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Titolo della tesi

Innovative training design for Industry 4.0

Building the skills for the digital transition

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General introduction

Digital technologies are creating opportunities for companies embracing the transition to Industry 4.0, providing novel, powerful tools that promise to tremendously increase the efficiency and the efficacy of their processes.

More than ever, the availability of data, computational power and connectivity promises to sustain people in their activities and decisions. To steer and manage these powerful tools though, requires novel and legacy competences and skills to achieve the full potential of technology, which may act as a booster to the process of creating those very skills.

Unbiased managerial decisions, advanced organizational methods and innovative forms of training are some of the key elements that can enable organizations to achieve the highest benefit from these innovations in technology.

This doctoral thesis aims at studying the relations between some of these elements.

In a first section, a conceptual model was built, aiming at disentangling the effect of the form of training and its reliance on digital technological tools, on the reduction of cognitive biases and performance in tasks related to digital transformations.

This paper has been accepted for publication in the book "Do machines dream of electric workers? Understanding the impact of digital technologies on organisations and innovation", part of the series "Lecture Notes in Information Systems and Organisation (LNISO)". The editors of the book are Luca Solari, Marcello Martinez, Alessio Maria Braccini, Alessandra Lazazzara.

Secondly, the process of developing an innovative learning path for the creation of digital competences and skills, is analysed through a practice-based case study, to test and understand the efficacy of the deployment of an Agile and Stage-Gate hybrid organizational model on development process performance. This second article has been submitted to an international journal for evaluation for publication in a special issue on the topic.

Lastly, a quantitative study is presented, where a dynamic model for training transfer is tested through remotely delivered, innovative forms of training, to understand its efficacy in upskilling learners on the topics of Lean methodologies and digital manufacturing in the context of operations management.

The aim linking these three articles has been to build a focused path on the topic of training to sustain the digital transition for companies. A file-rouge links the three articles, where in the first section, a conceptual model is being presented, posing the challenge of cognitive biases and how digital technologies and innovative forms of training can help to hinder them. In the second article, the topic of innovative forms of training, and specifically of the implementation for these forms of training, is deepened through a practice-oriented case study, aiming at deriving recommendations on how to best design and implement an innovative training journey. In the last article presented, an implemented innovative training path is analysed through an experimental methodology, to test a remotely delivered innovative training, when compared to a traditional lecture-based remotely delivered training.

Reducing cognitive biases through digitally-enabled training. A conceptual framework

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Paper accepted for publication in the book "Do machines dream of electric workers? Understanding the impact of digital technologies on organisations and innovation"

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Abstract. Since cognitive biases impair decision making processes, organizations strive to reduce their effect. Training sustains such effort, especially when innovative learning approaches are adopted.

The introduction of digital technologies, such as those related to Industry 4.0, challenges firms to up-skill and re-skill their employees. At the same time, these technologies offer a new set of tools for training.

This paper proposes a conceptual model that disentangles the effect of the form of training and its reliance on digital technological tools, on the reduction of cognitive biases and performance in tasks related to digital transformations.

Keywords: Cognitive bias, Training, Technology.

1 Introduction

Disruptive technologies will bring significant shifts in the labor market requiring workers and management to develop a completely new set of skills (World Economic Forum, 2020a). Technologies enabling automation, artificial intelligence and machine learning, often labeled as Industry 4.0 (Kagermann, 2015), are fostering an evolution of the social and industrial environment with huge impacts on production systems, creating the possibility to disrupt an increasing number of tasks. The digitalization of product and processes appears even more urgent now, in light of the unpredictable consequences of the COVID-19 outbreak on the organization of work and of global value chains (World Economic Forum, 2020b).

This rapid technological shift is bringing a great productivity increase potential, but also opening a transition phase. It seems that competence creation processes can take place at a slower speed when compared to technological change. This would result in gaps between skills required by firms and skills possessed by the workforce. Therefore, it emerges a need for reskilling, that is possible through innovative forms of training (Balsmeier & Woerter, 2019; Callan et al., 2020; David, 2015).

Digital technology-enabled forms of training promise to endow employees with the skills needed to operate effectively in this new industrial setting as well as to enhance their existing skills. In this paper, we focus on the latter, by outlining a conceptual model that disentangles the effect of digital technology-enabled training on the impact of cognitive biases on decisions within the setting of operations management.

The study of cognitive biases is gaining relevance for Operations Management as this filed is embracing a more human-centered view in its investigation, which entails the full recognition of the bounded rationality of actors and the emphasis on behavioral dimension of the process. This field appears therefore open to fruitful contamination with a well-established stream of studies in Psychology and Organization.

In this piece of research, we study the cognitive biases not only by the adoption of a new heuristic more unlikely to lead to a severe systematic error, but with the adoption of new technologies. Training, and specifically innovative forms of training, have been shown to be effective in reducing and preventing cognitive biases. But may technology play a role in this relation, by means of reducing cognitive biases when performing a new task?

2 Including the human side in operations management

2.1 Towards a behavioral view of Operations Management

The field of Operations Management is changing towards the inclusion of behavioral factors into its scope of analysis. From being a niche subfield, behavioral operations research has more than doubled the number of scientific publication between 2006-2012 and 2013-2017 (Donohue & Schultz, 2019), evidencing a growing interest on the topic, a vibrant methodological pluralism – leveraging on an experimental approach – and expanding from the original topics of supply chain management, product development, quality and production, to new areas of investigation (Croson et al., 2013) such as retail, healthcare operations and social and sustainability decisions (Donohue & Schultz, 2019). What links together these studies, and differentiates them from the earlier streams of operations management research, is the deviation from a hyper-rational conceptualization of decision making in the context of operations management that has long characterized the field (Croson et al., 2013).

Traditionally, operations management studies have assumed that decision makers, problem solvers and workers, are rational or that can be induced to behave rationally

(Gino & Pisano, 2008). As Gigerenzer and Gaissmaier (2011) put forward, rational or intentionally rational decision making rests on tools such as logical reasoning or statistics, and Operations Management research as much emphasized mathematical modeling as statistical testing as a way to advance our knowledge about production systems and to offer managers sound operational tools. However, it has also been suggested that in operations management "…techniques and theories ignore important characteristics of real systems, and therefore are perceived to be difficult to apply in practice. A common factor in this breakdown is people" (Bendoly et al., 2006: 737). To address this shortcoming, the study of operations management has added to its analytical models factors such as people's actions, emotions, reactions and intentions (Donohue & Schultz, 2019). Behavioral Operations Management is a multi-disciplinary branch of Operations Management that explicitly considers the effects of human behavior in process performance, influenced by cognitive biases, social preferences, and cultural norms (Loch & Wu, 2007).

The idea of a non-hyper-rational individual is not new in Organization Studies, at least since Herbert Simon's (1955) development of the notion of bounded rationality. However, the field of Operations Management seems to be lagging behind in the adoption of such perspective, as, still recently, Croson et al. (2013) suggested that any behavior that deviates from the hyper-rational is a candidate for research in that field of studies.

Simon's well-established notion of economic agents are incapable of acquiring, processing and deploying information with complete mindfulness has revolutionized management scholarship as it offered a more compelling alternative to the dominant conceptualization of the "homo economicus" that still characterizes much of Operations Management research. Furthermore, Simon's contribution has emphasized that agents are not capable of always taking rational decisions due to unavailability of complete information (informational limit), and inability to correctly interpreting and processing (computational limit) the limited information available, due to boundaries in time and cognitive limitations of their mind. Digital technologies are having an impact on this landscape as well, posing new challenges to address, as the information overload deriving from big data, affecting strategic decisions (Citroen, 2011) and helping to solve the problem of informational limit while sharpening the problem of computational limit, potentially requiring novel solutions.

2.2 The role of cognitive bias in operations management

Deviating from the tenets of perfect rationality, it is essential to acknowledge that decision-makers adopt other tools, in addition to logic and statistics, such as heuristics. Building on a wealth of studies in behavioral sciences, Gigerenzer and Gaissmaier (2011: 454) offer a definition of heuristic as "*a strategy that ignores part of the information, with the goal of making decisions more quickly, frugally, and/or accurately than more complex methods*". With specific regard to psychology, Katsikopoulos, (2011) defined psychological heuristics as formal models for making decisions that:

(i) rely heavily on core psychological capacities (e.g. recognizing patterns or recalling information from memory);

(ii) do not necessarily use all available information and process the information they use by simple computations (e.g. ordinal comparisons or unweighted sums);

(iii) are easy to understand, apply and explain.

Figure 1 offers a comprehensive view of the conceptual linkages between the notions of bounded rationality, heuristics and cognitive biases.

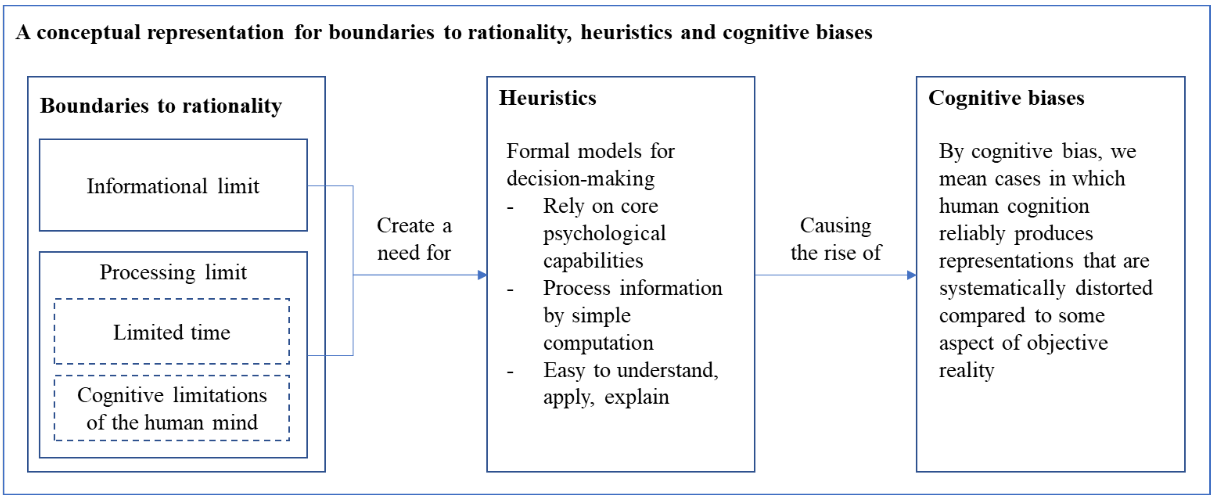

Figure 1. A simplified conceptual framework on boundaries to rationality, heuristics and cognitive biases.

Simplified heuristics, such as representativeness, availability and adjusting and anchoring have been shown to potentially lead to a series of cognitive biases, which in evolutionary psychology are meant as "*cases in which human cognition reliably produces representations that are systematically distorted compared to some aspect of objective reality*" and systematically hinder someone's ability to rationally perform a task or set of tasks (Haselton et al., 2015: 968).

A famous example of cognitive bias is this experiment performed by Tversky and Kahneman (1981) related to decision-making task, that highlights the relevance of information visualization, and specifically of framing in describing a problem outcome in the decisions patterns of two identical problems. Participants were posed the following problem:

Imagine the U.S. is preparing for the outbreak of an unusual Asia disease, which is expected to kill 600 people. Two alternative programs to combat the disease have been proposed. Assume that the exact scientific estimate of the consequences of the programs are as follows:

If Program A is adopted, 200 people will be saved.

If program B is adopted, there is 1/3 probability that 600 people will be saved, and 2/3 probability that no people will be saved.

Program A was preferred by 72% of participants.

The authors then presented the same problem to a different sample with the following outcomes to choose:

If Program C is adopted 400 people will die.

If program D is adopted there is 1/3 probability that nobody will die, and 2/3 probability that 600 people will die.

Program D was chosen by 78% of participants.

This simple, yet powerful experiment, shows how choices involving gains are risk averse and choices involving losses are risk taking. The two problems are though identical from a probabilistic point of view, yet they achieve opposite results, where the only difference comes from framing the outcomes in a positive or a negative way.

The seminal contribution by Tversky & Kahneman (1974) identified three bias categories originating from heuristic processes, namely representativeness, availability and anchoring, which affect decision making. Then, the researchers grouped them based on the hypothesized heuristic strategy that the individual follows in taking the decision.

The representativeness heuristic implies that during a judgement process, probabilities are evaluated by the degree to which A is representative of B, for example by the degree of similarity between them. However, several factors needed to assess likelihood do not play a role in judgements of similarity. Availability refers to the tendency to assess the frequency of an occurrence based on the easiness of recalling an event or topic in mind. Adjustment and anchoring biases the person making an estimation towards the initial value that has been anchored, for instance building on previous data or a partial estimation, where the following adjustment is not sufficient to lead the judging person to the real value.

Since the 1970s, many cognitive biases have been found (Kahneman, 2011), and efforts have been made in reviewing and categorizing them (e.g., Baron, 2000; Arnott, 2006). A recent systematic review has found some potential inter-relation between cognitive biases, strategic decision making and environmental change (Acciarini, 2020), building upon a set of categorization efforts developed to manage the growing complexity of the field. A fundamental contribution in this evolution has been the development of an integrative framework by (Das, 1999), who identified four basic types of cognitive bias, crossing them with five modes of decision making to develop some propositions to advance the field. The biases identified by Das are the existence of i) prior hypotheses and focusing on limited targets, ii) exposure to limited alternatives, iii) insensitivity to outcome probabilities and iv) illusion of manageability. These biases might become particularly dangerous in presence of some selected modes of decision making, including i) rational, ii) avoidance, iii) logical incrementalist, iv) political and v) garbage can.

Interestingly, Dimara et al. (2018) recently built on in a comprehensive task-based taxonomy that appears particularly useful to identify the biases that might occur when performing different tasks. In this analysis of cognitive biases in information visualization, the authors categorized a broad range of 154 biases into bias “flavors” and “task categories”. The “flavors” build on the heuristic concept and try to capture the phenomenon behind the bias, as much previous studies do. These flavors are (Dimara et al., 2018):

1) Association, where cognition is biased by associative connections between information items.

2) Baseline, where cognition is biased by a comparison with (what is perceived as) a baseline.

3) Inertia, where cognition is biased by the prospect of changing the current state.

4) Outcome, where cognition is biased by how well something fits an expected or desired outcome.

5) Self perspective, where cognition is biased by a self-oriented view point.

The biggest contribution in this piece of research was the identification of six defined “task categories” in which systematic biases found in the previous literature can be divided. These tasks are:

1) Estimation, where individuals are asked to forecast the quantity, or the probability of an occurrence. Biases in this task category include, for example, anchoring, availability and spotlight effect.

2) Decision, or choice tasks, refer to situations in which people make choices on a set of alternatives, and tend to be systematically biased towards one of them. Examples of biases in this category are Framing, Automation bias and Status-quo bias.

3) Hypothesis assessment tasks refer to cases in which people needs to confirm or reject a hypothesis conducting an investigation. This category includes a smaller number of cognitive biases, but nevertheless very relevant to the field, such as the confirmation bias, in which people tend to confirm previous hypothesis rather than disprove it.

4) Causal attribution tasks are also prone to cognitive biases. In this situation, individuals are asked to find root-causes and effects of phenomena, where the bias induced derives from their view of themselves, their empathy towards the part involved in the situation, or their belonging to one group over another. Some biases categorized in this task include the group attribution bias, in which group traits are attributed to an individual belonging to this group, or egocentric biases, in which the own contribution is perceived as disproportionately higher in comparison to others.

