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A scientific approach to decision-making: Key tools and design principles

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ABSTRACT

The recent empirical studies have shown the positive impact of a scientific approach to decision-making on entrepreneurial performance. Building on this evidence, this article offers a description of the scientific approach that is oriented toward its practical implementation by entrepreneurs. Focusing on the approach's two main pillars – the processes of theory building and evidence gathering – we outline a set of tools developed to facilitate the application of the scientific approach in practical decision-making activities. Ultimately, we derive a set of design principles that researchers can adopt to develop novel tools and methodologies to aid entrepreneurial actions based on the prescriptive aspects of the scientific approach.

1. Introduction

There is ample evidence that entrepreneurs and managers do not always follow systematic routines when making decisions and that this leads to suboptimal choices (e.g., Bonabeau, 2003; Kahneman et al., 2019), calling for a shift towards more structured approaches (Davenport & Bean, 2018; European Business Review, 2021). Within this context, scholars advocated for the use of decision-making frameworks for decisions under uncertainty in entrepreneurial settings that are backed by a *theory-building* process (Agrawal et al., 2024; A. Camuffo et al., 2023b; Ehrig & Schmidt, 2022; Felin & Zenger, 2009; T. Felin et al., 2024; Novelli & Spina, 2024; Zellweger & Zenger, 2021, 2022), such as a scientific approach to entrepreneurial decision-making (Camuffo et al., 2020, 2024). A scientific approach promotes the development of a clear definition of the business problem and its connections with potential solutions and the environment (Camuffo et al. 2020; 2023a, 2023b). Specifically, the scientific approach puts a large emphasis on the formulation of decision-makers' theories about the strategic problem to be solved. Theories are conceptual causal structures, through which decision-makers map their subjective beliefs (Camuffo et al., 2023b). The formulation of theories serves as the backbone of hypotheses articulation and testing, with the goal of making experimentation more precise and grounded in scientific principles (Spina et al., 2020), and of making hypotheses-testing less based on trial-and-error principles.

However, a significant challenge lies in practically implementing this approach and in delivering its principles in a pragmatic form (van Aken, 2004), due to the fact that entrepreneurs are not necessarily familiar with the use of concepts such as theories, probabilities, and hypotheses. Despite the availability of various toolkits focusing on aspects like entrepreneurial problem framing or testing, there remains a notable gap in tools and methods[1] designed for the practitioner-oriented application and implementation of scientific approach principles. Thus, the objective of this article is to articulate a set of principles that support the creation of such tools and methodologies. These principles are intended to translate the prescriptions of the scientific approach literature into actionable tools that can be used directly by entrepreneurs.

In doing so, we begin by reviewing the recent body of knowledge showing the effects of applying a scientific approach to decisions made by entrepreneurs and from the more general literature on systematic approaches to decision-making. Empirical findings from randomized control trials (RCTs henceforth) show how entrepreneurs trained to adopt a scientific approach to decision-making are more likely to operate a better project selection (Coali et al., 2024), implement more

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[1] In this context, "tools and methods" refer to the general resources, frameworks, and techniques that entrepreneurs employ when developing specific deliverables or tangible outputs (e.g., the Business Model Canvas for creating a business model or a tool for designing Minimum Viable Products).

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focused changes to their ideas (Camuffo et al., 2024) and achieve higher revenue performance (Camuffo et al., 2020, 2024). This latter effect is particularly observed among entrepreneurs at more advanced stages of business model development (Novelli & Spina, 2024). Agarwal et al. (2024) report positive effects on economic performance for agricultural entrepreneurs in Tanzania that were taught to apply a scientific approach emphasizing theoretical reasoning. Moreover, studies using observational data suggest that systematic decision-making practices based on experimentation, the latter being part of the prescriptions of the scientific approach, lead to higher performance (e.g., Harms & Schwery, 2020; Koning et al., 2022; Leatherbee & Katila, 2020).

Building on this foundational knowledge, we developed a set of design principles guiding the creation of tools and methods aimed at facilitating the practical application of the scientific approach to decision-making. Specifically, we discuss a series of tools created by a team of researchers studying a scientific approach to decision-making (Agrawal et al., 2024; Camuffo et al., 2024). These tools are intended to translate prescriptive principles into action plans for entrepreneurs. This manuscript presents an illustrative, rather than an exhaustive, inventory of such tools, with a primary focus on those critical for advancing theory and hypothesis development – two key components of the scientific approach methodology. While the validation of each tool's effectiveness falls outside this study's scope, we reference their application in a series of randomized controlled trials (RCTs) conducted in recent years.

