-74].

The potential economic benefits from this monitoring and improvement system include more efficient materials and energy use, increased revenues from the sale of "wastes", cost savings from lowered insurance costs and reduced environmental penalties and increased competitive capacity. The potential environmental benefits include the conservation of natural resources (especially non-renewable resources such as water, fossil fuels and minerals), reduced environmental impact through efficient energy and material use and less waste discharge, avoidance of toxic materials, extended life cycle of landfill sites, and recovery of local ecosystem [75]. The potential social benefits include improved social relations between industrial sectors and local societies, more employment opportunities from new recycling businesses, improved public environmental awareness and public health level [76-77].

Social innovations that allow for community involvement, wider public education, and broader media coverage are essential to the success of an initiative that applies the CE concept [78]. Further, without knowledge resources (i.e. informaiton), stakeholders either "do not know how to respond to recycling pressure or may employ tactics that do not effectively reduce their waste" [79-80-81]. Also, successful implementation of the CE concept requires that the stakeholders have a clear idea of the potential economic benefits, social disparities, waste reduction, reduced environmental burden, and reuse of materials [82-83-84-85-86]. Specific value chains, material flows, and products need to be assessed to show the value of applying the CE concept [87].

Picture n.1: A comprehensive CE framework



Source: [88].

Even if research shows that the comprehensive CE perspectives of resource scarcity, environmental impact and economic benefits are covered two major results can be highlighted (picture n. 1).

FUTURE PILLARS OF CIRCULAR ECONOMY

In order to adopt the CE as future economic model, immense efforts are required to perfect the existing measures as well as to deploy a wider range of policies to overcome these challenges. The government needs to continue its support for the major technologies necessary for the CE. This requires that the government accurately identifies key technological areas and projects in line with current and long-term requirements for the economy and supports research efforts in the field of energy savings, alternatives, and recycling, and eventually boosts the nation's capacity in proprietary technological innovation through R&D investment at both enterprise and academic levels. In order to improve public awareness and participation, activities related to the CE concept such as TV promotions, newsletters, achievement exhibitions and workshops should be carried out

periodically. Such initiatives can provide platforms at which experiences from different parts of the world and from different institutions could be objectively reviewed. Moreover, enterprises could strengthen their mutual understanding and friendship through information exchanges, which will be the solid foundation for further collaboration on promoting the CE.

Improvements regarding the enforceability of legislation as well as the management system within the government are also impressive. It calls for a reform in judicial management mechanisms, a more transparent monitoring and auditing mechanism. On the other hand, the government should seek standardized methods for data collection, calculation and submission procedures so as to ensure a more accurate assessment of CE's development [89]. It may be necessary to re-evaluate how the circular economy should actually be defined. The following definition is suggested: The Circular Economy is an economic model wherein planning, resourcing, procurement, production and reprocessing are designed and managed, as both process and output, to maximize ecosystem functioning and human well-being. Humans, their activities and their environment are all loci on the one circle, thus a circular economy recognizes this relationship. A circular economy involves entire networks of production, and there is a diffusion of responsibility throughout these networks, with the producer and consumer not remaining ethically neutral. The implications of re-aligning economic and management practice with properly formulated ecological and social models can only contribute positively to the development of ethical and sustainable business practice.

The perspectives of CE are huge and appealing. An overall increase of knowledge of theoretical and practical framework of circular economy, CE, as well as the monitoring of the presently existing projects at the different levels are fundamental for advancing CE progresses in worldwide. The most important aspect, i.e. the one that still seems to need improvement, is the knowledge and awareness of European producers and consumers, because of the important role devoted to producers and consumers responsibility in European policies. CE efficiency and environmental protection would become crucial factors to orient policies for the transition to new production and consumption patterns, capable to delay the descent and allow a smoother transition to different and more environmentally sound lifestyles and socio-economic dynamics.

To facilitate the evolution of eco-industrial initiatives, countries seem to need both a topdown approach and a bottom-up approach. The former is ensured by institutional arrangements, such as regulatory requirements set in place by the Circular Economy Promotion Law and by the Circular Economy Pilot Demonstrations program and the Eco-industrial Park program established by various government agencies [22].

CONCLUSIONS

A sustainable future for the human race will demand system-based thinking that involves, in equal measure, society, environment, and economics. It is the re-knitting together of these pillars of sustainability that must happen if we are to rediscover a balanced existence with the rest of the biosphere. Of the three pillars of sustainability (social, economic, and environmental) it is the former that is least expanded in most of the conceptualizations and applications of the Circular Economy, and yet the social, with an emphasis on intra and inter-generational equity is underpinned by ethical concepts, just as much as the environmental, in relation to the moral imperative of business to sustain the natural environment.

The Circular Economy is an economic model wherein planning, resourcing, procurement, production and reprocessing are designed and managed, as both process and output, to maximize ecosystem functioning and human well-being. Humans, their activities and their environment are all loci on the one circle, thus a circular economy recognizes this relationship. A circular economy involves entire networks of production, and there is a diffusion of responsibility throughout these networks, with the producer and consumer not remaining ethically neutral. Future research should begin to incorporate the latest ecological knowledge into our understanding of naturalistic economical models and systems, without silencing the social and human dimension. This may require significant reexamination of much of current theory, and lead to new practice. The implications of re-aligning economic and management practice with properly formulated ecological and social models can only contribute positively to the development of ethical and sustainable business practice [11].

The establishment of a future trajectory for a circular economy will require that this approach be extended so that the broader issue of sustainability can be addressed more comprehensively. Whereas external effects relate mainly to the present generations, the sustainability issue implies a need to address the future generations as well when the implications of the environmental pressures are quantified [91].

To address these and other sustainability issues, the concept of the Circular Economy e while not entirely new e has recently gained importance on the agendas of policymakers [92] and also become an important field of academic research with a steep increase in the number of articles and journals covering this topic during the last decade. Companies are also increasingly aware of the opportunities promised by the Circular Economy and have started to realize its value potential for themselves and their stakeholders [75].

Despite the concept's importance for academia, policymakers, and companies, the conceptual relationship between the Circular Economy and sustainability is not clear. This has potential detrimental implications for the advancement of sustainability science and the diffusion of practices based on these concepts. Therefore, this research aims to contribute to conceptual clarity by investigating the similarities, differences, and relationships between both concepts in theory [93].

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