education sciences

Case Report

Grasp the Challenge of Digital Transition in SMEs—A Training Course Geared towards Decision-Makers

Américo Azevedo [1,2] and António Henrique Almeida [1,3,*]

[1] INESC TEC—Institute for Systems and Computer Engineering, Technology and Science, 4200-465 Porto, Portugal; americo.azevedo@inesctec.pt
[2] Faculdade de Engenharia, University of Porto, 4200-465 Porto, Portugal
[3] ISEP—Instituto Superior de Engenharia do Porto, Polytechnic of Porto, 4200-465 Porto, Portugal
* Correspondence: antonio.h.almeida@inesctec.pt; Tel.: +351-222094000

Abstract: Small and medium-sized enterprises (SMEs) in Europe risk their competitiveness if they fail to embrace digitalization. Indeed, SMEs are aware of the need to digitalize—more than one in two SMEs are concerned that they may lose competitiveness if they do not adopt new digital technologies. However, a key obstacle is related with decision-makers' lack of awareness concerning digital technologies potential and implications. Some decision-makers renounce digital transition simply because they do not understand how it can be incorporated into the business. Take into account this common reality, especially among SMEs, this research project intends to identify the skills and subjects that need to be addressed and suggests the educational methodology and implementation strategy capable of maximizing its success. Therefore, and supported by a focused group research methodology, an innovative training program, oriented to decision-makers, was designed and implemented. The program was conceived based on a self-directed learning methodology, combining both asynchronous lecture/expositive and active training methodologies, strongly based on state-of-the-art knowledge and supported by reference cases and real applications. It is intended that the trainees/participants become familiar with a comprehensive set of concepts, principles, methodologies, and tools, capable of significantly enhancing decision-making capability at both strategic and tactical level. The proposed programme with a multidisciplinary scope explores different thematic chapters (self-contained) as well as cross-cutting thematic disciplines, oriented to the Industry 4.0 and digital transformation paradigm. Topics related with Digital Maturity Assessment, Smart Factories and Flexible Production Systems, Big Data, and Artificial Intelligence for Smarter Decision-Making in Industry and Smart Materials and Products, as well as new production processes for new business models. Each thematic chapter in turn is structured around a variable set of elementary modules and includes examples and case studies to illustrate the selected topics. A teaching-learning methodology centered on an online platform is proposed, having as a central element, a collection of videos complemented by a set of handouts that organize the set of key messages and take-ways associated with each module. In this paper, we present the design and practice of this training course specifically oriented to decision-makers in SME.

Keywords: digital transition; industry 4.0; education 4.0; SME; e-learning

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1. Introduction

According to the EU Commission, a small and medium enterprise (SME) is defined as a company employing fewer than 250 persons, with a total turnover not exceeding €50 million and with an annual balance sheet total not exceeding €43 million [1]. SMEs account for the highest number of enterprises compared with larger enterprises and therefore represent a considerable target group for digitalization [2]. SMEs are the backbone of the 'non-financial business economy' in Portugal. They account for over two thirds (68.4%) of overall value added and over three quarters (78.0%) of employment, against an average of 56.8% and

66.4%, respectively, in the EU as a whole. Almost 24% of Portuguese SMEs are active in the high-tech manufacturing and knowledge-intensive service sectors [3].

Traditionally, large companies have tended to exploit value from scale, allowing SMEs to fill in the gap with more specialized or more customized services and products. In fact, the advantage of SMEs traditionally lies in their greater adaptive and innovation capacities, enabled by shorter communication lines and more nimble cultures. The advantage of large companies lies in greater scale, reach, and efficiency, but at the price of higher overheads and more rigidity. However, the adoption of emergent technologies and the development of new business approaches enabled by advanced information technology may impact this division of roles. Large companies may have greater capacity to implement the technologies—and at the same time, it would give them the ability to match SMEs in flexibility and adaptive capacity.

Indeed, we can look at SMEs from two different perceptions. On the one hand, SMEs are seen as dynamic, flexible, and agile organizations, giving them a competitive advantage. On the other hand, SMEs are seen as financially constrained, conservative, inflexible, and averse to innovation. As a matter of fact, it is acknowledged that SMEs are generally less well-prepared for the new technologies and expectations. In fact, a number of barriers can be identified that could constraint SMEs in implementing Industry 4.0. Researchers have pointed out that the lack of awareness concerning digital capabilities, skilled workforce and financial resources, standardization problems and cybersecurity issues may be particular problems [4].

SMEs in Europe risk their competitiveness if they fail to embrace digitalization [5,6]. A key obstacle for a successful digital transition in SMEs is related to decision-makers lack of awareness concerning digital technologies potential and implications. Some decision-makers renounce digital initiatives simply because they do not understand how it can be incorporated into the business [7].

Although several initiatives are being done to support digital transition for SMEs, there are major challenges for SMEs to overcome in order for them to benefit from digitalization and Industry 4.0 as compared to larger enterprises in such a transition to digitalization. Large enterprises have a scale advantage and more capacity to employ at least some information and communication technology (ICT) specialists. In a recent study, based on several interviews, typically either from the CEO, directors, and several other experts of SMEs from a broad array of sectors, one of the first outcomes was unsurprisingly, a continuing focus on providing support for SMEs to develop their staff [4]. It is equally clear that this does not mean exclusively focusing on knowledge about Industry 4.0 technologies, but also the key elements of management and staff development. The interviewees demonstrated a clear awareness of the gaps in key internal capabilities. Filling these gaps should be their first priority [8].

In smaller companies, decisions are usually made by a small group of people. Generally, there are no formal strategic and decision-making processes. The managing director or CEO, taking into account his or her perception, knowledge, and analysis of the business environment, decides to minimize the risk that may arise from it. In the context of the digital transition, the knowledge he may have and, fundamentally, the ability to assess the potential and the synergies resulting from the combination of different technologies are fundamental in decision-making. Therefore, it is of interest to understand what is essential to consider in a training program for these decision-makers and how it should be structured and delivered to maximize its effectiveness. One of the points to consider will undoubtedly be to provide digital platforms that facilitate access to both geographical and temporal terms. Simultaneously and naturally, it can meet each participant's rhythm of involvement. In light of this context and seeking to address the Portuguese SME's needs to promote digital transition, the main research problem is to define what might be essential to include in a training programme for decision-makers and senior managers, and how such a programme might be implemented. Thus, three research questions were proposed:

- RQ1—What are the right skills and subjects to be addressed, capable of supporting SMEs' digital transition?
- RQ2—What could be a suitable educational methodology, oriented to support SMEs to develop skills and competences for digital transition?
- RQ3—How to implement these programme through digital learning?