5) Recall tasks are those in which individuals seek to remember past experiences or knowledge after some time has passed since the event, and misinterpretation or other factors have had the time to occur. Some of the biases occurring include, as an example, digital amnesia, that makes it more difficult to retrieve data easily available thanks to digital solutions. On the opposite, the bizarreness effect makes it easier to remember facts and situations when they are out of the perceived normality. Also, the misinformation effect is an example of bias in this category. In this case, memory is enriched with new pieces of information that were not included in the original experience or knowledge.

6) The last category of systematic biases includes the biases occurring when asking individuals to report others' opinions, mostly on situational sensitive topics. It has been observed that often participants to studies on such biases misreported others' opinions according to specific biases, such as stereotyping, which makes an individual attribute to someone some traits associated to a group he belongs to, or the focusing effect, for which reported beliefs are based on the main and most spoken portion of a message.

Cognitive biases affect a number of different areas related to operations management such as process assessment and risk assessment (Murata, 2018). Various field and laboratory experiments, e.g., Bisin & Hyndman (2020) and Di Mauro et al. (2020), Ancarani et al. (2020, 2016), confirm the relevance and vast diffusion of this potentially dangerous downside.

3 What training for developing operations management skills

Training has been demonstrated to be an effective mean to reduce the occurrence and effects of cognitive biases in different tasks and settings (Ludolph & Schulz, 2018; Sellier et al., 2019). Many de-biasing strategies have been proposed through training, such as rising awareness on biases, their directionality, and the importance of feedback and coaching. However, the efficacy of training in addressing these biases is associated with the design of the interventions.

Training can be conceived as a learning and development process aimed at increasing organizational performance by endowing people with the knowledge, skills and competencies need to carry out their work effectively and successfully (Armstrong & Taylor, 2020). The main domains affecting training efficiency concern Kontoghiorghes (2004):

- Trainee characteristics
- Training design
- Training transfer climate
- Work environment

For what concerns the training design, it is useful to distinguish traditional, scenario-based cases and problem-based experiential learning. The two latter forms of training are particularly effective in achieving the purpose of knowledge transfer in a perspective of re-skilling and up-skilling (Sellier et al., 2019).

Traditional forms of training take the form of frontal lectures in classrooms and apprenticeship for repetitive tasks with the demonstration of an activity to trainees, until they become able to perform it (Kraiger et al., 1993). One of the assumptions of traditional teaching methods is the predictability of tasks in a stable environment, while in an evolving situation with growing uncertainties it is necessary to create adaptive expertise.

Such adaptive experiences may be offered by exposing trainees to cases portraying different scenarios in a real setting, to “learn during their experiences while addressing desired goals” (Schank et al., 1994; Schank, 1996). The development of goal-based scenarios seems to have risen from a critic of traditional training methods concerning the drift towards an excessive emphasis on verifiability and standardization of knowledge, where facts are considered as basic notions with no real life meaning or implication. To create a scenario-based case study, namely a “learn by doing course”, it is necessary to combine simulation and case-based reasoning. The learner has a role to play, which can vary according to observed, real interests of the student, avoiding artificial world problems (Schank, 1996).

The development of problem based learning training modules entails the following activities (Boud & Feletti, 1998):

- Description of the problem provided to the student. The problem may be described either in neutral, clear, non-contradictory, realistic terms and refer to a fairly common setting (Boud & Feletti, 1998), or in an ill-defined fashion with the aim of involving trainees into the development of a complex solution and stimulating the analytical skills of participants (Allen et al., 2011). Realism, complexity and contradiction are on the other side probably characteristics of the working environment in which the trainees will have to apply the skills acquired during the learning.

- Definition of the scope for the problem solving activity.

- Time management. The time allocated to training activities is generally insufficient to address all the issues raised by the problem. A need for prioritizing the activities and allocating the cognitive effort emerges. It should be noted that participation is positively related to the sense of urgency for the problem.

- Design of cognitive conflict and social negotiation opportunities, that should be seen as a stimulus for learning through the evaluation of viability of individual understanding. To this purpose, it is important to encourage to test ideas rather to accept alternative views.

Problem-based learning is probably the most widely adopted experiential learning method within executive development programs (Wuestewald, 2016). Indeed, live projects, a concept very similar to experiential learning, have the highest positive result in terms of successful skill transfer, and, in general, teaching methods that trigger the student to acquire additional knowledge on his own may result in a more positive outcome (Narayandas & Moldoveanu, 2016). Although it is a very effective and motivating technique, it is very time-consuming, and therefore not particularly efficient (Boud & Feletti, 1998).

4 How Industry 4.0 technologies may attenuate cognitive biases

Some of the technologies that are part of the broad Industry 4.0 landscape promise to help to remove or attenuate both the causes of cognitive biases: the unavailability of information, and the human capacity to process information.

In 2013, a group of practitioners and academics at the yearly Hannover Messe enshrined in a Manifesto a set of recommendations for implementing what was called "Industrie 4.0" (Kagermann, 2015). The trend of automation and smart system development in both physical and intellectual contexts emerged decisively, interpreting and linking different new technologies that grew in the beginning of the new millennium, ultimately aiming at keeping competitiveness high, also through an optimized decision making.

For instance, the Internet of things allows for the collection of data through sensors and stacks that contribute to the creation of big data and data lakes constituting an organization's backbone for a data-based decision making. It is a new paradigm of interconnection of final goods exchanging information to provide data, optimization and self-control in the most advanced examples, which are transforming the business world (Porter & Heppelmann, 2015). This concept shares many of the characteristics of "smart factories", where Xia (2012) points out ubiquity, interconnection, glocalization and traceability as core enablers and constituents of this new paradigm, made possible by the low costs of these new technologies and their miniaturization. A further step has been the interconnection of production facilities to this network, captured as the paradigm of the Industrial Internet of Things (Gilchrist, 2016). This further step creates significant implications not only for strategic and marketing-related activities, but also for areas of the field of operations management, for example in production, capacity management and supply chain decisions.

Building on the same technological ground, also lean-empowered product lifecycle management (Hines et al., 2006) can now provide an increased and improved amount of information feeding the product development process, leveraging on big data (Zhang et al., 2017) and cloud to facilitate the exchange and usability of the collected data and information. Many examples of successful industrial implementation of these concepts now exist from aerospace, automotive (Borsato, 2014; Vezzetti et al., 2015), and prove the advantage provided by an enriched base for data-driven decision making.

While some technologies help to solve the information availability issue, others address problem of information processing. For instance, one of the key principles identified in Industry 4.0 is the adoption of knowledge tasks automation systems, such as Robotic Process Automation systems (Van der Aalst et al., 2018) and smart assistance systems, which have the scope of releasing workers from having to perform routine tasks, enabling them to focus on creative, value-added activities (Kagermann, 2015). In this, Industry 4.0 promises to grant more time for individuals inside organizations to take decisions of higher quality, reducing the information processing boundary to rationality.

At the same time, other technologies allow for a better use of this information during the allocated time, enhancing an individual’s ability to select, acquire and process relevant information. This is the case of wearable technologies, able to convey information in more ways than traditional, static visualization, and of VR (Virtual

Reality) when compared to traditional monitor visualization, thanks to its vividness and interactivity (Steuer, 1992) and by immersing the individual in a new, safe to experience of reality, recognizing the need for a better intermediation tool to enhance the cognitive abilities of humans (Chavan, 2016).

Augmented and Mixed Reality go further on this, by bridging the physical and cyber world (Porter & Heppelmann, 2017), enhancing human comprehension and information processing abilities by adding additional layers of information on the reality they see. The application fields are broad, as are the potential gains, that include an improvement of visualization, for example allowing for the inspection of internal components otherwise difficult to see, adding the possibility to test in a safe environment even complex tasks for operators, giving instructions, training and coaching (Porter & Heppelmann, 2017). Further applications included the use of Augmented Reality for prototyping and product testing (Billinghurst et al., 2015), demonstrating their usefulness as technological tools able to enhance humans' information processing ability.

5 How training and advanced technologies help to offset cognitive biases. A conceptual model

The inclusion of human factors into operations management has been a necessary step towards a better understanding of the real-world issues by overcoming the well-established hyper-rational conceptualizations. Embracing the perspective of bounded rationality implies the necessity of acknowledging the effect of cognitive biases on task results. Various studies have then analyzed how tasks in different fields of operations management can be prone to such biases, but training has proved to be an effective way to impair their effect.

The introduction of new technologies – such as those brought by the digitalization of production processes according to the Industry 4.0 paradigm – demand a re-skilling and up-skilling of employees who are asked to perform new, richer and more complex tasks. Training is therefore an essential activity to perform in this new industrial setting.

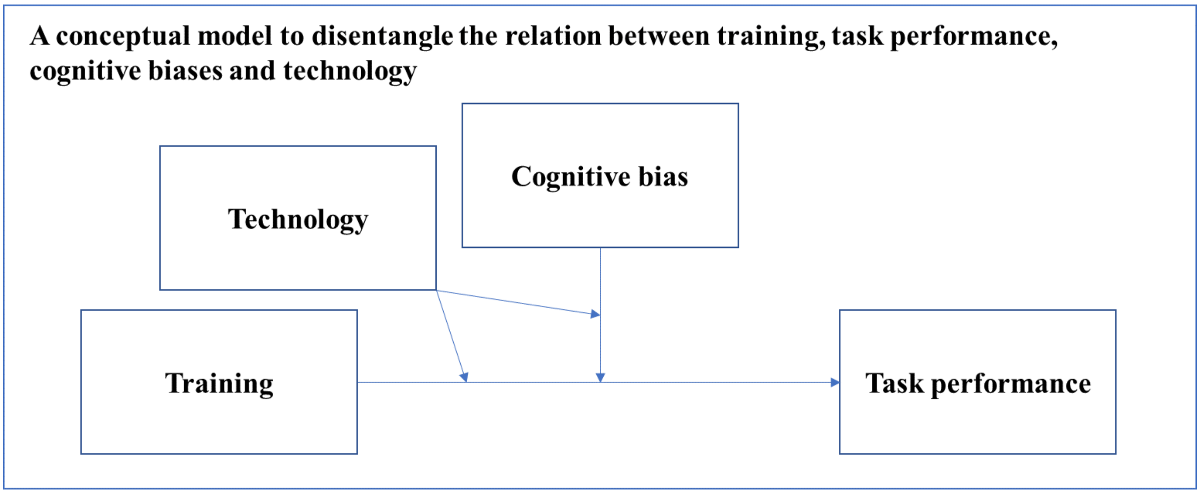

Figure 2. A conceptual model for the study of the relation between training, cognitive biases, technologies and task performance.

On the ground of such considerations, we propose the model portrayed in Figure 2 to study the relation among training, cognitive biases, adoption of new technologies and task performance.

Our model posits a direct relationship between training and the performance of operators in carrying out both existing tasks and new tasks introduced by the adoption of novel technologies. In the latter case, the training effort is more substantial, as employees need to learn completely new skills, competences, behavior and attitudes, since their job may be redefined. However, training is essential even in the case of established tasks, as the adoption of new technologies may alter the context in which such task is performed. An example may be the activity of safety check in a production plant that adopted Industry 4.0 technologies. In such an environment, old and new hazards coexist and the tasks of employees who perform safety check change and potentially become more complex.

We expect that innovative forms of training – such as problem-based scenarios, simulations and role-play – are powerful in improving the operators' performance in carrying out a task, by virtue of their ability of delivering knowledge through a more engaging approach.

However, as previously discussed, operators are prone to cognitive biases while making the decisions required by the task. Through training, operators may learn to be aware and recognize such biases and therefore their effect may be attenuated. We expect that different models of training have a different level of efficacy in attenuating the effect of the biases.

Furthermore, we acknowledge the role of technology as a support for training provision as well as the object of the training. On one hand, the use of technology could enhance the training, offering a richer learning experience. For instance, the use of VR tools that simulate a shop-floor where hazards such as wet floor or incorrect storage are present, may offer trainees a more realistic experience, improve the delivery of content and make trainees more aware of the biases that they may incur when they are evaluating the hazards of a real shop-floor. In this sense, digital technologies contribute to de-bias complex tasks and eventually improve task performance. On the other hand, the use of digital technologies for training may induce other series of biases, associated with the very use of such tools. Trainees may show a different performance in the training and in their operative activities, due to the fact that the training has relied on a specific medium for the delivery of the content. Indeed, the performance in the training may be due to the novelty for the subject of new technological tools, while it might fade away if the technology is repeatedly used.

Such conceptual model can be empirically tested in an experimental setting. In such experiments, trainees may undergo different forms of training, such as frontal lectures, cased-based simulations and digital supported training. Training may address either a task that has been improved thanks to the application of digital technologies or a completely new one. Trainees can be induced different kinds of cognitive biases (e.g. anchoring or overconfidence) through scenario-based manipulations. The joint effect of training method and cognitive biases should be appreciated in terms of learning as well as in terms of change of behavior in the long term.

Disentangling the relationship between new digital technologies, training and cognitive biases on task performance would contribute to the development of the field of behavioral operations, as outlined by (Gino & Pisano, 2008). This effort would also provide evidence of the benefits of the adoption of new technology-based tools when performing tasks that might be prone to cognitive biases, even when de-biasing training has been put in place.

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Effective organizational models for training development – a practice oriented case study

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Abstract. New directions in organizational methods point to Agile and Stage-Gate hybrids as a promising solution, capable of overcoming some of the shortcomings characterizing both methods when taken individually. This practice-oriented case study aims at creating the basis for future studies on this topic in the organizational literature and at defining a methodology for new product development that can be effectively applied by a training center in Northern Italy and can be extended to other knowledge-intensive service providers. The aim is to understand whether this novel, hybrid organizational method is a viable alternative in practice to develop innovative, experiential training modules, incorporating simulation exercises and digital use-cases, co-developed with tech partners, to more traditional training tools.

Keywords: Agile Stage-Gate hybrids, Organization, Training.

1 Introduction

The general objective of this study is to contribute to the knowledge on training development and delivery organizations on the most efficient and effective organisational methods to design a training.

Managers and practitioners face the challenge of selecting the organizational methods to achieve excellence in product development, to build products that meet customer expectations rapidly and efficiently.

Answers from theory seem to point to a hybrid model (Bianchi et al., 2020; Cooper et al., 2014), where two established methods, Stage-Gate and Agile, have demonstrated to bring benefits in terms of project performance over some critical dimensions. Yet, challenges have emerged for the implementation of those systems (Cooper et al., 2018, Dikert et al., 2016) and both theory and practice seek to clarify whether and under which conditions this novel method can provide a benefit to the product development process for the development of physical products and services. Stage-Gate practices have been long known for their ability to grant systematicity, visibility and long-term perspective to project management, while Agile has emerged as a comprehensive set of tools, enabling organizations to deliver value fast and to adapt with flexibility to a rapidly changing environment. The combination of the two has recently been found in literature to be a potential source of competitive advantage, by means of combining the goods of both those methods.

Product development is known for being a highly complex process for organizations, involving different functions and both internal and external actors with extensive interactions and potential coordination issues. For this reason, practice and theory have been studying and experimenting with organisational methodologies to best manage this complex process.