The paper is structured as follows. Section 2 analyzes the decision-making problems addressed by the scientific approach, reviews the relevant knowledge base, and outlies its main principles. This section also discusses some of the key distinctions between this approach and the Lean Startup methodology. Section 3 details the design principles derived from an analysis of the tools and methods that have been developed to help entrepreneurs effectively apply the scientific approach in their decision-making activities. Section 4 provides an overview of the methodology used by the research team to evaluate the tools' effectiveness. Finally, Section 5 concludes the article with a reflective discussion on the scientific approach and its practical implementation.

2. A scientific approach to decision-making

2.1. The principles of a scientific approach to decision-making

Entrepreneurs and decision-makers dealing with strategic problems often act under conditions of uncertainty (e.g., Agrawal et al., 2021; Gans et al., 2019; Knight, 1921). Prior research has identified two main types of approaches that entrepreneurs can use to navigate uncertainty and inform their decisions (Ott et al., 2017): *cognition-based* and *action-based* ones. *Cognition-based* approaches posit that entrepreneurs can gain a comprehensive understanding of the market and customer behavior by reasoning through mental models and cognitive structures, which inform their decisions and strategy formation process (e.g., Csaszar, 2018; Csaszar & Laureiro-Martínez, 2018; Csaszar & Levinthal, 2016; Gary & Wood, 2011; Walsh, 1995). *Action-based* approaches focus instead on the iterative formation of strategies based on learning from the feedback obtained from an initial set of actions (Ries, 2011; Blank, 2013; Bingham & Davis, 2012; Bingham & Eisenhardt, 2011). These approaches range for instance from trial-and-error learning to the controlled variation of activities that characterizes experimentation.

The scientific approach to entrepreneurial decision-making is in line with an approach where the insights from these two approaches are combined (Ott et al., 2017; Ott & Eisenhardt, 2020) .[2] It emphasizes the importance of starting from a cognitive (theory-based) understanding of the problem faced by the entrepreneur, which then guides a process of evidence collection (for example, via experimentation), which validates (or not) the cognitive understanding of the entrepreneur and eventually informs entrepreneurial decisions. The main pillars of the scientific approach (each composed by two subcomponents) are consistent respectively, with the intuitions behind the way in which cognition-based and action-based approaches address uncertainty. Fig. 1 provides a graphical representation of the way in which these two components are combined in a scientific approach to decision making.

The scientific approach starts the decision-making process with the use of *cognition*, its first pillar. The first and fundamental component of the cognition-based phase, and the distinctive point of the scientific approach compared to alternative approaches, is the development of a **theory "of value"** (Agarwal et al. 2024; Felin & Zenger, 2009). A theory is a system of ideas or concepts intended to explain, predict or hypothesize the existence of a precise causal chain of events (Camuffo et al., 2023b; 2023a)**.** Entrepreneurs define a conceptual causal structure and provide a subjective evaluation of how likely the future contingencies they predict will eventually manifest themselves (i.e., in probabilistic terms, they define a prior *belief*). The development of a theory is rooted in the literature on strategic representations (e.g., Csaszar & Levinthal, 2016) and the theory-based view of strategic processes (e.g., Ehrig & Schmidt, 2022; Felin & Zenger, 2009), which detail how having a holistic representation of the mechanisms and contingencies behind the development of a business proposition can lead to better strategies. A theory supports value creation if it is novel, simple, falsifiable, and generalizable (Felin & Zenger, 2017), and also decomposable into sub-problems that represent specific factors affecting the value of the business (Nickerson et al., 2007). Encouraging entrepreneurs to develop a theory in the terms proposed by the scientific approach, pushes them to think about the business problem they are facing – such as the development of a new value proposition or the introduction of an innovative product or service – in a holistic but structured way. By adopting this approach, entrepreneurs can gain a deeper understanding of the contingencies affecting their value proposition and identify key elements that are crucial for the potential success of their idea. The development of a theory supports the decision-making process by leading the entrepreneur to develop expectations before the testing phase regarding what would be the potential decisions in case of positive and negative outcomes of the test. The process of declaring expectations in advance helps in conducting a more objective and clearer evaluation, with direct implications for future actions.

After the theory formulation, the scientific approach prescribes the development of testable **hypotheses**. Starting from their theoretical models, entrepreneurs translate uncertain assumptions or unproven causal links into falsifiable statements. This helps decision-makers understand that their theory is a specific representation of the world and that alternative explanations may exist (adopting a counterfactual or contrarian thinking approach, see Zellweger & Zenger, 2021). The development of hypotheses based on these models constitutes the basis for conducting tests and experiments (Leatherbee & Katila, 2020) and enables the connection with the second pillar of the scientific decision-making process.