To answer these research questions, the fundamental research methodology applied was the focus group. The focus group methodology can be applied to pedagogic research by outlining strategies to understand the needs, motivations, and requirements to deliver a course. With its application, it is possible to highlight the best practices, and identify the key points to be considered in the framework to support the course delivery, namely the learning and teaching activities [9]. Moreover, it provides information on how to evaluate the success and effectiveness of the course provided. Like other qualitative methods, focus groups allow the researcher to gather in-depth information from a group of participants through interviews. Following a semi-structured format, informants can shape the research by dialogues rather than on one-direction interrogations [10].

According to the research methodology described, an innovative training program, oriented to decision-makers, was designed and implemented. The program was conceived based on self-directed learning and active training methodologies, grounded on the state-of-the-art knowledge and the pre-training benchmark assessment performed to evaluate the training course effectiveness, and supported by reference cases and real applications.

The proposed program aims that trainees/participants become familiar with a comprehensive set of concepts, principles, methodologies, and tools capable of significantly enhancing decision-making capability at both strategic and tactical level. Thus, it explores different thematic chapters (self-contained) and cross-cutting thematic disciplines oriented to the Industry 4.0 and digital transformation paradigm. Topics related to digital maturity assessment, smart factories and flexible production systems, big data and artificial intelligence for smarter decision-making in industry and smart materials and products, and new production processes for new business models, are addressed. Each thematic chapter, in turn, is structured around a variable set of elementary modules and includes examples and case studies to illustrate the selected topics.

Effective online courses depend on the learning experiences that are appropriately designed and facilitated by the experts/trainers. Considering that learners have different learning styles and needs, online courses need to follow hybrid strategies and sometimes multiple modes of learning.

Traditionally, in a teacher-centered approach, trainers control the environment because they control how information is shared. However, in an online course, the reality is different, the trainer does not control both the environment neither the audience. Moreover, attendees already have access to different knowledge sources, which makes them more independent on the way they can reason the knowledge received. Thus, learning is becoming more collaborative, contextual, and active.

Based on this paradigm, the methodology adopted was based on a learning-centered approach, where experts and trainers take on the role of facilitating and sharing information while guiding attendees toward solutions. In a more specific way, a self-directed learning strategy was followed. Self-directed learning is learner-initiated and may also be called self-paced, independent, individualized learning, or self-instruction. This methodology places the responsibility for learning directly on the learner, giving the freedom to select what and when to learn [11].

Therefore, the main objective to success is to attract learners that need to get knowledge on the subjects that are addressed in this course. It is clear that learners who take the initiative and are proactive learners learn more and better than passive (reactive) learners do. They also tend to retain and make use of what they learn better and longer than do reactive learners.

Thus, the online course here presented was designed and developed to support the self-directed learner in pursuing individualized, self-paced learning activities. The learner, working at a computer at a convenient time and pace, is able to search and utilize the vast resources of Internet research nearly on any topic imaginable. This asynchronous teaching-learning methodology critically depends on the technology used, therefore, a specific online platform was designed and developed [12]. Here, it is possible to find, as a central element, a collection of videos complemented by a set of handouts, that organize key messages and takeaways associated with each module. This content can be accessed whenever necessary by the student. However, an active learning methodology is also explored. Active methodologies place the attendee at the center of this process and make them the protagonists of discovery, rather than just passive information receivers. Thus, at the end of each thematic chapter, a detailed and challenging quiz is proposed, covering all the modules' contents to evaluate the formative effectiveness. Here, the main objective is to encourage attendees to explore and search for more information, from other sources, to answer the questions proposed.

The paper is organized into six sections. The next chapter presents the importance of digital transition, mainly focused on the industry domain. The third chapter describes the research methodology adopted in this research project. In chapter four, findings from literature related to the importance of digital transition/transformation and the challenges for its successful implementation in SMEs context are presented and the need for a new revolution in education. This is followed by a section describing the architecture and implementation details of the e-learning course on Industry 4.0, oriented explicitly to industrial SMEs' decision-makers. Later, in chapter number six, the conclusions and reflections on the work developed are presented, as well as the expected next steps.

2. Background

Today, the digital transformation is a challenge both for the university and research center, and for companies and their business and management strategies. If it is true that large companies can test and evaluate new technologies, both in terms of human and capital resources, on the other hand, small and medium enterprises (SMEs) struggle to survive in their competitive markets [13]. Consequently, although this digital transformation can bring exceptional competitive opportunities to companies, driving this digital transformation in SMEs is not risk-free or straightforward. Therefore, research centers and universities must support SMEs, developing the tools and methods to help this journey towards industrial digital transformation.

With the rise of the new digital technologies, not only in business but also in people's lives (e.g., social networks, new marketplaces, digital banks, among others), companies are consequently challenged to change their business strategy to explore the benefits of this social evolution. Thus, society is facing a fast and radical change due to the maturation of digital technologies and their ubiquitous penetration of all markets [7]. Companies such as Amazon, Facebook, eBay, among many others, are being conceived and designed to take advantage of this new digital era. They are exploring the Internet and digital technologies to scale their business and become the new largest and sustainable companies globally, dominating their industries and challenging the traditional value proposition.

Drawing on the emergent insights about the nature and characteristics of digital technologies, researchers conclude that the inherently editable, re-combinable, re-programmable, and generative nature of digital technologies impacts many aspects of innovation and entrepreneurial processes and outcomes [14]. Taking advantage of these digital technologies, company leaders become able to build, from scratch, scalable products and services that can drive change and consequently growth. Another advantage of digital technologies is the separation of content from the media, which imparts flexibility and encourages rapid experimentation and learning. Further, digital technologies' fluid and dynamic processes enable fast iterations in non-linear paths in the entrepreneurial process.

On the contrary, traditional companies using a non-digital mindset, based on:

- Closed and monolithic information systems architectures, supporting rigid production systems.

- Standalone products with no interoperable and upgrade capabilities.
- Services with local or national coverage, face difficulties adapting their business strategy, operations, and management structure to deal with this revolution.

In some industrial areas, we can state that real digital transformation is taking much longer and facing more difficulties than expected. Successful digital transformation requires an organization to develop a wide range of capabilities, which will vary in importance depending on the business context and the specific organization's needs. Digital transformation needs to become central to how the business operates, and organizations need to re-think and possibly re-invent their business models to remain competitive.

But what is digital transformation, and what are the impacts that it can bring to companies? In the state-of-the-art, we can find different definitions for this digital transformation concept [7]. For instance, Fitzgerald [15] and McDonald [16] define this digital transformation as using new digital technologies, such as social media, mobile, analytics, or embedded devices, to enable major business improvements like enhancing customer experience and streamlining operations or creating new business models. As such, digital transformation goes beyond merely digitizing resources and results in value and revenues being created from digital assets. In the same line, Collin [17] and Kane [18] expose the difference between digital transformation and digitization. While digitization describes the mere conversion of analog into digital information, the digital transformation term refers to a broad concept and a change of mindset, affecting politics, business, and social issues. According to the Plattform Industrie 4.0, this digital transformation describes a further step ahead of where people, machines, and products are directly connected and their environment [19].