New directions emerged from theory in recent years on the best alternative or synergic solutions that can be adopted when managing a product development process, with a fervid discussion on the interplay, challenges and opportunities arising from hybrid models combining Agile and stage-gate (also known as phase-gate), (Sommer et al., 2014, Cooper, 2014). Yet, recurring extensive studies (Michaelis et al., 2018, Lee & Markham, 2016) highlighted how that firms are largely still unable to achieve satisfactory results when developing new products over several critical dimensions, such as the time-to-market, cost of the new products when compared to initial budgets and number of ideas pursued for one good product launched in the market.

Several organizational prescriptions emerged in the latest years trying to address this issue, some of which from the manufacturing environment (Edwards et al., 2019, Cooper & Sommer, 2018) and some from the service environment (Bianchi et al., 2020). It is yet still not totally clear which are the key success factors and conditions for a successful adoption of this novel organizational method (Antons et al., 2019, Dikert et al., 2016). This piece of research aims to understand which are the organizational requirements of this novel method, such as Lean fundamentals (Sonnenberg, 2011), leadership practices, learning strategies (Beaumont, 2017) and others.

Organizations providing training and development have been studied to collect best practices and prescriptions on the key features, and elements to consider, that a training product should possess to achieve its goals (Sellier et al., 2019, Wuestewald, 2016, Kontoghiorghes, 2004). Yet, to the knowledge of this author, the best processes to develop such training products have not been studied thoroughly. In this context, development is intended as the development of novel approaches to training, where technologies offer great opportunities which can also bring a competitive advantage to these organizations.

This study aims to understand how the Stage-gate and Agile methodologies can be combined to foster the design and delivery of a training course that deals with the topic of digitalization of business process and adopts an interactive approach. As this study adopts a methodological stance based on the “practice-oriented case study” (Bleijenbergh et al., 2011), it pursues the goals of enhancing the capabilities of the management team of the training centre in new product development.

This article contributes to the literature on product development, and specifically to the growing discussion on the assessment of the efficacy of Stage-Gate and Agile hybrid models. In this field, evidence is being collected through a growing body of case-studies, (Edwards, 2019; Cooper 2016, 2018), but more evidence is needed (Bianchi et al., 2020) to fully understand and systematize this recently born, promising organizational method, to fully understand its applicability and requirements.

This work is articulated in a literature review of organizational methods for product development, built around the Lean fundamentals of the subject, then proceeding to study the Stage-Gate and Agile-Scrum approaches separately, trying to understand the context where they were originated, their potential benefits and potential sources of challenges. The article then studies the practice-oriented research as part of the case-study methodology, to then analyse the selected case in the section regarding the findings, where the training centre being studied, and its product development processes have been described. The results of the analysis are then presented, based on the strategic project leadership framework (Shenhar, 2004).

2 Literature review

2.1 Lean product development fundamentals

The evolution of the product development field has been rich in theories developed and studies conducted. Here we analysed background information on the evolution and history of the subject, without the ambition to develop a holistic view of the field, but to understand the case being investigated in the context of the previous theoretical ground.

A first systematic methodology to rapidly revolutionise previous paradigms in product development in recent history was lean management, developed after the second world war in manufacturing environments and rapidly diffused to other organisational settings. Topic studies in the car manufacturing industry (Womack et al. 1990) highlighted product development as a pillar of the competitive advantage acquired by Japanese car manufacturers when compared to American and European counterparts, with a superior performance across some major indicators monitored. The Lean methodology brought several prescriptions to increase efficiency and improve quality of the products being developed, far beyond manufacturing itself (Liker & Morgan, 2006).

Several constructs have been identified in literature, which are set to provide those outstanding results, achieved through the deployment of Lean methodologies.

One of the first elements of lean is coaching, also achieved through a servant leadership approach, based on trust and clear communication about objectives, with management based on experience and mastery (Anthony & Anthony, 2016). People systems in this context are a key element, through a direct commitment and engagement of the leaders, empowering and delegating their teams also by means of creating risk-free environments (Sonnenberg & Sehested, 2011).

Creating a learning culture is also a key success factor (Manville et al., 2012) in the lean methodology applied to services (Liker & Morgan, 2006) and innovation programs in general (Ward & Sobek, 2014). This can be achieved through a focus on *kaizen*, continuous improvement, corroborated by a strive for excellence and the engagement of employees (Angelis & Fernandes, 2012), also achieved through the celebration of success.

The creation of a collaborative structure, which can be intended as self-regulative forms of governance for teams (Angelis & Fernandes, 2012) and engagement for decision making and continuous improvement.

Lean principles also involve external actors through the creation of collaborative external networks (Tuli & Shankar, 2015) both upstream and downstream. The direct involvement of customers through engagement in the development process and in the definition of customer requirements (Solaimani et al., 2019a) is considered fundamental in this methodology. Supplier and stakeholder involvement have also been showed to be beneficial, through the development of study groups and collaborative problem solving (Tuli & Shankar, 2015).

Another construct relevant to lean product development are learning routines based on tools that can foster problem-solving and the systematization of knowledge, such as the PDCA approach, 5 whys, *Ishikawa* diagrams and others (Solaimani et al., 2019b). To this regard, another key element found in literature is the systematization and sharing of knowledge acquired through systematized knowledge sharing and transfer, also across different projects (Hoppmann et al., 2011).

2.2 Stage-Gate systems

The answer of American car makers to Lean product development was the adoption of the Stage-gate system, which has been reportedly been present in up to 60% of US companies, altogether with cross-functional development cooperation, in the early ‘90s (Griffin, 1997), trying to evolve from a “technology push” to a “market pull” orientation (Cooper, 1990).

This system is a structured, systematic, and prescriptive approach, and is based on different stages alternated with decisional gates to decide which concepts should proceed to the next stage (Cooper & Kleinschmidt, 1993). It is a cross-functional process including actors from marketing, sales, and operations alongside technical personnel and it has multiple stages spanning the entire idea-to-launch chain, from idea generation through the business case and market launch (Cooper, 2011).

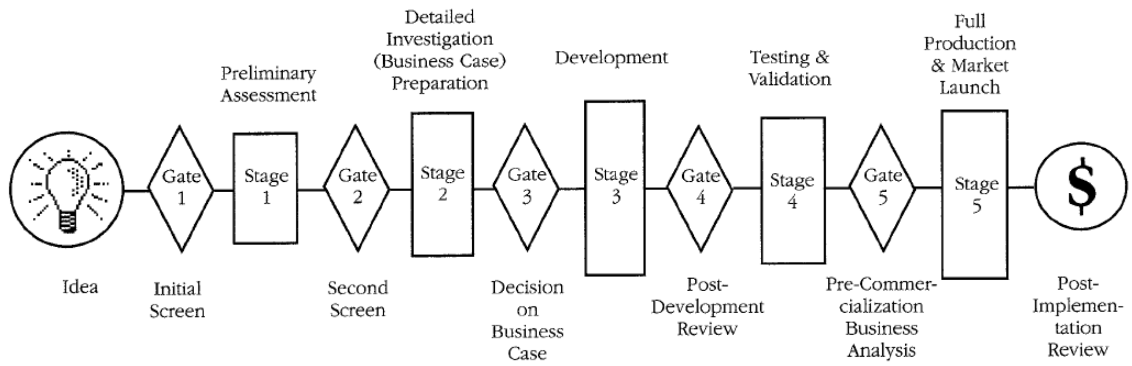

Figure 1: an overview of a Stage-gate system. From: Cooper (2011).

In Stage-Gate, the process is initiated by a new product idea, followed by a first gate consisting in an initial screening. The purpose of this gate is to keep fewer ideas, to be carried out through a detailed “must meet” checklist and a scoring model, including for example the strategic alignment, feasibility, differential advantages, but no financial criteria would be considered at this stage yet (Cooper, 1990). The Stage-Gate approach would then proceed by iteratively deepen the granularity of analyses, while increasing the financial commitment of the company at every decisional gate. Products passing a gate, would go ahead to the next phase, while products failing to pass a gate would then be discarded, or reworked in the previous phase. Stage-Gate does not assume that the same team working on a project on one stage would stay on the project for the following phases, and communication is granted through detailed information being frozen in the form of internal reports and documentation to transfer knowledge to the following steps (Sommer et al. 2015).

This approach would then lead to the development stage, where all product features would be developed, possibly applying the concurrent engineering principle (Koufteros et al., 2001), to then reach an already fully functioning and fully complete product. After the completion of the development of the product, a thorough testing and validation stage would start, followed by the last phase, with the full production and market launch. In Stage-Gate, feedback is then gathered at the end with a post-implementation review following the commercialization, with an evaluation of performance across several levels, including financials. A critical assessment is also performed to define strengths and weaknesses of the project for the organization learning.

This formal approach has been widely adopted (Lee & Markham, 2016), and demonstrated several benefits, by enforcing discipline and standardization into a previously unstructured process. It also showed to grant top-down visibility and simplicity in each stage, so that the overall process is understandable, and provides a road map for the actual planning, the objective setting and the tasks of the project leader (Cooper, 1990). It can enable management to have a holistic view and to take strategic decisions across different projects, deciding to re-direct resources at each gate (Lee & Markham, 2016).

Stage-Gate systems have also been revisited to adapt to externalities and environmental instability, with the development of new, lighter approaches relaxing some of its prescriptions (Cooper et al., 2002) and have evolved incorporating concepts of open innovation (Grönlund et al., 2010) to better capture customer feedback into the development process.

At the same time, some potential drawbacks in this approach have been identified. It comprises a potential risk for rework between different phases, particularly if communication has not been effective. Contrarily to Agile and Lean practices it also sets formalized validation and testing only after the development process, where this is embedded in every development cycle. More broadly, parallel, or concurrent engineering tends to be in Stage-Gate a characteristic of individual phases, such as development, rather than an inter-phase activity (Koufteros et al., 2001) as in Agile. In Stage-Gate, extensive documentation is produced as well during each phase (Sommer et al., 2015) and reviewed at the beginning of new phases, where teams might change. Other criticalities emerge specifically in the development stage, where this approach does not provide tools and detailed prescriptions (Sutherland & Schwaber, 2013), and it’s possible that inside phases work might become individually carried out by single individuals or functions, with a risk to create “knowledge silos” if a strong communication commitment is not embedded in the organizational culture.

2.3 Agile-Scrum methodologies

Some of the core constructs part of the Agile methodology emerged as early as the 70s, (Abbas et al., 2008) striving to provide a faster, more reactive, and more flexible response to customer needs when compared to the Stage-Gate approaches. Agile has originated from the software development environment and is less structured compared to Stage-Gate. The concept of Agile has been conceptualized in 2001 in its manifesto.

Narrowing the description of Agile to product development, there are three main constructs. An iterative approach is adopted in the process of product development, striving to provide a prototype, or minimum viable product (MVP) at the end of the development cycle (Cohen et al., 2004), addressing unknowns and reducing uncertainties by clarifying the desired solutions. Teams are the core of the development process, with a stress on multidisciplinary to cover for all skills needed in the development process, where this might be declined into a part-time commitment to the project, with a reliance on external partners or experts (Beaumont et al., 2017).

Governance is regulated taking some concepts from the Lean methodology, such as the *sensei* figure, the product owner and master with a full picture of the overall process.

Agile is focused on individuals and interactions over processes and tools, while a working product is to be preferred over comprehensive documentation.

The adoption of Agile might face some difficulties, undermining an effective adoption of the new system and its results. Some typical hurdles start with the tendency to fall back to comfortable pre-agile processes (Beaumont et a., 2017), or with resistance to change from other parts of the organization, for example the governance still acting in a command and control way, where a possible solution might be to rely on external "shadow-aid" to tutor the team and smooth the interactions between different organizational functions.

Item	Agile principle
1	Our highest priority is to satisfy the customer through early and continuous delivery of valuable software
2	Welcome changing requirements, even late in development. Agile processes harness change for the customer's competitive advantage
3	Deliver working software frequently, from a couple of weeks to a couple of months, with a preference for the shorter timescale
4	Business people and developers work together daily throughout the project
5	Build projects around motivated individuals, give them the environment and support they need and trust them to get the job done
6	The most efficient and effective method of conveying information with and within a development team is face-to-face conversation
7	Working software is the primary measure of progress
8	Agile processes promote sustainable development. The sponsors, developers and users should be able to maintain a constant pace indefinitely
9	Continuous attention to technical excellence and good design enhances agility
10	Simplicity the art of maximizing the amount of work not done is essential
11	The best architectures, requirements and designs emerge from self-organizing teams

12	At regular intervals, the team reflects on how to become more effective, then tunes and adjusts its behaviour accordingly.

Table 1: the Agile software development manifesto principles. From: Beck et at. (2001).

Agile practices are often associates with Scrum, a methodology within which people can address complex adaptive problems in a developing environment. Born in the ‘90s, it has already been adopted by many companies, aiming to cover the full process of product development, greatly focusing into micro-activities to enhance productivity and creativity to deliver products fast (Sutherland & Schwaber, 2013).

Similarly to Agile, Scrum focuses on the development of a product through sprints, where each sprint is preceded by a meeting in which to decide how to create value to the customer, what should be prioritized for the following sprint, and which work would be needed to achieve that goal.

Scrum consists of sprints, already partially conceptualized in the agile theories, consisting of limited, short timeframes where to concentrate the dedicated effort of the team to ideally get a working product, where it is possible to shown a result to the internal or external customer at the end of the sprint to align the product to the voice of the customer, checking consistency. The full product development process is then composed by a body of different sprints, each one ideally resulting in a working prototype, or a visible improvement in an existing prototype (Vedsmand et al., 2016).

Scrum also consists of a formalization of auxiliary, preparatory and reviewing activities to support the actual development phases. The team’s and organization’s experience is formalized into a product backlog containing the products and solutions already, to provide support in the planning and problem solving activities. A sprint planning meeting is set to plan the sprint activities, reviewing the product backlog, estimating the "sprint backlog", the current activities to be performed during the sprint, and to reassure the sprint alignment and commitment. The duration of the meeting is set to be no more than 8 hours (Vedsmand et al., 2016)**.** Daily meetings are set to last for a maximum of 15 minutes per day to share what was done since the last meeting, plan the day's activities and share impediments or challenges for the development teams. The last introduction develops the lean kaizen concept of continuous improvement. Scrum also advocates the adoption of a sprint review meetings at the end of each sprint to demo the outcome of development to the stakeholders involved, while retrospectively evaluate the sprint process, assess needs for adjustments and feed the product backlog with successful problem-solving solutions.

The introduction of Agile practices, particularly when the scale of the organization is large (Dyba & Dingsoyr, 2009). A number of potential drawbacks may arise in the implementation of purely agile practices (Dikert et al., 2016), some of which might be extended to the Stage-Gate Agile hybrid models (Bianchi et al., 2020). Among these struggles, a deep comprehension of Agile itself and its implementation requirements, as well as the integration with non-development functions are particularly relevant, but change resistance, also from hierarchical management is much reported (Chow & Cao, 2008, Boehm, 2002). Difficulties in the engineering of requirements are as well an important issue in macro-planning and in high-level requirements management (Dikert et al., 2016, Hodgkins & Hohmann, 2007).

2.4 Agile and Stage-Gate hybrid models

Recent developments in literature point to Stage-Gate and Agile hybrid models as the new perspective for product development organizational methods (Edwards et al., 2019, Antons et al., 2019, Cooper & Sommer, 2018) to overcome the limitations of Stage-Gate and Agile when taken individually. These systems try to combine the benefits of Stage-Gate and Agile-Scrum methodologies for product development, as companies in different industrial sectors are growingly interested in capturing the advantages of flexible solutions to manage external complexity while keeping the benefits of top-down visibility and long-term planning (Edwards et al., 2019).