The *cognition-based* phase is then complemented by the *action-based* phase, the approach's second pillar. Its first component is the collection of **evidence** based on entrepreneurs' prior beliefs. Mimicking what scientists do, entrepreneurs are encouraged to conduct experiments that allow them to precisely test their hypotheses. Entrepreneurs can use

[2] Cognition and action-based approaches are not necessarily mutually exclusive, and entrepreneurs are often observed combining them in some form. The scientific approach advocates for a systematic approach to the way in which these two approaches are combined.

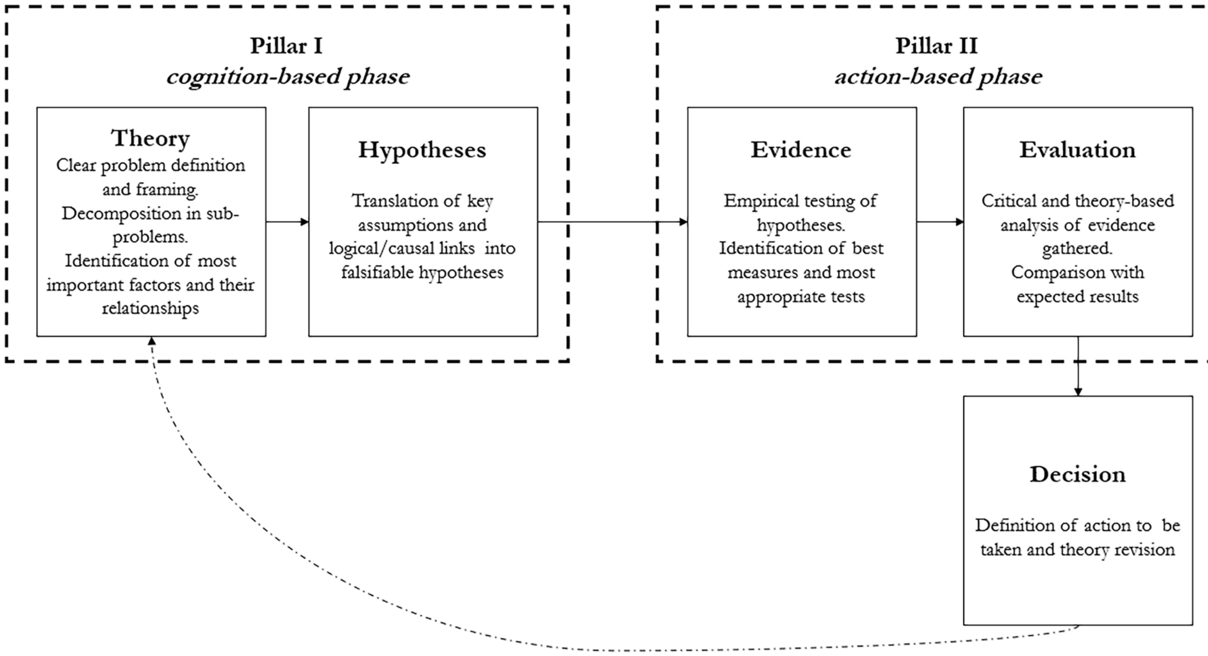

Fig. 1. – The scientific decision process.

different approaches to data-gathering, ranging from qualitative interviews to controlled experiments, depending on the stage of development of the project and type of idea to be tested (Shepherd & Gruber, 2021). The key point is that the evidence collected should be directly related to the hypothesis being tested, requiring careful consideration of the metrics used to assess whether the specific determinants predicted by the theory are valuable, possibly identifying causal relationships (Davenport, 2009; Koning et al., 2022; Thomke, 2020). Emphasis should also be put on statistical concepts such as sample representativeness, to ensure that the collected data is informative about the factors under investigation.

The last component is the critical and diligent **evaluation** of test results. The organizational learning tradition suggests that one important component of action-based learning is the absorption of feedback generated from actions (Levitt & March 1988; Ott et al., 2017). Based on this insight, evaluation of feedback is an important component of the action pillar. But whereas in a pure action-based learning model decision makers use feedback to devise new actions to perform, a scientific decision maker considers the feedback by comparing it with the original theory and the prior expectations. This process of comparison of the results with the expectations that have emerged from the theory feeds directly into the final step of the process, which consists in reaching a final **decision** ultimately leading to a business action. For instance, strategic decisions for early-stage entrepreneurs evaluating the potential feasibility of their business ideas include the possibilities to pursue the project in its current form, if the results support the theory; to pivot to novel strategic directions; to terminate the project if the results do not support the theory. A revision of the theory can also be an outcome of the process. By following a scientific approach, entrepreneurs act first as theorists and then as empiricists in making their decisions (Zellweger & Zenger, 2021). Overall, the scientific approach proposes a process for decision-making that mimics what scientists do when conducting research. This process can be summarized in five core principles:

Principle 1 (Formulate a theory): Begin by identifying key attributes that delineate potential future states, the problem addressed by the business idea and the identified solution, acknowledging the presence of uncertainty and of potential alternative paths. Identify the causal relationships between the attributes and the beliefs underlying those attributes and relationships.