By definition, digital transformation has always had a strong connection with industry, where Industry 4.0 and smart factories programs are introducing the fourth industrial revolution in place [20]. These European and American, respectively, programs have the main objective of forcing the end-to-end digitization of all physical assets and their interoperability and force the integration of the digital term in the DNA of industrial companys' business models. The main objectives include:

- Individualization of customer requirements;
- Flexibility and adaptability of manufacturing and logistics systems;
- Improved decision-making, the integration of ICT and cyber-physical systems (CPS);
- Introduction of advanced production technologies such as additive manufacturing;
- Intelligent automation concepts;
- Adapted business and organization models and concepts for more sustainable production and logistics processes.

To accomplish this revolution, people must be at the center of the new strategies and the technology adoption drivers. Consequently, digital transformation needs to evolve according to the availability and capacity of people to adopt and take advantage of new technologies. This should be a pleasant journey, which needs to be adjusted according to the market and industrial sector culture and circumstances. Therefore, people need to understand their current capabilities and be trained to be involved in these digital working ecosystems.

For instance, top managers need to learn how to make decisions based on the massive quantity of data available and how they can enrich their cognitive capabilities with the new available artificial intelligence services. Mid-level managers need to understand how the emergent technologies can support their teams' work and produce practical added value to the organization to maximize the return of investment on these digital technologies. Operators need to develop new communication skills and knowledge to embrace these virtual worlds, considering that workplaces are being redefined to be virtualized entirely and capable of being remotely controllable. Socially, customers are also acquiring new competencies, changing their habits and mindsets to engage with these new digital, ubiquitous, and sometimes non-physical organizations.

Based on this context described, it is necessary to evolve the education science discipline to cope with the industrial SME's digital transformation challenges. It is essential to explore new channels and methods to provide advanced training for companies and select the topics that better fit the trainees' objectives and needs. Therefore, this research paper proposes a research project that will address these needs following a systematic research approach described in the following chapters.

3. Research Methodology

To fulfil the objectives defined for this research project and to answer the raised research questions, a structured qualitative research methodology was followed.

Qualitative research, widely used in different fields, is an experimental method of observation to gather non-numerical data, description of things, characteristics and meanings, and observations and interpretations. Some of the common approaches to conducting qualitative research include interviews and focus group discussions. A recognized challenge in a qualitative research approach is the ability to maintain objectivity and avoid bias. In other words, it is ensuring that the reality involved is not distorted and thus does not condition the validity and reliability of the results achieved. Although this approach is often criticized for its potential subjectivity, it has the great advantage of facilitating involvement, flexibility, and creativity, resulting in additional information that may prove very pertinent and useful for the research in progress.

In this project, the research plan defined comprised three main stages. Firstly, researchers performed a content analysis from the literature review and other sources of information. Here, several sources of information were considered: reports promoted by business and sector associations, articles in periodicals, opinion articles in different media. This stage was crucial to understanding better the relevance of the digital transition/transformation for industrial SMEs and mainly to understand the main barriers concerning decision-making related to the adoption and implementation of digital transition initiatives in the SMEs context.

At a second stage, the researchers' strategy was to work with the major Portuguese industrial association to understand better the industrial SMEs' requirements and expectations related to advanced training on digital transformation. Here, a focus group methodology was applied, followed by unstructured interviews. This research stage's main objective was to collect, from main stakeholders, the main requirements for successfully adopting a new and disruptive online course on industrial i4.0 awareness, concepts, and technologies. Focus group discussion methodology is frequently used as a qualitative approach to understanding specific issues and generating information on collective views and the meanings behind those views. The method is beneficial for exploring people's knowledge and experiences and can be used to examine not only what people think but how they think and why they think that way [21]. In practical terms, the focus groups consist of panels, facilitated by a moderator, who meet to exchange perspectives, knowledge, and thoughts on specific thematics for a particular time. This is a powerful approach to "data collection" because it promotes the interaction between participants. Information is produced through natural conversation and discussion amongst participants, questioning each other and explaining themselves [22].

Two specific focus groups were performed, one internal, with the digital transformation experts, and a second one external, with the industrial association responsible for this project. A total of 17 people were involved. In addition to three members of the research team, 14 participants from SMEs and different sectors (traditional and non-traditional industries) were involved in the first focus group: 7 general managers, 4 technical managers, and 3 continuous improvement managers. The first focus group's main objective was to identify the main subjects to be explored and this digital transformation course's organization. The second focus group objective was to determine the suitable structure to provide this course to industrial SMEs.

Concerning bias, we take into account the two acknowledged main types—participants and researchers. Most biases can be avoided by framing the questions and structuring the interview skillfully. It may also be a good practice to have the questions and the data reviewed by a colleague or mentor for a second, unbiased opinion. To avoid participants bias, we frame questions in different ways and in a manner that allows the participant to feel accepted no matter what the answer is. The critical point was to formulate open-ended questions to prevent the participant from merely agreeing or disagreeing or avoiding the answers as "Yes" or "No". The principle was guiding the participant to provide a truthful and honest answer. Another relevant point, and from the researcher side, is maintaining neutrality to avoid bias the participants' responses. Moreover, the session's plan should consider general questions first before moving to specific questions. The plan defined for the session and the task of consolidation and analysis of the data obtained should be addressed with a clear and unbiased mind and reviewed by a second team of researchers (unbiased opinion).

In the last stage of the defined methodology, the team involved consolidated the results obtained in the first stage with those obtained in the second stage. This work resulted in the key lines to be considered for the training programme's development and operationalization. It was possible at this stage to list not only the set of thematic modules to be explored but also the contents and cases of application and experimentation to be considered.

4. What We Already Know

4.1. The Digital Transformation Opportunities and Challenges

Considering the digital transformation challenges and opportunities described before, it is possible to understand that SMEs, mainly those with very traditional and familiar roots, may struggle to follow and compete in such an industrial 4.0 revolution [23]. This reality represents a significant problem in the current economic landscape. In fact, in most countries, SMEs form the backbone of the economy. Due to this reality, the European Commission considers SMEs and entrepreneurship key to ensuring economic growth, innovation, job creation, and social integration. In this respect, the challenges, opportunities, and requirements of Industry 4.0 have to be examined, especially for SMEs, thus paving the way for the digital transformation of traditional SMEs into smart factories.

Considering the average size and structure of an SME, the digital transformation and Industry 4.0 technology may offer great opportunities if mid and high management layers are influenced and trained to implement this digital revolution [13] successfully. For instance, SMEs are often well-positioned to implement the digital transformation more rapidly than large enterprises because they can develop and implement new IT structures from scratch more easily. According to PWC market analysis, many SMEs are already focusing on digitizing products to stand out in the market. The integration of information and communication technologies and modern Industry 4.0 would transform today's SME factories into smart factories with significant economic potential. However, the smaller SMEs are, the higher the risks they will not be able to benefit from this revolution. European SMEs are conscious about the knowledge in adaptation deficits. This opens the need for further research, awareness, and action plans for preparing SMEs in a technical and organizational direction.