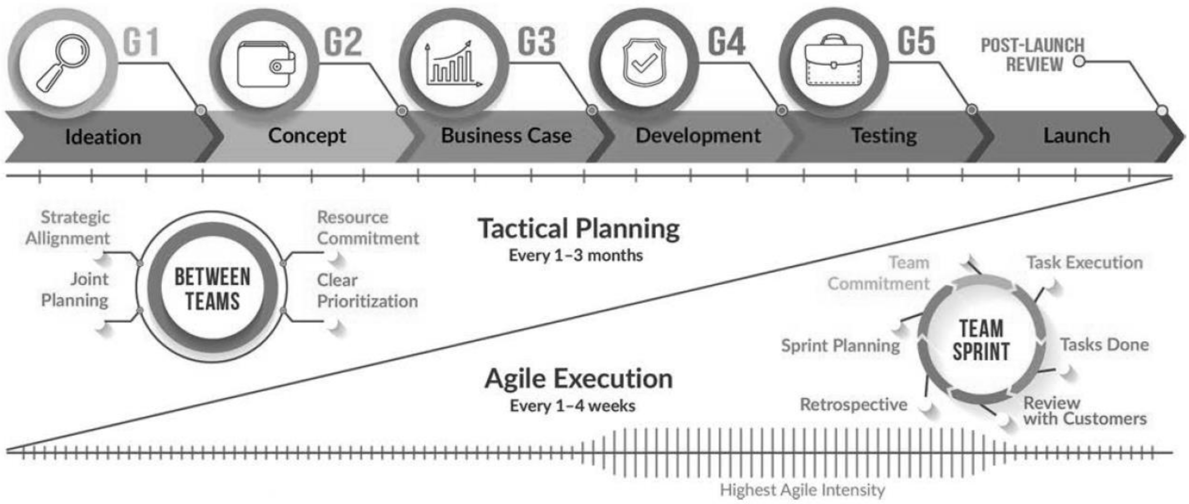

Figure 2: a typical Agile–Stage-Gate hybrid model, with Agile sprints built into stages. From: Cooper et al. (2018).

While, as mentioned, Agile was initially developed for the IT industry, manufacturing and physical products have traditionally been adopting Stage-gate models (Cooper, 2016). This paradigm has now been questioned, as industrial companies are adopting hybrid methods, with beneficial results being reported in different settings (Bianchi et al. 2020, Conforto & Amaral, 2016, Sommer et al., 2015). However, the mechanisms underlying these benefits are still being studied. Preliminary results seem to point to Agile tools inside Stage-Gate as providing improved collaboration, knowledge sharing and visualization as possible key success factors (Sommer et al., 2015).The research has shown how the combination of Stage-Gate and Agile sprints is positively associated with speed and quality performance, but that Agile specification negatively relates with speed performance (Bianchi et al., 2020), possibly for the conflict existing between freezing specifications early in Stage-Gate practices opposed to the constant adaptation to changes in specifications that is advocated by Agile at the end of every time-boxed sprint.

Micro-planning seems to be improved in this hybrid approach, while increasing flexibility by incorporating customer feedback into the development process, contrarily to purely Stage-Gate models (Cooper, 2016). Additional benefits span to the macro-planning level, allowing for higher visibility, transparency and risk mitigation when compared to purely Agile models (Karlstrom & Runeson, 2005).

3 Method

3.1 The practice-oriented case study methodology

Case studies have long been known as a useful tool to disentangle the relations between actors in product development (Bonaccorsi & Lipparini, 1994) and methodologies to foster this process (Liker & Morgan, 2011), confirming a need in this rapidly evolving field for recurrent in-depth analyses to validate and test new advancements being made in theory and new practices developed in companies and organisations.

To achieve the goal of this study, the practice-oriented research methodology (Dul & Hak, 2007) has been selected as it "*…aims at a group of problem owners or stakeholders of a problem in their task of taking an adequate decision or formulating an efficient solution to a problem by means of making use of participatory strategies*" (Bleijenbergh et al., 2011).

This study aims to strengthen the design development, and delivery of innovative training modules in a training center focusing on digital technologies. Specifically, the study aims at understanding *how* the principles of Stage-gate and Agile methodologies can be combined to strengthen the efficacy of the development of a knowledge-intensive product.

3.2 Case selection

This study investigates the case of the introduction of a new line of service within the offering of a center specialized in experiential training for managers and professionals.

This case was selected on theoretical grounds, as it represents an extreme case. In fact, training is a category of knowledge-based services that is characterized by the prevalence of intangible features and its value is highly dependent on the interaction between producer and user. The design of the service poses additional challenges to the producer, that needs to anticipate the variability of the forms of interaction. These challenges are augmented when the training service builds upon an interactive approach, that combines teaching with physical artifacts.

The study of this case is expected to provide insight about the suitability of a hybrid approach with specific regard to highly challenging product development initiatives.

3.3 Validity criteria

This practice-oriented research builds on data collected through a qualitative in-depth analysis of a single case study. This method builds upon the case study methodology (Yin, 2015), and relies on those developed for theory-oriented research (Bleijenbergh et al., 2011), derived from the positivist tradition (Crook & Garratt, 2005), where four criteria are commonly used to assure rigorousness of the research process: internal and external validity, construct validity and reliability (Gibbert et al., 2008). These four criteria have been received and adapted in the context of practice-oriented research (Bleijenbergh et al., 2011), where some additional criteria have been considered.

Internal, or logical validity refers to the existence of a causal relationship between the variables observed and the results. In this case, the performance outcomes of the application of an organizational method have been derived from the review of the literature, where a relation has been drawn from the deployment of an organizational method and the predicted outcomes (Bianchi et al. 2020). Moreover, the patterns observed, are consistent with the literature reviewed, and a triangulation has been performed during the observation of the case and the interviews performed, to assess the recognition of phenomena and dynamics from different actors involved in the process observed.

Construct validity refers to the extent to how constructs are translated accurately into the operationalization, where there needs to be a clear chain of evidence to depict the translation of initial research questions to the final conclusions. Triangulation should as well be used to look at the same phenomenon from different data sources. In this study, data triangulation has been pursued through the observation of different sources of data, such as internal reports from the periodic reviews, the direct observation of tools used, such as collaborative platform environments, interview data to different cohorts of actors, including the development team, the steering committee management team, and training recipients, and participatory observation by the researcher of different key moments of the design, development and delivery of the training product being implemented. Data and observations had been collected also thanks to an established partnership between the training center and academic partners.

External validity, or generalizability, is intended as the degree to which the results or inferences of one study can be applied to different settings and populations other than the unit of analysis (Gibbert et al., 2008). This criterion is deemed to be less important for practice oriented research than for theory building, having its focus on addressing a problem in a specific context (Bleijenbergh et al., 2011, Dul & Hak, 2007), where the contribution in the development of more general knowledge on a specific topic can be achieved through a higher analysis of a series of practice-oriented studies, which has been argued not to be necessarily the scope of individual studies (Calder et al., 1982). In this piece of research, an attempt to achieve external validity has been made through the adoption of a nested approach, analyzing the unit of analysis, one workstream in the context of a greater project, granting visibility on other workstreams within the same organization.

Reliability aims at minimizing the errors and biases in a study by means of allowing for the replication of the study, for example documenting the procedure followed (Yin, 2015). Yet again, in the case of practice-based research, reliability is less significant (Bleijenbergh et al., 2011) due to challenges in repeating measurements and has a reportedly blurred boundary with a different criterion, which is specific of practice-based research: the concept of verifiability. In this case, to be as reliable as possible by analyzing the case observed, and to provide verifiability and transparency, the strategic project leadership framework (Shenhar, 2004) has been adopted as a protocol of analysis. The concept of verifiability "emphasizes the openness and transparency of the knowledge production in practice-oriented research (Bleijenbergh et al., 2011), and has been targeted by sharing results obtained through a clear summarization and representation of the knowledge acquired, also thanks to the deployment of an existing framework.

As mentioned, in practice-based research, some additional criteria should be present to assure rigorousness of the study performed, other than the previous, namely comprehensibility, acceptance and holism (Bleijenbergh et al., 2011).

Comprehensibility responds to a need for the target population to adapt its behavior corresponding to the recommendations or the resulting decision making. This implied an effort to shape the results in clear, common-sense language, with operational practical implications.

Acceptance refers to the willingness of the group whose needs have been addressed in the study to recognize themselves in the results and to be committed to implement them.

Holism calls for an understanding during the analysis of the whole problematic phenomenon, instead of focusing on individual aspects or relations. To address this issue, attention has been put in the analysis and the discussion to describe the context and the super and sub-systems to which the unit of analysis was related.

Data collection has been performed aiming at applying data triangulation as means to increase the quality of the research performed (Yin, 2015, Denzin, 2009). To achieve triangulation, different data sources have been considered. Unstructured interviews have been performed with different actors from the organization for the project being studied, among which development team members, middle management, managers from the steering committee. External actors have been considered in the study as well, with interviews performed to technological partners. The participant observation (Noor, 2008) technique has been used to observe some key moments in the process, such as daily scrum meetings, periodic steering committee review meetings and delivery to the customers. Documentary resources and other resources have been analyzed as well, including the documentation presented during steering committee review meetings, development team coordination tools (online Kanban boards) and client feedback modules collected at the end of the product testing phase.

The practice-based case study research approach required to identify a unit of analysis that was representative, complete, and manageable during the study. To achieve these objectives, one of the several workstreams being pursued in the greater context of the selected group needed to be identified. The unit of analysis needed to be a typical case, representative (Yin, 2015) of other present and future projects that would be endeavored by the group. This representativeness had been identified with the group of problem owners (Bleijenbergh et al., 2011) with the selection of a workstream regarding a topic where previous experience from the group was negligible, where at least two external tech partner would be involved, and where all three elements comprising the offer of the center would be included: a lecture-based learning module; a simulation exercise and at least two digital use-cases.

3.4 Validity criteria

This practice-oriented research builds on data collected through a qualitative in-depth analysis of a single case study. This method builds upon the case study methodology (Yin, 2015), and relies on those developed for theory-oriented research (Bleijenbergh et al., 2011), derived from the positivist tradition (Crook & Garratt, 2005), where four criteria are commonly used to assure the rigor of the research process: internal and external validity, construct validity and reliability (Gibbert et al., 2008). These four criteria have been received and adapted in the context of practice-oriented research (Bleijenbergh et al., 2011), where some additional criteria have been considered.

Data was collected striving to follow three principles, from Yin (2015): 1) the use of multiple sources of evidence, 2) the creation of a case study database, and 3) the maintenance of a chain of evidence.

The use of multiple sources enabled for the triangulation of both in-source triangulation, for example the comparison of different answers given in open-ended interviews by multiple interviewees, in the case of the evaluation of some areas of the strategic project leadership framework (Shenhar, 2015, 2004) adopted, and for triangulation between different source categories, for example the triangulation of information from focus interviews to the management and from surveys to trainees in the case of the evaluation of the overall success of the process developed. The convergence of evidence from different sources triangulated, led the conclusions formulated.

The principle of creation of a case study database was followed by gathering in one folder all evidence collected, organized by the main source category (interview, direct observation, documents and records, tabular materials coming from surveys). Data has then been reduced, by archiving information not related to the case studied, such as technical documentation strictly related to technical details of the solutions being developed by the team rather than on their organization, coded across the areas of the strategic project leadership framework and coded into strengths and challenges observed by each area.

To maintain a chain of evidence, the case study results have been articulated into the areas of the selected framework, with the aim to achieve a collectively exhaustive report of the project analyzed to assess the success or unsuccess of the studied organizational method within the case observed. These results were derived from the database, where specific evidentiary sources have been coded according to the framework observed, with a direct link created in the findings through the use of direct citations. Ultimately, case study questions and requested documentation were originally collected aiming at covering the areas identified by the selected framework.

Although the criteria of validity of qualitative research are relevant also in practice-oriented research, they have lesser importance compared to the practical relevance. As Bleijenbergh et al. (2011, 146) state: "*…we argue that these [traditional] criteria are not adequate to meet the specific needs of research that is directed at solving practical problems. For practice oriented research external validity is of less importance than for theory building, since the knowledge is primarily developed for a specific case. Also reliability is less significant, since repeating a measurement is practical not feasible. In contrast; the practical utility of these research results is much more important than in theory oriented research. Criteria are needed to evaluate the quality of practice oriented research in general.*"

In this perspective, to grant verifiability and transparency, the strategic project leadership framework (Shenhar, 2015, 2004) has been adopted as a protocol of analysis, to map key success factors and challenges identified. The framework has been selected for its fit as a comprehensive approach to project management. This framework is built around five main areas, described in the following paragraphs.

Strategy: covers a missing link between the business strategy and the project plan. It incorporates elements of analysis of the competition and their translation into competitive advantages. It is defined as a clear vision and direction on the objectives of the process as well as the process to achieve them, to gather the best value from the project outcome.

Spirit describes how leaders formally bring their teams to overcome obstacles, energize and create excitement with an inspired state of mind focused on a project expected achievements.

Organization describes how the project is organized and is the main focus of this study. It comprises a description of the organizational methods adopted, as well as the implicit or explicit trade-offs encountered and managed.

Processes relies with the different activities performed, based on different knowledge areas. They include communication and information, as well as monitoring, control and review.

Tools in this framework are intended as subordinate to the previous elements, to serve in the different processes and help in streamlining and managing activities.

4 Findings

This paper studies the case of the development of a learning module on the application of digital technologies in research and development. This learning module is part of a course on digital transformation directed to professionals and executives. The course is offered by an experiential training center that allows trainees to interact in a hyper-realistic environment, i.e. to interact with people and machinery that closely reproduce the processes of a real company. Training modules typically start with an introductive briefing where a traditional lecture-based approach is used to transfer skills for the topic, and participants are asked to share their previous knowledge and experience. Secondly, an exploration phase starts, where participants get to explore an “as is” process with the aid of guiding templates. Participants in this phase interact with actors, machines, tools and documents that are designed to bring alive several typical issues and inefficiencies. Reflective observation and re-elaboration then start with the help of a coach, where participants analyze and conceptualize key learnings from the assessment of the “as-is” state. Later, participants experiment by applying theory to the process previously assessed, and are brought to design an optimized, “future-state”. At the end of the learning journey, participants are shown a possible “future-state” solution, where those actors, machines and tools previously observed are now organized according to the principles transferred, and in some cases sustained with the help of new technological solutions. A consolidation phase, where reflections upon the entire path and which concepts could be used in the participants’ context of origin, concludes the journey.

The development of one of these training modules was observed in the course of this study. This was part of a larger effort to increase the modules available for the experiential training center, whose main shareholders are a multinational strategic consultancy company, and an industrial association.

This training center is focused on the development and delivery of experiential training sessions, with a vision to “Instill in everyone the awareness of their potential and strengthen the capacity for continuous improvement”, and a mission to “Provide to manufacturing and service companies the expertise needed to achieve operational excellence and to successfully implement the digital transformation through an effective combination of scientific approach and a hands-on experience.” This center was founded in 2011, at a time when companies in this geography were struggling from the fallout of the subprime mortgage crisis. Legacy, structural inefficiencies in organizational methods and work practices had been identified by an extensive assessment commissioned by the founding industrial association of the training center. These inefficiencies, previously neglected, emerged abruptly after the financial crisis, when criticalities in the processes of the SMEs forming the backbone of the local economy, especially found in the operations area, could no longer be mitigated through access to credit. To take action against this phenomenon, the founding partners decided to create a center for competence building, to instill critical skills for process improvement, particularly through the deployment of Lean practices.