Today, many SMEs are still not prepared to implement Industry 4.0 concepts, especially in less developed countries. According to the research done so far, SMEs are still unsure if, when, and how they should start to introduce Industry 4.0 in their firms. They are not ready to evolve from a product-based business model to a servitization paradigm, where products become capable of delivering services to customers and, consequently, increase income opportunities for companies.

Therefore, particular research, investigations, and competent knowledge transfer mechanisms are mandatory for successfully implementing Industry 4.0 technology and concepts in SMEs. Some authors compare the i4.0 adoption challenges in SMEs to the difficulties observed in the past with lean management's introduction in SMEs. While most large companies have introduced or integrated lean principles into their corporate strategy, most SMEs have gradually addressed this topic, following specific lean methods and tools for SMEs. As a result, lean has now been implemented in many SMEs in practice. As with the introduction of lean, the success rate for introducing i4.0 in SME manufacturing can be increased by developing SME-customized implementation strategies, SME-adapted concepts, and technologically feasible solutions. Otherwise, the actual effort for sensitization and awareness building among SMEs for Industry 4.0 will not show the expected success and results.

However, today, the concepts proposed by the research centers and consultancy companies are still on a very rough and abstract level without any clear and tangible recommendations about how to achieve the proposed goals. As future steps, it is necessary to invest in collaborative competence centers, learning factories, and laboratories for Industry 4.0, capable of working as a middle point. Here, academia and industry can meet together to offer/find advanced training courses, perform specific research based on industry needs and promote knowledge transfer to small and medium enterprises.

4.2. Education of Digital Manufacturing Engineering

The digital transformation concept is entirely dependent and related to a new and innovative digital education approach, Education 4.0 [24]. It is impossible to continue implementing the digital transformation within the industry when new students or even companies' employees continue to use traditional and passive learning methods based on chalk and board teaching methods. The emergent technologies from Industry 4.0 are also capable of providing positive impacts not only in the manufacturing operations and decision processes, or even in the society lifestyles, but also on education [25].

Such digital-based teaching and learning processes are the core concepts of Education 4.0. This sort of tech-based education and learning experience provides a self-learning opportunity at a student's own pace. The industrial revolution 4.0 provides the advent of the digital age and claims that educational institutes embrace this education revolution too, using new technologies and almost real information in its processes [26].

Within such competitive and revolutionary circumstances, learners or employees need to be trained and not taught to ensure that students become technically competent for today's industrial operations. Information needs to be available, and students need to learn how to find relevant information according to its main educational objectives. Students are not alike. They have different starting points, unique comprehension capabilities, and different interests and needs. Consequently, within this digital transformation era, it is necessary to develop people with multidisciplinary expertise that will evolve along with their professional careers, according to the problems and projects they will face in the real industrial scenario.

Different research institutes or even industrial associations worldwide, including INESC TEC, one of the largest research center in Portugal, and COTEC, the largest industrial association in Portugal, have been working together to produce and offer a series of webinars and e-learning platforms capable of reaching the real industry more effectively. They are using and developing teaching mobile apps such as Khan Academy, Toppr and Byju's learning app, or even the YouTube channels to disseminate the educational content in the different fields of expertise. In the same line, educational e-learning platforms such as Coursera or NPTEL are being developed to provide advanced courses to people interested in developing new competencies and knowledge in specific areas, using a self-service approach.

Today, these educational e-learning platforms can be fully integrated with FabLabs, taking advantage of installed industrial Internet of things (IIoT) platforms and simulation environments based on digital twin. These ecosystems provide a more democratic, hybrid, and immersive experience to all people that intend to explore skills and expertise on specific technologies from Industry 4.0. Within these types of innovative educational courses, students can use digital platforms to have access to lectures in real-time, where teachers can combine theoretical subjects with real experiments in FabLabs, at the same time and without logistics costs. Students can be challenged to develop mini-projects or solve exercises with a hands-on experience. The code generated can be downloaded into the FabLab, and the student can observe the real behavior of its code within real machines or robots to get more concrete feedback about the work done.

Nevertheless, and using the best of our knowledge, this type of educational offer is still minimal in Industry 4.0, mainly in the Portuguese market. However, companies and their employees have been showing a growing interest in these types of advanced services. At a European level, this is also a topic attracting the attention of the European Commission (EC). For example, the EC had promoted the European Advanced Manufacturing Support Centre (ADMA) to help SMEs adopt advanced manufacturing solutions to transform their organization towards next-generation factories with more competitive, modern, and sustainable production.

Another European institution promoting advanced training for SMEs is EIT Manufacturing, through the guided learning platform (GLP). EIT Manufacturing's GLP delivers digital learning content based on learning nuggets, allowing students and workers to get fast access to the latest manufacturing knowledge and support learning as and when needed, without enrolling in a long-term program. The learning nugget is the smallest learning object relying on different kinds of didactic media like e-learning units, practical task lessons, AR/VR sessions, and learning assessments to achieve and verify desired competencies. By combining nuggets as needed, it is possible to create individual and personalized learning paths. This way, EIT's GLP will ultimately allow the up-skilling and re-skilling of European manufacturers' next generation, contributing to learning democratization.

This national and European context was the main driver for the development of the first phase of the Industry 4.0 course that INESC TEC, the major research institute in North of Portugal, and COTEC Portugal, the main industrial association for innovation and industrial technology cooperation in Portugal, decided to introduce in the market, free of charge for the Portuguese industry.

5. Design and Implementation of a Training Concept

5.1. SME's Digital Transformation Educational Requirements

Based on the results previously described, the main challenge presented in this research paper was the development of an advanced e-learning training course for Industry 4.0, targeted to middle and high-level management. This course was expected to provide the means and tools that will enable the Portuguese industrial companies to understand better what the fourth industrial revolution is and how it impacts the traditional business models and organizational structures. Furthermore, and from a more technological perspective, understand the technologies that characterize it, which are the barriers and opportunities for its implementation, based on real use cases and lighthouses, and how to define an effective and sustainable digital transformation roadmap.

As described in the research methodology, the focus groups performed with companies and i4.0 experts were the primary source of information to build the proposed training course. The focus group analysis with companies revealed that industrial SMEs are interested in exploring digital and e-learning mechanisms for training on digital transformation. Participants unanimously agreed that practice based on asynchronous digital platforms allows employees to manage their time better and learn at the right pace. Equally important is adopting flexible and user-friendly digital educational platforms that allow attendees to focus and deep dive into the topics that better fit their professional needs. These platforms should enable them to retain the main takeaways from subjects that are not so relevant and evaluate the lessons learned based on interactive questionnaires.

Moreover, from these focus groups, it was possible to understand that industrial companies believe that online courses are not enough. These should be complemented by hands-on classes, mainly in experience labs, where attendees can learn by doing and put in practice what was explained in the online courses. According to the stakeholders interviewed, this type of blended approach is the one that may bring better results, focusing on each specific company's needs.

5.2. Skills and Subjects for SMEs Digital Transformation

The "brand image" of this fourth industrial revolution is undoubtedly the intelligent sensing for the digitization of production processes and the alignment of Internet technologies, namely: the massification of the "Internet of things; flexible architectures with distributed processing; the exponential increase in computational capacity; and the so-called "cloud computing" and robotic systems, increasingly intelligent and capable of interacting with operators. A new generation of industrial systems based on innovative services, whose functionalities lie in cyber-physical systems and the "cloud", will therefore emerge. In summary, it is possible to list the following key ideas for the characterization of the Industry 4.0 concept: intelligent factories and machines, cyber-physical systems (CPS), natural human-machine integration, autonomy and adaptability, product and service systems, virtualization and augmented reality.

Considering this wide range of topics, designing and developing an influential Industry 4.0 e-learning course requires a strong synergy between academia, as the source of knowledge and research, and the industrial associations, as the entities that centralize and better know the main requirements for educational and advanced training services. Based on the internal focus group's outcomes, performed with the digital transformation experts, it was possible to design and propose a multidisciplinary course, exploring different thematic chapters (self-contained) and cross-cutting thematic disciplines oriented to industry 4.0. Various topics, covering critical subjects such as digital maturity assessment, smart factories, and flexible production systems or even big data and artificial intelligence for smarter decision-making in industry, were structured in sections, as depicted in the Figure 1. Each section explores one of the topics previously enumerated. In turn, each section is split around a variable set of elementary modules and includes examples and case studies to illustrate the selected topics.

Section 1—Road to Digital Transformation: This section explores the digital transformation journey, as the need to plan and manage the organizational, strategic, and technological roadmap to introduce companies to the Industry 4.0 paradigm. As the digital transformation will be different for each organization or company, according to its industry sector, characteristics of the market itself, and typology of operations, it may be difficult to identify a common strategy or recipe. Thus, this section's main objective is to provide companies with the knowledge and information that will support them to understand how to design and develop the necessary actions that will successfully lead to the implementation of digital transformation strategies.

Besides the difficulties associated with multidisciplinary, inherent to this digital transformation, several internal and external challenges are identified. In fact, with digital transformation, it will result in fundamental changes in the way organizations and companies operate and how they deliver value to customers. Challenges are identified covering different dimensions, namely, those related to production resources, information and integration technologies, operating practices, organization and management models, and naturally to people. Transformation presupposes change and, in this context, also cultural change. This cultural change requires organizations to continuously challenge the usual way of operating, to experiment new operative approaches and value creation methods, in order to evolve to higher performance levels.

To successfully overcome these challenges, it is mandatory to build a holistic vision of the organization and its 'current digital maturity', considering the different dimensions inherent to digital transformation. Having a global vision and one that is understood by the whole organization means considering three fundamental pillars, namely: the business model—how the company wants to create, deliver, and capture value in the future; the internal processes—how the company intends to develop its activity and with what technologies and tools; and the relationship with the customer—how to manage customers' needs and expectations throughout products and services life cycles.

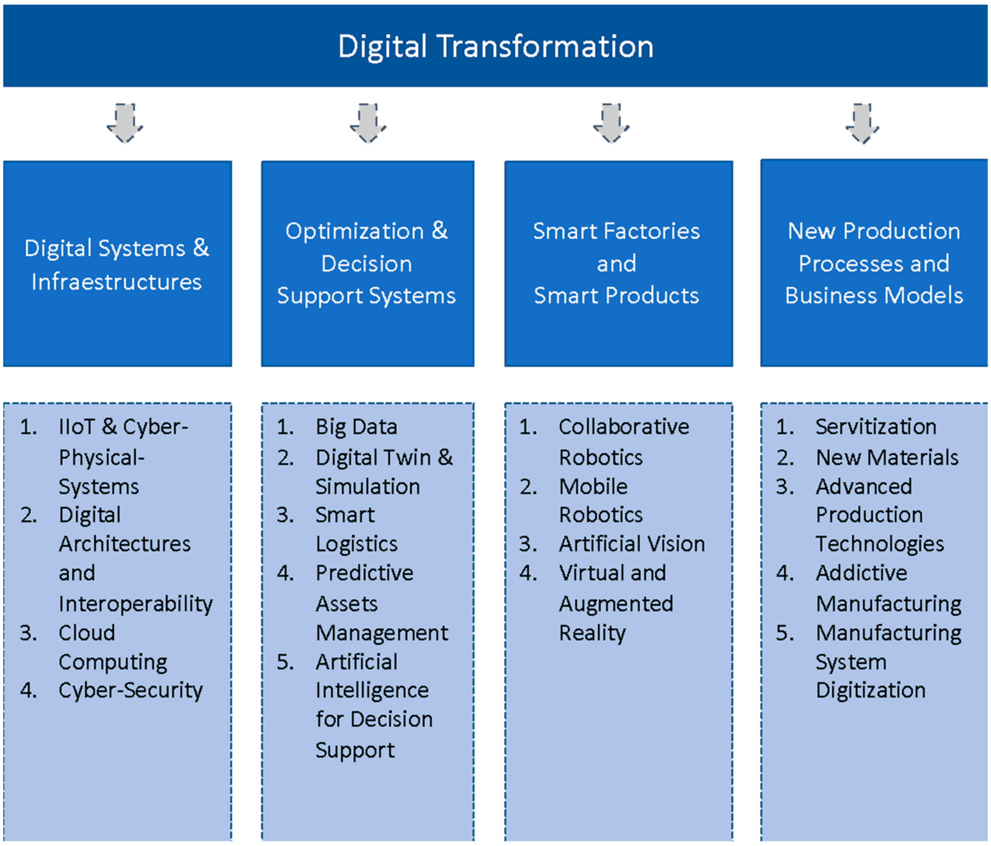

Figure 1. i4.0 e-learning course programmatic structure.

Section 2—Digital Systems and Infrastructures: Depending on the size, scale, and geo-location of the companies, the topics related to distributed systems architecture and the design of digital infrastructures based on cyber-physical systems, leveraged on cloud/edge processing with high security and high data privacy levels, may be essential for the introduction of organizations to Industry 4.0.