The approach applied to transfer knowledge in the center proceeds in consequent steps, defined by the founding institutional partners: creating awareness, demonstrating the potentials in production systems and service operation, learning, and implementing by participants in a real context, transferring learnings to own organizations from training participants.

To achieve these goals, exercises and the application of theory are built around a simulated process representing a factory, manufacturing compressors for household appliances. There are two real production lines, complete with manual and CNC machinery with operators trained to bring alive potential issues, common pitfalls and pain-points of a specific function or process. It is a demonstrative site to enable to directly experience new technologies, best practices, and successful approaches, to learn by practicing and applying concepts previously transferred through a lecture-based approach. The goal of the center is ultimately to build team capabilities for participants and to help in the training of internal experts, while acting as a testbed for new Industry 4.0 technologies, formulating best practices and achieving performance breakthrough.

When the training center was first established, the hermetic compressor was chosen for its average complexity level, not too simple and not too complex to be machined and assembled to require an excessively long time to be understood, and yet representative of the average process and product complexity from companies in the reference geography. The product consists of different modules: an electromechanical group built around a casted pig-iron body, with a stator and valve; a shell group providing protection and support to the other modules; an electrical group providing power, and a digital module collecting and transferring data from sensors on the product. After 10 years since its founding, the management of this training center felt a need to renovate its offering, and consequently its physical and intangible assets through a step-change renovation going beyond the continuous improvement that still had been in place. A large-scale effort was started, with financial, human, know-how and other intangible resources from institutions, partners, and companies to build learning modules aimed at creating skills and competences and increasing the efficiency and effectiveness of the end-to-end processes in the value chain of a company. The input to start the development of these products was given by a clear vision, shared by both institutional partners, to broaden the scope of the training center, which was initially focused on operations management only, across an ideal end-to-end value chain, spanning from research and development to aftersales support, to meet growing requests from actual and potential customers and partners, and to ultimately consolidate and grow a distinctive competitive advantage in its training capabilities.

In the context of this greater effort, several different workstreams were started to cover different functional elements of a model company value-chain, altogether with staff functions.

The selection of the unit of analysis for the study followed the rules identified in the methodology. Among the different workstreams, research and development emerged as the most promising candidate, following all three prerequisites identified. There was negligible, scattered previous experience regarding this function in the development group, and information needed to be researched and processed with the help of experts both external and from the founding partners. There were three major different external tech partners pre-identified for the implementation of the use-cases, and all three elements comprising the offer of the center would be included: a lecture-based learning module; a simulation exercise and at least two digital use-cases.

The management team of the project decided to adopt a phase-gate approach for the execution of the project. This methodological opportunity allows us to appreciate the extent to which the principles of the approach have been actually implemented and the nature of the deviations and hybridization to the canonical approach.

The project was enacted through periodic steering committee meetings, occurring on average every three weeks, over a period of 14 months. This allowed to govern the macroplanning, where the entire process, which had been divided into 11 workstreams proceeding in parallel, and monitored through defined phases, was managed by a definition of the main milestones to reach within a fixed time, with more strategic decisions to be taken, by workstream. This resounds with the theory reviewed, which highlighted how stage-gate is a preferrable option to grant visibility to the decision-makers, enabling strategic decisions to be taken rapidly and more boldly.

In this case study, I focused my attention on the study of one of these sub-streams, the research and development one, as part of the greater project. Individual workstream leaders were free to organize their workstream if they were delivering items agreed at a higher level, within the milestones generated. Mindful flexibility had been granted by the stage-gate macroplanning approach when a deliverable was needed in advance or when additional time was required while not blocking other important activities. The research and development module was governed with an Agile approach from the development phase on, setting fast sprints of one week. The team was flexible according to the deliverables to achieve within the weekly sprint, with a fixed scrum master in teams composed of 3-6 members with a diverse technical background, including business, engineering and programming competences. One downside of having a team that comprehensively included skills and competences needed to develop the product, was that some of the team members were working part-time on the project, sometimes creating coordination issues. Daily activities were facilitated through daily check-ins, and sprints were opened on Mondays with a check-in, and with check-outs on Fridays, where the product owner was also present.

To build a backlog at first, the team received a list of potentially relevant use-cases identified in previous phase-gate stages by a different team. The first two sprints had then been governed in Agile, building an intense client partnership to validate the relevance of the modules being developed, to collect their ideas and feedback and to prioritize the effort to undertake over the following months. At this stage, both internal and external clients and experts have been involved, supporting a fervid discussion through mock-ups of the expected final product. Their feedback was incorporated through the addition of some modules and use-cases to the backlog to develop, and for the definition of product backlog blocks with different priorities, with an approximate idea regarding the implementation effort they would later require, and the point in time where to start those activities. Their feedback, altogether with a literature review from academic sources and from the review of internal being involved in the development, lead not only to the understanding of the different research and development digital and organisational tools and best practices to bring alive, but also of the different pain-points being experienced by research and development teams, to bring alive in a live simulation.

After this activity, the team had a backlog repository of the different items to develop but did not assign "story points" to the ideas in backlog, where the effort required for the development of the different solutions had not precisely been estimated, nor formalized, yet it was kept as informal knowledge from the team. This might also have been due to a bias induced by the tool used by the team to keep track of the development process, which was a popular collaborative Kanban board, which allows for the creation of Kanban tickets in different stages, in this case in the backlog session, but does not allow to assign different weights to those tickets.

This resulted later, on in occasional misalignments with the product owner and the steering committee, requiring efforts to re-align on the time required. This is a potential conflict area deriving from the joint deployment of Agile and Phase-gate practices, with development team members aspiring to higher autonomy, and management more comfortable with certain milestones as in phase-gate.

From here, the team started a first "grooming" session, where they defined their goals for the first sprint, and shared them with the steering committee for validation. The informal internal knowledge of team members played an important role in this first stage, where team members recalled some of the already existing material from courses dating back up to 5 years in advance, that could be taken as basis for some of the items composing the training module. This happened by chance, but a formal meeting to retrieve any useful previous material available could have potentially saved time during the development and could have helped in better setting priorities for the development process. This informal process brought to a decision to start from the area that was less advanced, which consisted of the simulation to be carried out, including for instance a description of the spaces, the key personas in the simulated process, their scripts with pain-points to highlight, derived from previous activities, and secondarily of the documents that have been developed, to allow participants to the training session to gather an understanding of the overall research and development process they were observing, to derive their conclusions and propose potential solutions.

Some members of the development team members have reported having felt somewhat frustrated by the frequent request from the product owner to reach out to internal and external experts to get feedback, ideas and to validate ideas being inserted to the backlog, where abstract concepts were sometimes challenging to decline into the product setting. Some of their testimonies went as follows: “I am grateful for the opportunity we get for learning so much, but sometimes we get some general feedback, and it’s challenging to apply it into the operational process to our product and context” or “I feel we are spending so much time in getting feedback, that we don’t have time to actually get the work done. It would be better sometimes to just move on”. To triangulate these affirmations, the direct observation of the work practices revealed that formalized feedback tools were though in place to be sure of the alignment and morale of the team, because not only weekly team meetings were in place, but also formalized periodic surveys on team morale, work-life balance and team dynamics, showing that the team members simply needed to be encouraged and open in discussing their feelings to be able to take counter-actions.

This light misalignment from the team might though evidence the relevant need for high transparency and sincerity in communication and in building and growing an Agile culture with a positive obsession for continuous feedback, customer involvement and continuous improvement to assist the introduction of the novel tools and formalized practices.

The team then proceeded to assemble the learning module in the form of material to support a lecture-based training delivery to transfer knowledge on organisational tools, trends, and relevant technologies to participants. Adopting a modular approach to the development of the learning path, the lecture-based learning module has been considered the platform onto which to be able to plug-in the experiential simulation-based exercise, and the different digital use-cases, each one being supported by a dedicated technology-focused sub-learning module. Periodic reviews with experts have been run at this stage, without the involvement of potential final customers during the individual development sprints. This feedback had been collected only later, through the delivery of the lecture-based learning module, in local language, to a classroom from an innovation management training course delivered remotely. In this context, although the general satisfaction rate expressed by participants was higher than 8/10, some un-structured feedback was collected on the lecture being somewhat theoretical and lacking deeper insights on technological tools and practical applications of what learnt. The development team decided then to use the next sprint to try to address those issues, by sketching potential training agendas incorporating technology-oriented insights, and by reframing the material used for the lecture-based module in a more visual manner, adding some application examples and best practices. The lack of feedback loops from customers during the sprint reviews might have contributed to cause this rework, and in case incorporation of customer feedback in previous moments was not possible for some reason, the team mentioned that a rework sprint might be needed and planned in the backlog. Some doubts emerged from the development team upon interviews on the use of one week time-boxes for some of the solutions being developed, suggesting quite surprisingly to grant some flexibility to the team itself in relaxing the closed time-box for development, choosing whether the sprint would last one, two or three weeks.

The development proceeded with the implementation of 9 digital use-cases to support the observation in a showcase of an optimized version of the research and development model office that was being developed.

The different use-cases had been prioritized based on the feedback collected and the availability of tech partners supporting the development of the different solutions. Adopting an Agile way of work was reportedly somewhat confusing for some of the tech partners involved in the development, as their precise commitment could not be precisely booked in advance, occasionally creating challenges in coordination.

A key success factor mentioned by the team involved, that enabled to overcome those challenges, has been to precisely design mock-ups of the solutions and their functioning logics beforehand, validating them with experts and the tech partners themselves. This made it easier for the tech partners to start the development knowing precisely what their goal was, without requiring many intermediate alignments where the use-cases needed to be discussed. Another critical success factor in the relation with tech partners has been to fully embrace a Lean idea of client-supplier relation, based on collaboration rather than precise contracts and penalties. This led to mutual adjustments during the development, where in some cases the result coming from tech partners went beyond the expectations of the team and the management, with results that were greater and more accurate than the specifications mocked-up beforehand by the development team. On the other hand, the beforementioned degree of uncertainty in precise timing resulted in occasional delays in the expected outcomes from the tech partners, which were transparent also to the product owner and the steering committee. When such cases occurred, the product owner and management would offer to escalate the topic, directly connecting with the tech partners if needed. In most cases, this offer was not pursued further, still being able to reach the goals set by the following steering committee meeting. A key success factor mentioned again here, was transparency and a more complete adoption of the MVP (Minimum Viable Product) approach to the development, also when prioritising the effort from tech partners. This approach was highly endorsed by the management, with a clear mandate not to waste time in preparing extensive documentation or presentations between the periodic review meetings, but to focus on real development of the learning modules and the use-case products, asking to be able to see mock-ups and drafts of the tools being developed as they were being delivered. This practical approach from the management, favoured teams working with an Agile methodology. The clear focus on delivering Minimum Viable Products led to an “inverted” development with regards to the use-cases to showcase during training sessions. The initial approach proposed by the tech partners when approaching the solutions to develop was a phase-gate, that generalising followed five main steps: system infrastructure deployment, backend development, database structuring and data consolidation, data analytic structure development, and frontend development.

This approach would have constrained the possibility of receiving robust expert and customer feedback, without a tangible value in showing wi-fi antennas, raw databases, or lines of code, without a graphical interface to tell the story of what was aimed with those instruments. On the contrary, the Agile approach adopted by the research and development workstream team was “inverted”, prioritising also in the effort of the tech partners, the transformation of mock-ups into frontend dashboards, then working backwords to build the data analytics and visualization on dummy data etc. This approach would not have been possible without a technological infrastructure supporting this approach. Critical success factors here were the possibility to develop without yet having the infrastructure required, thanks to the use of virtual machines in cloud and of remote collaboration tools such as desktop remote access and control software, enabling the development team to work remotely on machines from the tech partners, and vice versa. This approach had also drawbacks. Working on virtual machines and not on the final environment where solutions were meant to be embedded, meant that software installations had to be run twice: once on the initial virtual environment, and a second one on the final environment. This rework has been remarked as physiological by the development team, mentioning that gains outperformed the losses with this Agile approach, being able to get design validations from both the management and clients faster, delivering a product that was able to add value immediately.

This concept was proofed several times during the development of this learning path. Showcases of the different use-cases were performed to actual and potential customers while the development was still not completed, through the deployment of intermediate Minimum Viable Products only. This enabled to provide a more responsive service, enabling to envision technological solutions relevant to the customers, and to incorporate customer feedback early into the development process, when it was still possible to steer and adapt the outcome of the use-case. An illustrative example came from a digital twin use-case, which was showcased among others to a potential customer group, which showed great interest in the solution, yet demanding if there were any measures of the sustainability of the product, and its energetic efficiency, which were not present at the time. From this feedback, the team went on to incorporate among the parameters monitored a measure of the energetic efficiency, and an estimate of the Co2 emissions from the product in the simulation.

The final, complete learning path was released with a slight 5% shorter delivery time with regards to the overall learning modules expansion project. The final learning path was comprised of several items:

- lecture-based learning modules, serving as platforms for the following items
- two exercises, based on an assessment of the simulated office process and of the office documents provided, and based on the re-design of the office work practices and processes
- nine use-cases to be used for participants to envision the future-state model simulated office and research and development process

This latter element was released with two out of the nine use-cases still in an intermediate Minimum Viable Product stage yet being fully viable solutions to be displayed during training sessions. This compromise had to be made on two of the use-cases that were relying heavily on the network infrastructure of the building, with issues probably caused by a lack of transparency and detailed communication between the research and development team and other development teams, resulting in a delay. This anecdotical evidence might suggest that communication between development teams, when adopting an Agile Stage-gate hybrid organizational model might be more challenging when compared to a traditional phase-gate approach, where all information is more vertically integrated by relying on a more structured and systematic production of documentation. This might be mentioned as one of the trade-offs to manage when choosing the organizational model to adopt.

The chance to run a comprehensive final test of the learning module, occurred two months after ending the development cycles. A class attending an executive MBA was invited to attend the 2-day learning path on Digital research and development. The group comprised 28 participants, with an average of 37 years of age and 10 years of experience, 82% male and 18% female. The higher title held by participants was PhD in 54% of the sample, a Master of Science in 43% and a bachelor's degree in 4% of the sample. The composition was varied by occupation, with 32% of the sample working in Academia, with the rest working for private companies.

The evaluation of the learning path was qualitative, with an evaluation performed through an anonymous survey, which received 21 responses (75% of the participants). Several satisfaction items have been considered, among which the workshop execution, the clarity of the lecturer's delivery, and satisfaction connected to the individual items delivered. The overall rating was 8.65 on a scale from 1 to 10. Open questions have been asked to understand what participants would keep, and what they would change from the learning path. 7 out of 10 respondents to the open-ended questions mentioned the simulation exercise as the top element to keep. When asked what to improve, participants mentioned particularly that characters in the simulation sometimes tended to be somewhat stereotypical, suggesting that realism of the simulation is a key element where the development team would need to improve the product, and that they would have preferred to get more time for the simulation exercise. One participant mentioned that a potential solution could be to divide the group of students into groups, and to run the simulation multiple times, one with each group. The same observation was also made by the training delivery team of the lecturer and the actors performing the simulation. These insights, and more broadly the test of the learning product delivered, provided precious information on how to improve the product developed. The development team received positive feedback from both the management team and the first pilot group, which altogether with the overall delivery time and the results achieved, proved the efficacy and effectiveness of the organizational method that the team have adopted.