Thus, this second section of the course explores the chapter related to cyber-physical systems as the main driver for the industrial 4.0. Cyber-physical systems are a synonym for the "industrial Internet of things". They should be understood in the sense that more devices—sometimes including unfinished products—will be enriched with embedded computing. This will allow devices in the field to communicate and collaborate without the need for centralized controllers. This technology will decentralize analysis and decision-making, enabling real-time responses. It will also facilitate computing and communication between physical and virtual processes, covering all production levels, from the physical manufacturing process and production equipment to the production and logistics networks. These technologies enable and foster the decision support through sensorization and data collection and visualization for the optimization of performance and increase of efficiency of processes throughout the entire value chain of a plant.

Data sharing between different companies and various sites (belonging to the same company) is increasingly required. The use of distributed and digital architectures, leveraged on the cloud computing, enabling the access to machines, systems, and tools in the form of a service, without the need for companies to invest in expensive products and infrastructure is a new reality in smart factories. Therefore, this second chapter also addresses the need to increase connectivity between systems and equipment and the exponential growth of data that needs to be stored, retrieved, and shared. The use of the cloud to meet these needs is increasingly crucial. On the other hand, with the increasing performance of these cloud technologies, achieving reaction times of only a few milliseconds, data and application functionality will be increasingly deployed in the cloud, enabling more advanced and data-driven services.

The spread of digital communications and the consequent increase in connectivity between the different elements that integrate companies' production systems, increase the risk of intrusion in systems, network equipment, and data. In this way, the need to protect systems and production lines against external threats increases dramatically. As a result, the third chapter explores the need to develop secure and reliable communications protocols, channels, and sophisticated identity and access management for machines and users. These technologies make it possible to increase data, systems, networks, and equipment security.

Section 3—Optimization and Decision Support Systems: Industry 4.0 is characterized by the transformation of system data into knowledge that the different actors of the organizations can use to improve decision-making at varying levels of granularity, thus enhancing the organizations' performance and ability to respond to market demands.

At the first stage, data pre-processing is more and more a fundamental assumption for the correct application of innovative and disruptive data-driven algorithms. Therefore, this section starts with a reflection about the big data technologies capable of performing the treatment and analysis of large volumes of data: continuously generated; complex (text, images, audio, etc.); originating from multiple sources (production, sales, third parties). These technologies make it possible:

- A more informed decision-making in real-time throughout the business processes of the entire value chain;
- Optimization of operational costs through the reduction of waste of resources;
- Improved supply chain risk management;
- increased accuracy in the need for machine repair and maintenance;
- Identification of quality problems and defects in the final product and the perceived workload.

Taking advantage of these massive data, data-driven services based on artificial intelligence or simulation models can be developed to support the decision-making for complex circumstances. Therefore, in the second chapter, different types of artificial intelligence algorithms are explored as well as the main opportunities for implementation in industry. In a third chapter, the simulation technologies are explored and how they can be used extensively in companies' production operations to enhance real-time data availability and mirror the "physical world" in a "virtual world" model, including machines, products, and operators. These simulation environments provide the opportunity for operators to test and optimize the configurations of the systems and production resources involved in a "virtual world" environment by anticipating possible problems and assessing what the subsequent performance of their physical production might be.

Section 4—Smart Factories: Industry 4.0 explores different technologies that allow organizations to develop new smarter factories, capable of quickly adapting to new production requirements in a more transparent and predictive way.

The robots, autonomously and collaboratively, will interact with each other and work safely side by side with humans, and learn from them. These new intelligent robotic technologies will free up time for operators to perform higher value-added tasks, operate and collaborate in the same physical space with humans safely, and ensure greater accuracy in implementing more demanding tasks. These robots will cost less and have a wider range of capabilities than those currently used in production systems.

To enhance collaboration between humans and machines, immersive reality concepts need to be explored and adapted to the industrial context. Emerging AR/VR technologies, as head-mounted displays, tablets, smartphones, or even 3D environments and information projection over the shopfloor, will revolutionize how information is communicated to the human-worker, as to how humans can communicate with the robots or machines. Consequently, the advantages of artificial vision arise, not only to collect data from the shopfloor but also to take automation and control disciplines to a new level, where robots and other things become more autonomous and able to collaborate with other machines or even humans.

Section 5—New Production Processes and Business Models: Leveraged by the concept of greater specialization and control over industrial processes, i4.0 allows organizations to explore new production processes, new materials, and consequently new business model proposals, based on a concept of service and extension of the life cycle of products.

The set of technologies allows printing objects from the controlled overlay of plastic or metal materials (3D printing), avoiding the waste of traditional manufacturing processes by 'subtraction' or cutting the fabrics. It is used to produce prototypes, small series of complex parts, spare parts, and even custom tools. As the technology matures, printing speed and accuracy are increasing, becoming a truly crucial technology in a unitary production environment of complex components.

These technologies make it possible to: create objects with very complex geometries, which is very difficult, if not impossible, to achieve with other manufacturing methods; optimize geometries to reduce weight or control part density; reduce the need to produce complex assemble lines; and finally promote greater manufacturing flexibility and customized production.

5.3. Implementation Strategy through Digital Learning

As previously identified, one of the results from the focus group performed with the Portuguese industrial association was that it would be beneficial to use an e-learning platform. This way, it would be possible to reach a wider audience and accomplish its primary purpose: creating awareness and introducing theoretical subjects related to the fourth industrial revolution and its enabling technologies.

Consequently, a web-based e-learning platform was built to provide industrial companies with i4.0 educational media content (Figure 2), grounded on effective videos produced in a proper test and demonstration facility called iiLab—industry and innovation lab. These videos put in contact, virtually, the course attendees with the experts, and demonstrate the technology application in near-real scenarios or even in lighthouses. Each video, related to each thematic module, also includes the most important takeaways and key messages that attendees must retain. Finally, per subject, an evaluation quiz is presented, which will validate the attendees' understanding of the presented topics.

Figure 2. Digital transformation e-learning platform menu and video formats.

In addition, during the focus group performed with SMEs, companies demonstrated their preference in using platforms that follow an asynchrony learning method. This way, employees would be able to select the topics that better fit their current needs, and when it is more suitable. Following this recommendation, the learning platform adopted was designed so that trainees can define their own learning path, managing the sequence of modules that they want to attend. Concluding all the thematic modules with success, attendees receive a certificate that validates the modules attended.

5.4. Results Analysis

More than 770 attendees enrolled in this course since the online launch (almost one year). This high level of participation highlights the opportunity that the programme provided. The participants, from SMEs, represent more than 500 companies from different sectors of activity. With these results, and in the national context, we can consider that the course achieved the objectives set: creating awareness in a significant number of Portuguese organizations. As identified and presented during this research paper, organizations need flexible e-learning platforms that allow their employees to access the contents they need and when they need it. The analysis of the data we obtained enable us to conclude that it took 43 days to complete the course. It is also interesting to note that only 16% of the participants completed the whole program. This result is not so surprising considering that the program and the support platform were designed to allow the program's customization to each participant, i.e., to attend the modules for which they would have a particular interest. Table 1 illustrates the distribution of the number of approved participants across the different chapters of the training programme.