5 Results

This case has illustrated how the adoption of a hybrid organizational model has helped a team to develop and deliver a complex product involving different functions, with an articulated environment of both internal and external actors, with extensive interactions and potential coordination issues. The analysis of this case also helped to shed light on additional insights coming from the thorough observation and interviews that have been performed, helping to develop the discussion around organizational models based on Stage-Gate and Agile methods, and their interplay. The role of underlying Lean principles for product development (Sonnenberg & Sehested, 2011, Sehested & Sonnenberg, 2010) showed to be another critical factor in enabling to achieve success over several dimensions of the framework observed, effectively supporting the adoption of a Stage-Gate and Agile hybrid organizational model.

An analysis of the elements that worked well and that were more challenging for the team to address has been performed based on the Strategic Project Leadership framework (Shenhar, 2004) across its five dimensions, striving to capture the interplay effect of the Stage-gate and Agile hybrid approach.

	Key success factors	Challenges
Strategy	Strong orientation to the achievement of a competitive advantage through formal ex-ante analysis and value proposition, definition of clear goals	Challenges in capillary sharing the strategic vision to all the structure.
Spirit	Management endorsement and servant leadership, commitment to systematically remove obstacles	Challenges in embedding an Agile culture into all levels of the company, creating a feeling of trust and empowerment
Organization	Teams with a comprehensive set of competencies Availability of eternal expert support Network of external partners deploying mutual adjustment	Challenges in balancing accurately external support into team dynamics
Process	Stage-Gate for macro-planning creating vertical transparency and enabling strategic and tactical decisions Agile for development and testing bringing efficiency and flexibility to incorporate customer requirements Elimination of communication silos thanks to the adoption of Agile during development and strategic orchestrations inter—teams through Stage-Gate reviews	Challenges to fully capture benefits from concurrent engineering, deployed more intra-stage than across different stages Challenges to systematically deliver a Minimum Viable Product at the end of each development sprint
Tools	Project monitoring simplified via cloud connecting individual workstream tracking tools Virtual, ubiquitous whiteboards and virtual machines	Challenges to capture different weights for items in the backlog due to limited possibilities from scheduling software – risk of misunderstandings between team and manager

Table 2: A summary of findings observed, based upon the Strategic Project Leadership framework from Shenhar (2015)

5.1 Project strategy

The analysis of the case highlighted that a thorough, formal analysis of the competitive landscape and distinctive client offer was performed before starting the development process, applying the Stage-Gate principles. This allowed for a strategic macro-planning of the overall project, becoming a key success factor of the case studied. This vision and plan were positively transferred to the team coordinators of individual workstreams inside the overall landscape, who were made responsible of outcomes and business results and helped to be leaders with their team of internal and external resources.

This vision was though sometimes not capillary shared with individual team members involved in the development teams. This only partially complete vertical integration and communication confirms results encountered when analysing Agile implementation potential challenges (Dikert et al., 2016), stressing the importance of managerial commitment in empowering team members and creating a shared vision to deploy strategic objective into operational change.

5.2 Project spirit

The strong endorsement from the management for the Agile approach reportedly made the team feel empowered. The adoption of the Lean concept of servant leadership (Sonnenberg & Sehested, 2011) enabled teams to see managers as strongly committed to remove obstacles, corroborating as a success factor the implementation of an Agile culture. Informal learning and development opportunities through frequent interactions with recognised field experts were recognized by the product manager and by some of the team members, effectively helping to create a learning community, evidenced as a success factor both for Lean and for Agile practices (Beaumont et al., 2017). The team interviews though, revealed that to frequent requests from the management to reach out to experts might be perceived as a lack of empowerment, and might show a need for reinforcing Agile culture beyond the creation of a safe environment alone, and to fully leverage the structured feedback tools and practices in place.

5.3 Project organization

A key success factor for the organization was the deployment of teams with a diverse background and with complementary skills, in accordance with findings from previous studies (Dikert et al., 2016), enabling the team comprehensively address complex problems.

The creation of external networks, as proposed by the Lean methods for product development (Tuli and Shankar, 2015) were reportedly positive for the organization, confirming that a hybrid model can enable a positive mutual adjustment with external actors (Cooper, 2014).

Some challenges were reported where resources were available only for limited portions of their time, being part of more than one team, a trade-off that needed to be managed to have all competences and skills needed inside the team. The presence of external experts as well was reportedly complex to manage, where opportunities to learn for the team, and to improve the quality of the final product, met isolated stress in managing and incorporating feedback in the development process, and to decline abstract concepts into the setting framed for the product developed.

5.4 Processes

The organizational method observed was a Stage-Gate process for the macro-planning, which enabled the steering committee to take decisions based on clear strategic objectives in the first phases of the process on which workstreams to prioritize, and to then monitor progress transparently, being able to orchestrate by re-allocating resources when needed, and moving delivery dates when changes were needed for mutual adaptation, also with suppliers (Solaimani et al., 2019b).

The Agile approach was more evident from the development stage on, consistently with observations from theory (Cooper & Sommer, 2018). Time-boxed sprints prioritized based on the backlog would be run, achieving minimum viable products that enabled to deliver value fast, confirming benefits of this hybrid model from theory (Edwards et al., 2019, Cooper, 2016), and enabling to test concepts with clients already during the development phase.

The organizational method adopted confirmed the expectations in allowing the development team to deliver the final product earlier than initially planned, achieving a satisfactory result based on the feedback from clients. This has likely been achieved thanks to benefits from the Agile methodology for the intense development stage, whereas those coordination and communication tools might have been missing in a purely Stage-Gate approach (Sutherland & Schwaber, 2013). Potential communication silos deriving from individuals (Beck et al., 2001) have been tackled with the Agile and Scrum techniques, such as the daily and weekly meetings registered, while the danger of having multiple teams working separately has been mitigated through the periodic monitoring of Stage-Gate.

The Minimum Viable Product approach was effective in helping to deliver value fast, as predicted (Cohen et al., 2004), but led to reportedly unavoidable rework when migrating from the software development environment to the final IT environment. This highlighted how in few cases where technological boundaries were involved, the predicted contribution of this hybrid approach to both micro-planning and macro-planning (Cooper & Sommer, 2018) was weakened, and might suggest for the adoption of a more structured macro-planning to support the allocation of backlog priorities also when working with an Agile approach.

Concurrent engineering (Koufteros et al., 2001) and concurrent planning were sometimes unable to express their full potential as they probably would in a purely Agile approach, suggesting that in a Hybrid organizational model, the full potential of this practice would be limited to an intra-functional application, rather than to the holistic process. The development team observed adopted a one-week time-box for sprints, which sometimes resulted in a difficulty to deliver a finished, working Minimum Viable Product, fulfilling the Agile-Scrum methods entirely, consistently with findings observed in theory (Cooper & Sommer, 2018). A surprising suggestion from development team interviews came in the direction of relaxing the fixed iteration time-box of a sprint while in contrast fixing the delivery of a Minimum Viable Product, but this approach has not been experimented during the study.

5.5 Project tools

Several organizational tools, of which many coming from the Lean and Agile environments have been reported and helped the team to deliver consistently, as predicted from theory (Sommer et al., 2015), enriching Stage-gate with more operational tools. These organizational tools were also empowered by digital technologies, which helped in streamlining and structuring communication. These tools included tracking and monitoring tools in the form of a cloud-based dashboard, virtual, ubiquitous whiteboards to help in the design phases, and virtual machines enabling for parallel engineering of some of the use-cases.

Tools meant to facilitate the development team alignment sometimes created misunderstandings between the team and the management, such as in the case of a digital Kanban board to which both the development team and the product manager had access. Development advancement was measured through the number of Kanban cards moving forward only, biasing understanding because important information such as Agile story points was not included in the software platform that was used. This would suggest caution in potential biases resulting from the adoption of digital tools without a preliminary evaluation and sharing of results.

6 Conclusion

This study was conducted to help in developing the knowledge of a group of problem owners, from a training center in Northern Italy, around the Agile and Stage-Gate hybrid organizational model for the development of new training products. A development team applying the Agile approach inside a Stage-Gate framework has been observed and studied through multiple data sources, applying the practice-based case study methodology. This research has found that this hybrid organizational method has been evaluated as effective in both enabling to reach a satisfactory delivery time, and a satisfactory quality of the resulting training product upon testing. This result, consistently with previous studies (Bianchi et al., 2020; Cooper, 2016) showed the benefits of this hybrid approach to mitigate potential downsides from both the Stage-Gate approach and the Agile approach when taken individually. This hybrid approach resulted in an effective complementary compound, specifically where Agile integrated the traditional Stage-Gate with tools to manage the complex Development stage, while Stage-Gate provided a broader view of the overall processes, enabling for more punctual macro-planning. Findings, though resulting in encouraging results, have also shown how some elements should be managed cautiously. Confirming previous observations regarding the challenges to adopt Agile at scale (Dikert et al., 2016), team communication and management commitment have shown to be critical when balancing the two approaches, particularly when fixed-time and customer specifications from Stage-Gate encounter variable development time and customer specifications as for the case of Agile.

Some elements of Lean have been observed to be present as underlying fundamentals to collaborative product development (Tuli & Shankar, 2015), with its comprehensive set of tools and approaches to help teams in problem-solving, prioritizing and scheduling.

This piece of research can contribute to the broader literature on organizational methods, with regards to the Stage-Gate and Agile hybrid model, by providing a case of successful application in the development of a training module. Limitations of this study emerge from the presence of one only case being studied in depth, with limited generalizability, also due to the practice-oriented methodology adopted. Focusing the scope of research to precise relations would benefit to adopt experimental approaches to the study of these organizational methods, as well as adopting comparative case-study methods to be able to generalize the findings more robust

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Remotely delivered innovative training for digital operations management

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Abstract. Industry 4.0 technologies offer companies growth opportunities but demand the reskilling and upskilling of employees and future workers. The literature on training has evidenced that innovative forms of training are more effective in transferring knowledge and developing a positive learning experience, traditionally relying on in-person training and workshops. The Covid-19 pandemic has accelerated a trend towards remotely delivered training. Are innovative forms of training still to be preferred over traditional lecture-based learning also in this setting?

The aim of this study is to contribute to the dynamic model of training transfer (Blume et al., 2017) by testing its validity out of the context of in-person training, deploying instead a remote delivery method. To do so, a remotely delivered simulation on lean management practices applied to the digital transformation in operations has been developed and tested measuring for student satisfaction, self-evaluation and intention to transfer, and comparing it to a remotely delivered lecture-based training only.

We aim at developing the understanding of this field by disentangling the relations between different elements in the dynamic model of training transfer theory and training performance by designing, testing and

comparing two simulations developed leveraging the design science principles, and game design specifically, in an experimental setting. The results of this analysis may lead to a superior understanding in the field of the key variables to consider when studying training-related outcomes and dynamics in the context of the dynamic model of training transfer and may shed light on valuable insights and best practices for the design and delivery of training.

1 Introduction

The labor market is expected to experience a shortage of specialized workers, able to manage the challenges of Industry 4.0, reporting a shortage of skilled manpower that would be possible to overcome with technologies able to extend their working lives, while improving the working environment and the work-life balance despite the challenges posed by Covid-19 (World Economic Forum, 2020, 2018; Manyika et al., 2017).

Two relevant struggles emerged in this early stage of the so-called "fourth industrial revolution": one from the industry, in the difficulty to find a skilled workforce, and one, from the workers' side. The social implications of automation and assistance systems are relevant, and workers will see their tasks change, hoping for a better life condition. This second problem is relevant in Germany, where the concept of Industry 4.0 was firstly developed, and it may be one of the drivers that pushed for the development and recognition of this new jump in the history of industrial systems. This might though be even more relevant for less economically developed countries, where buffers of unemployed workforce exist, enhancing some problems that are already present.

These struggles are addressed by many different sources, which found in recent studies some impressive data that shows how industry is changing faster than the workforce, creating misalignments. It is reported that “over one in four adults surveyed in the OECD reported a mismatch between their current skills and the qualifications required for their jobs” (World Economic Forum, 2017), and them “approximately 35% of the skills demanded for jobs across industries will change by 2020” (World Economic Forum, 2017), in particular in the field of office and administrative workers and production. In other recent studies we find some more insights, as Arntz et al. (2016) found that 9% of jobs in 21 OECD countries surveyed are automatable, while a study conducted by McKinsey Global Institute, focusing on changes in activities and tasks with the rise of automation estimates that by 2030 “60% of current occupations have more than 30% of activities that are technically automatable” and that “Technical automation potential is 50% of current work activities by adapting currently demonstrated technologies” (Manyika et al., 2017).

In front of such huge gap between demand and offer of labor, a way out of the impasse can be provided by the reskilling or upskilling of the present and future workforce. A una tantum effort is reported not to be enough to grant sustainability, as skills needed will reasonably continuously change and evolve, following the development of new tools to implement the technologies and paradigms that have so far been categorized, and the ones that will be created. There will be a need for continuous learning and skill upgrading, in both hard and soft skills during the entire working life of a person, and it would be an error to consider these shifts as only occurring in the managerial field, because as Pereira & Romero (2017) points out, we are assisting to the rise of the augmented operator paradigm, in which also the line or office worker needs to acquire new digital skills to support and manage the transformation and its outcomes.

Among the skill and attitudes that need greater development many soft skills are found such as curiosity, creativity, imagination, confidence in continued learning (World Economic Forum, 2017), numeracy and literacy, problem-solving, work ethic, leadership, information technology and management (Penesis et al., 2017), and again dealing with complexity, supervising, assessing, deciding, teaching, but also care and personal interaction (Eichhorst, 2015). A stress is put in literature on the growing need for multidisciplinary training, altogether with hard skills for specific industries.

In this context, the existence of sound, efficient and effective ways to train people acquires a renewed importance in the human resource development theory (Blume et al., 2017). I aim at contributing to this theory as well as at offering practitioners a viable tool by developing a remotely delivered experiential training course. The dynamic model of training transfer, originated in the context of in-person training, suggests that the addition of a safe ground where to positively apply knowledge acquired would reinforce student satisfaction and ultimately training outcomes in terms of learning and knowledge transfer, through the establishment of an early knowledge transfer experience where to positively apply acquired knowledge, skills and attitudes. This experience of a positive application of the knowledge acquired during traditional training suggests a potential for boosting training performance, that has been measured as training satisfaction, and self-evaluation reported by participants. The dynamic model of training transfer suggests that a positive application of knowledge can be achieved through innovative forms of training, as simulations.

To our knowledge, empirical evidence of this relation is still missing in the case of training delivered remotely, where physical distance poses new challenges to both learners and trainers. Deploying this simulation to reinforce learning, this article aims at disentangling this relation to confirm or reject theoretical predictions in this novel context. The course developed including the simulation is expected to create awareness and transfer knowledge on operations management, to improve the digital opportunities assessment process in the operations management field, building on the methodological ground of lean management. Two simulations have been developed, sharing the same practice and methodology, to this purpose: one to assess opportunities of improvement applying Lean methodologies, the second to assess opportunities of improvement applying digital technologies relevant to the production process observed.

An additional element is suggested by the dynamic model of training transfer to play a role in this relation between the training method and the training performance in terms of satisfaction and self-evaluation of knowledge acquired, which is the intention to transfer. The intention to transfer knowledge acquired to the working context is a variable introduced by the model that has been overlooked to our knowledge in previous studies. Yet, theory suggests it is an element that must be taken into consideration when designing and delivering a training session, that might help to explain the effect of training methods on training performances, and in this article we aim to study it as a moderator to understand this complex phenomenon.

2 Theoretical framework

2.1 Learning and innovative forms of training

In the human resource development literature, one stream of research focuses on learning and development strategies, aiming at ensuring that people in the organization acquire and develop the competencies they need to carry out their work effectively (Bell et al., 2017; Armstrong & Taylor, 2020). Moreover, it is a crucial task to provide new workers entering the workforce with the skills that are more needed on the job market itself. In this context, one recent theory from Blume et al. (2017) has brought light in the training design techniques, through the formalization of the Design training method. This methodology framed the problem of training as a process aiming at knowledge transfer, with two basic means, which are personalization of transfer and dynamic interactionism. These are based on three basic conditions, which are the credibility of information transferred, the practical relevance of the skills (at least in adult learning, when teaching to professionals) and the perceived need for the transferred skills (Blume et al., 2017, Narayandas & Moldoveanu, 2016).

Personalization of transfer has long been known as a driver for effective knowledge transfer, since Riding & Sadler-Smith (1997) formalized the two dimensions of trainees cognitive styles across the two dimensions of verbal-imagery and wholist-analytic to plot preferences for knowledge visualization. Dynamic interactionism (Blume et al., 2017) in on the other side an emerging topic with interesting implications on training design. The core concept is that when feedback from the first application of what learnt is positive, the trainee will be more likely to apply that knowledge in the future. In this light, experiential learning becomes a powerful instrument enabling for a strong reinforcement of what learnt in traditional lectures, where in the knowledge transfer environment is also present a testbed to apply in practice what had just been taught during a lecture.

Recently, Cascio (2019) recognized that technological development is one of the macro-trends affecting training. Furthermore, the author pointed out the effects of adoption of digital technology and the implications on the demand for training services by firms and employees.

Traditional forms of training take the form of frontal lectures in classrooms and apprenticeship for repetitive tasks with the demonstration of an activity to trainees, until they become able to perform it (Kraiger et al. 2007). To this regard, Cascio (2019) pointed out that learning by observation has long been known by psychology. The author reports its effectiveness as an innovative training design method in transferring different elements, from facts and procedures to changing on-the-job behaviour.

The last decade has been characterized by an increase in the theoretical depth of training interventions, the centrality of the trainee and an approach that values work experiences and simulations responding to a change in the nature of work and training (Bell et al., 2017). The author suggests that traditional approaches "may be effective for developing routine expertise, [but are] ill-suited for developing the flexible and adaptable skills".

The process of training is recognised to be more and more dependent on the nature of the trainee, and differences characterize interventions addressing students, workers and executives. In the literature only two authors, Wuestewald (2016) and Narayandas & Moldoveany (2016), mentioned the use of innovative forms of training for executives training, while systematic analysis has not been found on the application or applicability of most of the forms of learning and training design mentioned before for managerial reskilling and upskilling. Research is needed to effectively transfer the application of these methods to adults and managers.

Training design refers the field of studies on Human Resource Development, addressing the activities designed to produce behavioural change (Knowles et al., 2014). Two main theoretical frameworks have been applied in organisational literature to understand training: traditional instructional design model, focusing on the instructor with a top-down approach, and a bottom-up approach focusing on the trainee, and its conditions and satisfaction (Kraiger et al., 1993).

New trends have emerged in literature after some research showing that "most learning does not occur in formal training environments" (Salas et al., 2012), where prescriptions found highlight the need for the creation of communities of practice and to leverage the benefits of experience as a foundation of knowledge transfer, where Bell et al. (2017) reported some of the huge advantages of affective-experiential training including or merging some of the techniques listed above such as role plays and simulations as powerful tools to enhance trainees satisfaction as well as training outcomes.

To this purpose, the literature has outlined the phases and the activities to be performed for the development of a training module (Salas et al. 2012), including steps to be undertaken before, during and after the training, with a critical attention to pay to the needs assessment before, and to the evaluation of outcomes across the main stakeholders involved, significantly the person and the organization the person belongs to.

2.1.1 The dynamic training method theoretical framework

To address and contextualize the problem of the creation of a case study, the Dynamic Training Method by Blume et al. (2017) has been applied. Proposing an evolution in the human resources theory on training, regarding the transfer of knowledge, skills and attitudes from the training to the work environment. This model has four main stages, articulated in the following.

2.1.2 Intentions to transfer

Addresses the intention of the trainee to apply in his job what learnt during the training. Some key metrics, useful for the training evaluation itself, have been identified, addressing:

1) How credible the information was;
2) How practical the skills were;
3) To what extent was the knowledge or skill needed.

It is also noted that trainees do not transfer all knowledge acquired but modify it according to their own needs and experience, possibly trying to further develop some portions. An interesting difference is that more experienced trainees would be more likely to look for some hints or previously unknown recommendations in their knowledge, while more junior learners would be more willing to integrally apply a strategy or set of prescriptions. Finally, their internal network of goals or desires would play an important role in the intention to transfer their knowledge (Narayandas & Moldoveanu, 2016). An important point made by transfer researchers is that the opportunity to immediately apply what learnt plays a key positive role in the willingness to transfer on the job what learnt, while intention to learn plays a crucial role too (Culpin et al., 2014).

2.1.3 Initial attempts of transfer and evaluation

If the intentions are positive, it is likely that the trainee will attempt to apply what learnt in a work situation. In doing so, and important role is played by self-regulation processes, setting some objectives to provide feedback to its behaviour. After a first adoption, a self-evaluation will be adopted to determine subsequent actions. Blume et al. (2017) specifies that at this point an important difference has to be made between labour performance and outcomes. In fact, labour performance increase after a training would be an effect of the training itself, while the outcomes are likely to have the training as an influencing variable, but many more might still exist, creating "disturbance" and affecting positively or negatively the judgement on training too.

2.1.4 Attempt to future transfer

After the first attempt and evaluation, trainees process internal and external feedback to inform future decisions and actions. Development of capabilities, retention of knowledge/skills and identification of gaps to fill with future training are some desired outcomes of training, further positively or negatively affecting motivation to transfer. Trainees might also decide to discard or giving up transferring some knowledge, skills or attitudes if these have been found to be subjectively meaningless (Blume et al., 2017). These findings provide further evidence of the focal role that positively applied knowledge, skills and attitude have on capability development and knowledge retention, further demonstrating the potential of simulations and experiential learning.

Three key elements to deliver effective training have been found in the Dynamic Training Model, reported below.

2.1.5 Understanding transfer criteria

Criteria upon which transfer is evaluated are critical as further application of what learnt will be decided on them (Blume et al., 2017). A previously mentioned critical difference must particularly be made between performance, directly impacted by knowledge, skills and attitudes - and outcomes, sensitive to other factors (Narayandas & Moldoveanu, 2016).

2.1.6 Dynamic interactionism

This second element is contrasted to a mechanistic view of interactions, which does not account for time. Individual, situational and criterion variables must be considered with their direct and indirect impacts, and their interactions should be seriously related to the transfer to Knowledge, Skills and Attitudes (KSAs) acquired during training and their application in a work environment. This has not always been recognized in the training and learning literature, but an evolution towards interactionism and dynamisms has appeared in the last decades in theory (Bell et al., 2017). The interplay and reciprocal influence of the variables should be considered over time, altogether with the context of transfer, with attention not only to one transfer episode but to the transfer path, to its evolution over time and to how feedback shapes it.

2.1.7 Personalization of transfer

This last element implies an empowerment of trainees on the choice of what and how to transfer trained Knowledge, Skills and Attitudes (KSAs). Consistently, the Dynamic Training Model is based upon the choice of trainees to discard, maintain, apply or modify trained knowledge in their work context (Blume et al., 2017).

2.2 Training with remote delivery

Some studies have been performed to compare in-person, online and blended learning to measure student satisfaction and performance. The discussion is still very vivid, and many aspects of this field are still to be clarified, with studies investigating the effect of the training format on students’ engagement, satisfaction, and performance. The answer seems to be dependent on the context and the field of study, but while simulations and innovative forms of training seem unanimously related to higher student satisfaction, or performance, the delivery format has not a clear answer yet. Some studies argue that a blended delivery format has a slightly better impact than the others (Hong & Gardner, 2018, Bernard et al., 2014), and other authors found that training effectiveness can be comparable in both online and face-to-face learning even for complex tasks (Kalpokaite & Radivojevic, 2020; Francescucci & Rohani, 2019; Ryan et al. 2016). In a comprehensive literature review of the field, Nortvig et al. (2018) found that "… in F2F sessions of blended courses designed for professional bachelor programs, educators should create opportunities for students to apply the theory studied and to discuss and train the practical dimensions of the profession that may not translate well online", creating a connection with the dynamic training method from Blume et al. (2017) and the concept of interactionism. In this paper we will try to understand if it is possible to achieve a similar benefit from the application of the practical dimension of a field of study through the use of an online simulation delivered remotely, and to do so we are going to apply some training design recommendations from game design.

2.3 Training design recommendations

To develop effective training sessions both in-person and remote, several recommendations have been generated (Westera, 2019) to address misconceptions and improve training design effectiveness through the instructional design theory. This has been possible through the study of sources such as educational video games (Dondlinger, 2007) for informal and formal education. Game mechanics have been studied to generate a set of manageable formal prescriptions, listed by Dickey (2005) in a conceptual framework consisting of eight design principles to engage students and improve their satisfaction and performance in training in the context of simulations.

• Focused goals

• Challenging tasks

• Clear and compelling standards

• Protection from adverse consequences for initial failures

• Affirmation of performance

• Affiliation with others

• Novelty and variety

• Choice

Additionally, the simulation should include according to Dickey a strong narrative with the possibility for the student to interact and empathize with characters, hooks to affirm performance in the simulation and the possibility to affect outcomes.

This set of prescriptions has been successfully applied to develop innovative, gamified learning experiences in different settings such as environmental science (Wu & Lee, 2015, Baytak & Land, 2011), engineering education (Callaghan et al., 2015) and programming (Combéfis et al., 2016), and in this study we are going to apply them to the development of a remote training session in the context of lean and digital training for the operations management context.

3 Methodology

The structure to develop and test the simulation, intended as an artefact to solve a problem (Henver et al., 2019, 2004), was taken from the design science research methodology (Peffers et al., 2018). This methodology had already been applied to the case of several classroom design studies (Lamberg & Middleton, 2009; Lehrer, 2009;

Froyd & Simpson, 2008), in professional development design studies (Cobb et al., 2016) and in business innovation (Winter & Aier, 2016). In the design science research methodology, the six-step design research process method was chosen, for its consistency with prior literature, its ability to provide a nominal process model for doing research, and to provide a mental model for presenting and evaluating the design science research (Peffers et al., 2007). The Design Science process method is a nominal process helping to provide a roadmap for researchers, while building on priori research.

This methodology has the final objective to provide a mental model, intended as “a concentrated, personally constructed, internal conception, of external phenomena (historical, existing or projected), or experience, that affects how a person acts” (Rook, 2013).

The Design Science process includes six steps, progressing in a nominal process sequence as follows: problem identification and motivation, definition of the objectives for a solution, design and development, demonstration, evaluation, and communication (Peffers et al., 2007).

Problem identification and motivation. The core problem is to be able to effectively reskill and upskill workforce and the future workforce, a problem highlighted by relevant think tanks and practitioners (Manyika et al., 2017, World Economic Forum, 2018, 2017). An opportunity raised from the presence of innovative forms of training (Bell et al., 2017) such as Problem Based Learning (Wijnen et al., 2017), simulation (North-Samardzic & de Witt, 2019) and training design prescriptions (Blume et al., 2017) with opportunities to help students to better focus, reason and manage their time in comparison with traditional lecture-based learning (Wijnen et al., 2017).

Definition of the objectives for a solution. The objective for the solution is to build a training course applying problem-based learning, simulation and training design prescriptions on manufacturing assessment to improve knowledge acquisition through the application of theorical principles learnt. To assess effectiveness of the solution, self-efficacy and student satisfaction were chosen as measures, in comparison with traditional, lecture-based learning.

Design and development. The principles and framework to build and evaluate the solution have been taken from the dynamic model of transfer (Blume et al., 2017) and from Dickey's (2005) framework. The aim has been to build an artefact with embedded formalized knowledge, resulting in a construct of technical, social and informational resources to address a problem (Järvinen, 2007). To develop the scenario-based training course. Common topics for operations management were chosen, starting from the lean management principles (Womack et al., 1990) to provide a methodological framework to address the problem of opportunity assessment. To incorporate the digital opportunity assessment, based on a value-driver approach, the McKinsey global compass has been chosen (Baur & Wee, 2015).

Demonstration. The course developed was tested to demonstrate its usefulness to address the problem identified in the selected context. This was done through a pilot study between the author and a pilot study group consisted of four classes of students from vocational schools in Northern Italy, with no formal previous knowledge on the topic. The tutor facilitating the group was a doctoral fellow, and the case used in the tutorial was designed to match the contents defined. The pilot study was conducted collecting satisfaction and self-evaluation on training performance and resulted in some minor layout and typographical adjustments to improve clarity and avoid the possibility of misunderstandings for participants. The Likert scale items measured on a scale 1-5 were changed to a 1-7 scale to prevent results from being too polarized. So far, the focus group had been concentrated on the study of the of relation of an innovative versus lecture-based training method on training performance. These preliminary results, although encouraging towards a confirmation of theoretical predictions, seemed to be mingled in the test group, with a low explicative value towards the model. An unexpected, significant difference in training outcomes emerged on the other hand in relation to the topics proposed to the pilot study group. This difference has been investigated thoroughly, specifically going back to the theory. The initial study perimeter had been enlarged, including the conceptually previous element in the dynamic model of training transfer, incorporating the intention to transfer to the study. This additional variable suggested from theory had also been confirmed as a potential mediator in the relation between training method and training outcomes from anecdotical evidence coming from the pilot study group. After these changes suggested from theory, observation and feedback, data from the pilot study was discarded, as it was missing the information on intention to transfer, and the study was run on a full scale, and evaluated.

Evaluation. This phase consists in the observation of the effectiveness and efficiency of the tool developed to address the problem. This was done through the comparison of the actual observed results from the use of the artefact in the demonstration with the solution objectives from the objectives defined. The nature of the indicators taken depends upon the solution tested and the context, and can consist of budgetary or operational measures, satisfaction measures from surveys, client feedback and simulations. They can include any appropriate empirical evidence or logical proof (Peffers et al., 2007). In this case, a study has been carried on groups of 20 to 30 undergraduate students per time participating to online training sessions. The students were given a traditional online lecture on the topic (lecture-based learning) first, and they have answered the questionnaire (T0) to measure their self-reported performance and their level of satisfaction. In a second moment after 5 to 11 days from the first lecture, students have participated to a second training session, applying their knowledge in an early transfer experience through a simulation based on the abovementioned prescriptions. The students were asked to solve a case in which they were assessing digital opportunities for improvement in a factory environment via a web application. To create a compelling story and setting, a real factory environment has been 3D scanned using 360° imaging and videos of individual operations on single workstations and machines have been shoot with the help of a drone. The individual elements, correlated with appropriate descriptions, have then been merged in a single web application where students could browse the factory, observe operations being performed, and assess wastes through time-studies and checklists. After this second part, they have answered the second part of the questionnaire (T1) to again measure their self-reported performance, their level of intent to transfer and satisfaction.