Table 1. Number of attendees approved by course chapter.

Chapter Names	Number of Approvals	Avg. Score
CH I-DIGITAL TRANSFORMATION	356	94.7%
CH. II-COLLABORATIVE ROBOTICS	271	94.5%
CH. III-MOBILE ROBOTICS	219	94.4%
CH. IV-IIOT & CYBER-PHYSICAL SYSTEMS	239	94.1%
CH. V-ARTIFICIAL VISION	183	95.5%
CH. VI-VIRTUAL AND AUGMENTED REALITY	187	95.5%
CH. VII-SMART FACTORY	210	94.6%
CH. VIII-BIG DATA	194	94.4%
CH. IX-SIMULATION AND DIGITAL TWIN	200	92%
CH. X-SMART LOGISTICS	167	94.8%
CH. XI-PREDICTIVE ASSET MANAGEMENT	226	90.3%
CH. XII-ARTIFICIAL INTELLIGENCE AND DECISION SUPPORT	170	93.4%
CH. XIII-SYSTEMS ARCHITECTURE AND INTEGRATION	179	91.5%
CH. XIV-CLOUD COMPUTING	134	100%
CH. XV-CYBERSECURITY	167	93.5%
CH. XVI-SERVITIZATION	167	93.8%
CH. XVII-NEW MATERIALS	163	92.7%
CH. XVIII-ADVANCED MANUFACTURING TECHNOLOGIES	146	95.3%
CH. XIX-ADDITIVE MANUFACTURING	154	90.2%
CH. XX-DIGITISATION OF THE MANUFACTURING PROCESS	160	94.9%

Concerning the number of participants approved by chapter, it is relevant to mention that the digital transformation chapter was the one with a higher number of approvals with 356 quizzes, with a positive rate of 94.6% on average. The collaborative robotics, IIoT and cyber-physical-systems, and predictive asset management courses were the ones with a higher number of attendees approved, with 271, 239, and 226 participants approved per course, respectively. It is interesting to see that the cloud computing chapter had a lower approval rate (134), which needs to be explored. It is also interesting to see that the chapter that had lower rates is additive manufacturing. Here, attendees were able to answer successfully to 90% of the questions, on average.

On another perspective, Table 2 shows the total number of quizzes answered per chapter and the number of quizzes with successful and unsuccessful scores. It is interesting to see that in chapters number 1—digital transformation, 5—artificial vision, and 19—additive manufacturing, attendees need to do more than 2 quizzes on average to have 1 quiz with a successful score. We consider these chapters more theoretical, bringing more difficulty to attendees to follow and keep attention during the entire chapter. Moreover, these courses have a higher duration and number of modules, affecting the attendees' performance. On the other hand, chapters related to simulation and digital twin, servitization, smart factory, and big data have lower unsuccessful tentative per attendee. These chapters have more examples and case studies, which simplify attendees understanding of the subject.

Regarding the attendees' roles and positions, it is interesting to see that a significant number of participants belong to the technical and top-level management (Table 3). Thus, 21% of the participants enrolled are senior technicians, and 16% are directors, head of department, or heads of division. We can also see that 8% belong to the administration or are CEOs or general managers of Portuguese organizations. It is also relevant to highlight that people who belong to the sales and business development departments also show interest in this topic (4%).

However, not only industrial organizations are attending this course on digital transformation. Thus, it is relevant to see that 15% belong to academia and 9% belong to the consultancy sector. These numbers show that even students, professors, and consultants, who are already familiar with some of the topics addressed in this course, are also interested in extending their knowledge and structuring their ideas and concepts around the digital transformation and Industry 4.0 paradigm.

Since the launch of the programme, we have had the opportunity to interact directly with participants. We have also taken into account the feedback received and the interactions with participants that the platform provided. It is essential to mention that globally the level of satisfaction that was transmitted to us was always very positive. We witnessed the fulfilment of the participants regarding the opportunity and usefulness of the training programme. However, this is only one dimension of the evaluation of the programme's success. The other, and undoubtedly more relevant, will be the evaluation of its effectiveness.

5.5. Assessment of Training Effectiveness

The assessment of the training effectiveness and evaluation of the knowledge transfer has increasingly gained importance for understanding the training real impacts and benefits. However, this is not a straightforward process. Indeed, several studies have demonstrated that the transfer of knowledge acquired during a training session is a complex process that involves several factors [27]. In the meantime, the adoption of e-learning approaches has become more common, and companies are thus experiencing a shift from a traditional physical training environment to e-learning platforms [28]. The difficulties in assessing the effectiveness of training are widely recognized, and the adoption of training approaches based on electronic media could add further challenges. Therefore, and in line with the Baldwin and Ford [29] transfer process model, the training design must envision the knowledge transfer's success.

Table 2. Number of tentative per chapter.

Chapters	Number of Success Quizzes	Number of Unsuccess Quizzes	Number of Total Quizzes	Avg. Quizzes per Attendee and Chapter
CH I-DIGITAL TRANSFORMATION	440	356	796	2.24
CH. II-COLLABORATIVE ROBOTICS	96	271	367	1.35
CH. III-MOBILE ROBOTICS	159	219	378	1.73
CH. IV-IIOT & CYBER-PHYSICAL SYSTEMS	99	239	338	1.41
CH. V-ARTIFICIAL VISION	98	183	281	1.54
CH. VI-VIRTUAL AND AUGMENTED REALITY	196	187	383	2.05
CH. VII-SMART FACTORY	42	210	252	1.2
CH. VIII-BIG DATA	39	194	233	1.2
CH. IX-SIMULATION AND DIGITAL TWIN	27	200	227	1.14
CH. X-SMART LOGISTICS	54	167	221	1.32
CH. XI-PREDICTIVE ASSET MANAGEMENT	186	226	412	1.82
CH. XII-ARTIFICIAL INTELLIGENCE AND DECISION SUPPORT	71	170	241	1.42
CH. XIII-SYSTEMS ARCHITECTURE AND INTEGRATION	65	179	244	1.36
CH. XIV-CLOUD COMPUTING	82	134	216	1.61
CH. XV-CYBERSECURITY	53	167	220	1.32
CH. XVI-SERVITIZATION	31	167	198	1.19
CH. XVII-NEW MATERIALS	81	163	244	1.50
CH. XVIII-ADVANCED MANUFACTURING TECHNOLOGIES	82	146	228	1.56
CH. XIX-ADDITIVE MANUFACTURING	250	154	404	2.62
CH. XX-DIGITISATION OF THE MANUFACTURING PROCESS	49	160	209	1.31

Table 3. Distribution of attendees' roles and position in their organization.

Role and Position	Number of Attendees
Administrative Area	8
Legal Area	3
CEO/President/PCA	14
Consultant	68
Director/Head of Division/Head of Department/Coordinator	120
General Manager	11
Student	89
Commercial/Sales Manager	21
Business Manager	11
Project Manager	76
Researcher	28
Other	90
Professor	30
Partner/Manager/Administration	41
Senior Technician	163

It is recognized that, in general, fewer actions for maximizing training effectiveness are implemented after training courses. Usually, at the end of a training program, experience shows that the vast majority of companies obtained relevant information when measuring participants' satisfaction with training and their learning success [28]. However, assessing the actual transfer of knowledge and the impact on work activity or, at a more tactical/strategic level, the effect on the quality and coherence of decisions is not considered. There is a difficulty in defining and implementing concrete measures that can assess effectiveness. There is undoubtedly potential for improvement in this area.

To assess the training course's effectiveness, we draw inspiration from well-known models that have received significant attention in the training research literature. Thus, we took into account Baldwin and Ford's (1988) model of training transfer and one of the most accepted training evaluation models developed by Kirkpatrick [30]. A four-dimensional measurement is considered (i.e., reactions, learning, behavior, results). Another attractive model was the one provided by Kraiger [31]. This model emphasizes three areas for evaluation: training content and design (i.e., design, delivery, and validity of training), changes in learners (i.e., affective, cognitive, and behavioral), and organizational payoffs (i.e., transfer climate, job performance, and results).

In practical terms, we defined the following instruments to address the assessment of effectiveness:

- Learner reaction through platform feedback mechanism—functionality embedded in the platform and allowing the learner to interact in real-time with other learners allowing the cross-discussion between them.
- Asynchronous interaction with experts—A very important instrument to support the consolidation of the learning process after the course. Particularly rich in order to understand the degree of difficulty and the successes achieved.
- Structured survey related with the application of the learning—instrument with two key components: one offline and one online. They allow the offline component to facilitate a reflection on the effectiveness of the learner's learning process. In addition, the online component again promotes the exchange of experiences, post-course, between different participants.
- Pre and post training benchmark key performance indicators (KPI)—In the course design phase, it was decided to identify a set of measures to assess the level of

literacy of potential participants. For example, measures about the basic knowledge of the technologies, the origin, and date of the technologies, the potential for practical application, the difficulties of application, the level of complexity, the potential for synergies, etc. There was a concern to seek to characterize the universe of participants. To this end, a semi-structured online survey was triggered with the possibility of receiving open answers. This instrument will be used equally after the course and for participants who have completed the course at least after 2 months. This will allow us to study the evolution of the pre- and post-benchmark from the perspective of formative effectiveness.

We intend that after some training rounds focused on this course, and in this case, due to the asynchronous nature, we understand rounds by the number of participants involved over at least one year, we will develop a specific study around effectiveness. At the end of this period, we will have a significant data level, which will allow a robust quantitative analysis.

6. Findings and Conclusions

The digital transformation process is already in place in almost all sectors of the economy and all countries. Precisely, in the industry sector, the industrial 4.0 revolution will shape the planning and manufacturing processes and the new business models that, based on the digital tools, will revolutionize how companies interact with their customers. Consequently, it becomes clear that manufacturing companies, and mainly SMEs, need to become aware of the Industry 4.0 paradigms and understand how its emerging technologies may contribute to the company's business evolution.

As a consequence of this industrial revolution, education needs to evolve to allow current leaders and managers to make the right decisions regarding new digital technology adoption and prepare operators or even students to use and take the most advantage from the emerging technologies. Therefore, companies' leaders and managers need to understand which technologies are needed and how they can be combined to leverage the company value proposition. On the other hand, workers and students need to learn how to use these technologies. Therefore, it is necessary to access updated test and experimental laboratories and the right educational learning platforms. They can have access to knowledge, machinery, data, and digital infrastructures to practice and demonstrate the application of their acquired expertise.

Based on this vision, this paper presents a project that intends to be a first step towards the creation of an overall understanding and awareness of the Industry 4.0 domain within the Portuguese industrial companies. To support this research project, three research questions were proposed in the beginning of this document. The first research question was to identify the right skills and subjects to be addressed, capable of supporting SMEs digital transition. As main outcomes of this research, and based on the focus groups performed, we conclude that a digital transformation course requires a multidisciplinary approach. It is necessary to include not only technology subjects, related with the emergent i4.0 technologies but also business and digital transformation strategy topics. Companies must be able to understand the opportunities, challenges, and barriers to the successful application of i4.0 technologies but also learn how to manage the implementation of these technologies along the time and in an integrated way. Topics related to digital maturity assessment and technology road mapping are becoming more and more important as the complexity, interoperability, and combinatory capabilities between these technologies increase.

The second research question is related to the need to identify the suitable methodology capable to support SMEs' employees and leadership to develop skills and competences for digital transformation. Therefore, the program here presented was conceived based on a hybrid learning strategy, instantiated on a self-directed learning methodology, grounded on the state-of-the-art knowledge and the pre-training benchmark assessment performed to evaluate the training course effectiveness, and supported by reference cases and real applications. Through an asynchronous training approach, the proposed program aims to follow both an expositive learning approach, so that trainees/participants become familiar with a comprehensive set of concepts, principles, methodologies, and tools, as well as an active learning approach, supported by quizzes and communication channels with experts, capable of significantly enhancing decision-making capability at both strategic and tactical level.

The last research question is to evaluate how digital platforms can leverage these new educational methodologies. As main research outcomes, it was possible to implement a digital platform for e-learning on Industry 4.0 foundations. Considering the feedback from the attendees of the course (more than 700 attendees), it was clear that this is an excellent channel to disseminate the knowledge and subjects on this matter, allowing the possibility to achieve a wide range of companies and stakeholders in a short period of time and with controllable costs and resources. Moreover, with these types of educational channels, attendees become able to manage their time, attend the module when possible, and select the topics and subjects more aligned with their needs.

This online and free of charge course is available to all industrial companies in Portugal. When this paper was written, it already had more than 800 registrations and excellent feedback from the attendees on social media. As a consequence of this project's success and understanding, the need to have a different type of courses depending on the audience needs, the authors decided to prepare other i4.0 courses based on innovative concepts, such as hands-on masterclasses performed in specialized learning factories, or even advanced learning programs, with visits to i4.0 lighthouses and innovation labs, targeted for industrial companies' leadership.

As future research objectives, the authors will follow, together with the Portuguese industrial association, the impacts of this type of e-learning course in industrial SMEs and its impacts on their digital transformation journey. The main objective would be to understand better if the educational program presented here could increase industrial SMEs' awareness on digital transformation subjects and technologies. Here, an already existing self-assessment digital maturity online tool will be used to assess Portuguese industrial SMEs' evolution in terms of digital technologies adoption.

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