3.1 Study group

The study group consisted of more than 200 students from vocational schools in Northern Italy, with no formal previous knowledge on the topic, who have attended two classes as part of their curricular activities. The first, a traditional 3-hour lecture on the theoretical grounds of Lean management, or in alternatively a lecture on digital transformation and technologies. The second, a 4-hour immersive simulation as described in the previous section, on the same topic of the theoretical lecture they had been given in advance. The data was collected on a subset of 9 lectures, part of a larger training program. Students were attending their last year of vocational schools oriented towards professions in the field of operations, such as logistics, or technologies, such as machine programming or coding. Reference teachers selected the topic (Lean or Digital) for their classes, according to their judgement on the best fit with the programs that students were attending.

The tutors facilitating the groups were trained professionals from a training and development centre offering services to public and private institutions on the topics of organization and digital technologies, and the case used in the tutorial was designed to match the contents defined in this section.

3.2 Evaluation method: self-evaluation, intention to transfer, training method

To measure learning outcomes and evaluate performance, the literature has investigated the indicators of learning and teaching in terms of quality (North-Samardzic & de Witt, 2019), and the outcomes of students' learning experience have been identified as self-evaluation and performance (see Kahu, 2013; Wimpenny & Savin-Baden, 2013).

An indicator of training quality is student engagement (Wimpenny and Savin-Baden, 2013), and it has been shown to have positive outcomes such as an increased academic performance, as well as social and personal benefits (Kahu, 2013).

Simulations and innovative forms of training are means to increase student satisfaction and training quality, with positive effects on knowledge retention and student performance. Confirmation studies have been performed in a variety of different fields and settings, such as Human Resource Management (North-Samardzic & de Witt, 2019,) and staffing operations (Small et al., 2018), and we intended to check our results by confirming this relation.

In this study, we have chosen to measure students' satisfaction based on the questionnaire developed by Palmer & Holt (2009) for wholly online learning, translating the questionnaire items to Italian, the mother tongue of our selected sample. The questionnaire developed by Palmer & Holt (2009) was applied in its 4 main areas: training organization and structure, teaching and learning, teaching staff and other students attribute development. Satisfaction items collected were used to confirm consistency with previous studies. The questionnaire incorporated a score for self-evaluation consistently with previous studies (Palmer & Holt, 2009), that has been used as the primary measure of knowledge transfer (Small et al., 2018).

We have adopted a 7-point Likert scale from 1 (Very dissatisfied) to 7 (Very satisfied). Additionally, we measured the self-reported level of training satisfaction and self-reported performance level on a Likert scale from 1 (Low) to 7 (High). To complete the analysis in accordance with the selected theory, we developed an ad-hoc scale to measure the intention to transfer knowledge acquired, as per the dynamic model of training transfer. This variable has been directly derived from theory (Blume et al., 2017) and declined for study into a set of four questions, evaluating: the degree of future usefulness of the contents presented during the training; how practical the skills learnt were; how credible the information transferred was and if the respondent intends to apply knowledge acquired in their future jobs.

Test score reliability for reported satisfaction and for intention to transfer have been computed through Cronbach's Alpha, finding a standard alpha of 0.85 for Intention to transfer and a standard alpha of 0.92 for the Overall computed satisfaction.

The training method was identified based on the training that participants attended, and consists of a dichotomic variable: lecture-based training, or innovative training, designed as described in the previous sections.

3.3 Statistical analysis

Effects of training method and of intention to transfer on self-evaluation have been separately measured through linear regression. In accordance with the findings of the demonstration phase from the method adopted, an additional regression has been built to analyse the moderated effect of intention to transfer on the relation between training method and self-evaluation from individuals attending the survey, with the aim to better understand and disentangle their relation.

4 Results

The total number of questionnaires collected between T0 (lecture-based training) and T1 (innovative training) amounts to 136, of which 6 questionnaires have been discarded, where respondents did not accept the use of the data collected for research purposes. The remaining 130 questionnaires resulted from 77 participants who attended the Lean curriculum, and 53 who attended the Digital curriculum. Among the responses, 59 were coming from participants attending a lecture-based training, and 71 from participants attending an innovative training.

The effect of the training method on self-evaluation from participants has been found significant (see Table 1), with a positive effect of an innovative method with respect to a lecture-based approach only. This result has though been further investigated based on the feedback received during the demonstration phase with the pilot group.

Observations	130			
Dependent variable	Self evaluation			
Type	OLS linear regression			
F(1,128)	26.92, p = 0.00			
R²	0.17			
Adj R²	0.17			
	Est.	**S.E.**	**t val.**	**p**
(Intercept)	4.02	0.18	21.81	0.00
Training method	1.29	0.25	5.19	0.00

S.E. = Standard Errors, OLS

Table 1: summary of the regression of Self-evaluation on Training method

A second analysis has been run regressing self-evaluation on the intention to transfer, finding again a positive, significant relation between the two (see Table 2).

Observations	130			
Dependent variable	Self evaluation			
Type	OLS linear regression			
F(1,128)	66.40, p = 0.00			
R²	0.34			
Adj R²	0.34			
	Est.	**S.E.**	**t val.**	**p**
(Intercept)	3.98	0.14	27.80	0.00
Centred intention to transfer	0.72	0.09	8.15	0.00

S.E. = Standard Errors, OLS

Table 2: summary of the regression of Self-evaluation on Intention to transfer

Based on the dynamic model of training transfer and the anecdotical evidence collected during the demonstration phase run with the pilot study group, an additional analysis has been performed, considering now the intention to transfer moderating the effect of training method to predict self-evaluation from participants. This analysis ultimately showed that a difference indeed exists between the training method and the self-evaluation between students, but the relation between these variables is more complex than what initially appeared to be (see Table 3 and Figure 1). When considering intention to transfer to have a mediating effect on the relation between training method and self-evaluation, the model considered has shown how the training method is not significantly correlated with self-evaluation from the participants when considered jointly with intention to transfer, while intention to transfer remains significant to predict self-evaluation, and is positively correlated to self-evaluation.

Observations	130			
Dependent variable	Self evaluation			
Type	OLS linear regression			
F(3,126)	27.96, p = 0.00			
R^2	0.40			
Adj R^2	0.39			
	Est.	**S.E.**	**t val.**	**p**
(Intercept)	3.83	0.17	22.42	0.00
Centred intention to transfer	0.40	0.14	2.97	0.00
Training method	0.30	0.29	1.04	0.30
Centred intention to transfer : Training method	0.38	0.19	2.04	0.04

S.E. = Standard Errors, OLS

Table 3: summary of the model regressing Self-evaluation on Centred intention to transfer, Training method and their interaction

Training method has been particularly interesting to study with regards to disentangling the effect it might have on different individuals, with a different attitude towards the topic of study. The interpretation of this relations is made easier by Figure 1, with the addition of the representation of the confidence intervals for the two regression lines. This analysis shows how for students with a low intention to transfer with regards to the topic being taught, the training method does not have a significant impact on the self-evaluation from individuals with a low intention to transfer. On the contrary, for individuals who are highly motivated to transfer knowledge acquired to their work and

to the next phases of learning, an innovative training method is significantly increasing the self-evaluation of individuals, when compared with a traditional training method.

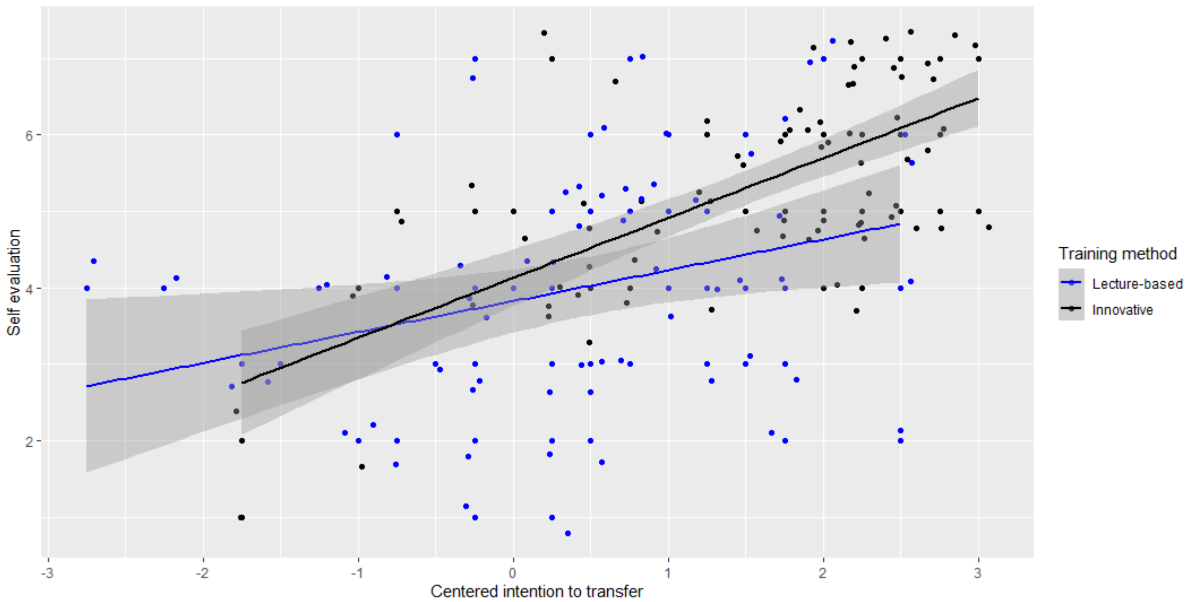

Figure 1: plot of Self-evaluation regressed on Centred intention to transfer, by Training method.

5 Discussion

The results have proved to be consistent with the dynamic model of training transfer (Blume et al., 2017). Training performance, measured as self-evaluation from students, have proven to be significantly increasing when fully applying, in full, prescriptions from theory. Disentangling the effect of the motivation towards the topic studied, measured in terms of the intention to transfer topics learnt to future job-related tasks, has also proven to be effective to understand the dynamics behind the training phenomenon. The effect of a reinforcing a traditional lecture-based approach with an innovative problem-based scenario has appeared to be more complex to understand. Being seemingly significantly correlated with an increased self-evaluation from students, the single effect relation was not enough to comprehend the phenomenon and risked being misleading at first. The study with the pilot group was crucial to decide to study jointly both the training method and the intention to transfer, unveiling that an innovative training method can be significantly improving the training performance reported from students only when intention to transfer is high, while its effect is not significant for low levels of intention to transfer.

This implication can be taken from both theory and practitioners willing to study or to act in designing new training modules. The dynamic model of training transfer was not previously tested in this setting, where this research confirms its implications and creates a basis for future development and enlargement of this theory.

This study may be of interest for both the academy and professionals researching and providing learning and development tools. Interest on the topics was raised, as mentioned in the introduction, by important think tanks aiming at reskilling and upskilling the workforce with technical knowledge, as a strategy to enable workers and firms to face the challenges of the fourth industrial revolution. This research suggests that experiential training, provided based on the problem-based learning literature and on the dynamic model theory, is indeed effective when combined with traditional, lecture-based learning and with a sound motivation towards the topic studied. This helps to enhance technical skills, and to transfer knowledge on tools to address complex, interdisciplinary problems. This result suggests that universities and training centres providing training to students and workers should include this training strategy, adopting a mixed experiential and traditional teaching approach, and to keep in account these theories when designing their training courses.

6 Conclusion

This research led to a superior understanding of the implicit elements of the dynamic model for training transfer. The aim was to address the problem of reskilling and adult training in a complex, multi-disciplinary topic, striving to prove and deepen the understanding of a method potentially leading to a higher efficacy and efficiency of training.

The dynamic training model theoretical framework in human resource development was applied to understand the viability of one of the training theories developed in the last decades in a vivid discussion, proved the interest in the topic coming from the industrial and social environment.

Research has been carried to understand some executive and managerial training best practices, to demonstrate and enable the implementation of novel skills referring also to digital solutions and Industry 4.0. This paper contributed to the dynamic training model theory by disentangling the relations between its intrinsic elements, and by confirming its implications in the case of a multidisciplinary, cross-functional topic being transferred in a remote setting.

The model proved to be effective when applied in full, in significantly reinforcing the skills of trainees aiming at upskilling their abilities acquired through lecture-based learning.

Limitations of this study include the measurement of variables through self-reporting, limiting their reliability. Future streams of research could benefit from the adoption of other, more powerful stimuli, such as augmented and virtual reality (see Wang et al., 2018, Yang et al., 2018) and biomedical measurement of mediating factors in training.

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General conclusions

This thesis presented an analysis of the relations between unbiased managerial decisions, advanced organizational methods and innovative forms of training as some of the key elements that can enable organizations to achieve the highest benefit from innovations in technologies.

These innovations are creating disruptive opportunities for organizations to improve their performance, but preliminary studies and important think tanks showed how these phenomena will require an empowerment of legacy skills and competences, as well as novel skills, to be managed properly.

The first article presented in this thesis builds on this ground proposing a conceptual framework to analyse digital technologies and innovative forms of training as means to potentially hinder the effect of cognitive biases in operations and managerial decision making. The framework proposed was built on research showing how training has traditionally been deployed as means to cope with this issue, and suggests that innovative training, as well as digital technologies might be powerful tools in this endeavour, with the potential to ultimately result in a higher performance from operational tasks and decisions driving them.

The second article focused on the study of methods for an effective development of innovative training products. From a review of the literature on product development, a case was studied with a practice-oriented research that confirmed some of the latest trends found in theory. These findings suggest that a stage-gate and Agile hybrid organizational model can help in raising the process efficiency and the efficacy of the development in the case of innovative training products, with results potentially extensible to the advanced services sector. This hybrid approach resulted to be effective, specifically where Agile integrated the traditional stage-gate approach with operational tools to manage the complex development stage, while stage-gate provided a broader view, enabling for more punctual macro-planning with a clear overall vision in terms of direction and effective resource allocation to attain goals.

The aim of the third article was to address the problem of reskilling and upskilling in a complex, multi-disciplinary topic, aiming to confirm potential levers of superior training efficacy and effectiveness. The analysis performed regarded the case of comparison between a traditional, lecture-based remotely delivered training and an innovative remotely delivered training in terms of efficacy and satisfaction reported by trainees. The context chosen was lean and digital operations management, testing a dynamic model for training transfer. The results showed how the innovative approach to training has proven to effectively reinforce the traditional, lecture-based training, both in terms of satisfaction and reported training self-efficacy from participants, when the items of the dynamic model of training transfer are considered in full.

This thesis, is a path that unfolds across different methodologies, from the development of a conceptual framework, to a qualitative and a quantitative study, aimed at building a multi-perspective understanding of its broader subject, as well as at developing a holistic learning experience for the author of this thesis, to be set as basis for future research and professional endeavours.

The outcomes of this piece of research have both implications for theory and practice. In particular, this thesis evidences the usefulness of innovative forms of training to steer, manage and exploit the full potential of technology and novel organizational methods to increase process performance in organizations.

The contributions also span to the domain of implementation for these advanced products and processes, with the positive evaluation of Agile and stage-gate hybrid models for the development of these innovations in technologies and organization.