Principle 2 (Outline hypotheses): Identify the main elements of uncertainty in the theory, and outline clear, falsifiable hypotheses to gather informative signals about them.

Principle 3 (Gather evidence): Test hypotheses by conducting experiments and collecting rigorous evidence. Use the most appropriate methodology, according to the hypotheses to be tested, ranging from interviews and surveys to randomized experiments.

Principle 4 (Update the theory): Use the evidence collected to update the theory.

Principle 5 (Make a theory-and-evidence-backed decision): Make a decision based on the revised theory. The decision can also be to repeat the cycle by collecting evidence on the revised theory before making a decision.

2.2. Empirical evidence on the scientific approach to decision-making

The empirical evidence supporting the positive outcomes arising from the application of this approach is growing. Camuffo et al. (2020) provide initial evidence of the effect of a scientific approach to decision-making through a pilot with 116 start-ups. In this study, the authors ran an RCT involving entrepreneurs joining a business support program starting with a business training course. Entrepreneurs were randomly assigned to either a control or treatment group – with each group receiving comparable but different training. The control training taught entrepreneurs to validate their business ideas using standard tools and techniques. The treatment training instead augmented the control approach with the "scientific" framework: these entrepreneurs were taught to develop a theory of their business problem, derive falsifiable hypotheses, and conduct a more rigorous empirical evaluation of such claims. The initial results from Camuffo et al. (2020) have been replicated and extended by Camuffo et al. (2024) who provide evidence from large scale field experiments, where more than 750 early-stage entrepreneurs in four different locations and times were randomly assigned to two business training courses following the same approach used by Camuffo et al. (2020). Results show that entrepreneurs taught to follow a scientific approach are more likely to 1) terminate their projects, 2) conduct more focused pivots, 3) perform better in terms of realized revenues within the period of observation. Agarwal et al. (2024), through an RCT conducted in Tanzania's agricultural sector, show that entrepreneurs taught to adopt a scientific approach with a peculiar emphasis on theory-building have higher economic performance when compared to entrepreneurs taught to follow an approach emphasizing experimentation. Theory-driven entrepreneurs also make more holistic changes to the business model.

More recent studies explore the boundary conditions and mechanisms underlying the approach. For instance, Novelli and Spina (2024) explore quantitatively and qualitatively how the impact of the approach on entrepreneurial performance varies depending on the stage of development of the firm business model and the consequent level of strategic commitment already made by the entrepreneur. The application of the scientific approach helps entrepreneurs who have already committed to a specific business model configuration to fine-tune it, with a relatively quick positive effects on their performance. Instead, it brings entrepreneurs who are still earlier in their business model definition "back to the drawing board", increasing their level of epistemic uncertainty. This enables them to understand and correct their earlier mistakes, which might offer positive returns in the longer term. Complementing this finding, Coali et al. (2024) show how the higher termination rate recorded for scientific entrepreneurs is preceded by a phase in which scientific decision makers adjust their expectations regarding the values of their ideas, suggesting that the approach created more awareness about the promise of the idea. However, this tighter process is associated with a better project selection: treated entrepreneurs do not discard projects that are on average better than the ones developed by control entrepreneurs, with the former being better performers even years after the training.

2.3. The scientific approach and the lean startup approach

It is worth noting the main differences of a scientific approach with the Lean Startup approach (Ries, 2011; Maurya, 2016). As elaborated by Felin et al. (2020, 2024), the Lean Startup is based on the scientific principles of hypothesis testing and experimentation so that entrepreneurial decisions are informed by evidence. However, the scientific approach differs on a series of distinctive features. First, it recognizes the fundamental importance of the theory-building process, of the identification of cause-effect relationships and subjective beliefs and of making probabilities explicit (Agarwal et al., 2024; Camuffo et al., 2023a; 2023b). While tools like the "Five whys" canvas (Ries, 2010a) used in Lean Startup can also help entrepreneurs uncover the underlying causes of unexpected test results or faulty products or activities, in the scientific approach the identification of causal structures is a necessary condition preceding any hypothesis development and experimentation effort. With the guide of the theory, part of the search process takes place cognitively and offline. The theory helps identifying the more promising or uncertain elements of the value proposition, enabling the decision maker to focus the hypothesis development and evidence collection phases on those areas, ultimately saving times and resources (see Spina et al., 2020 for a detailed example). While the two approaches have in common the phases of experimentation and customer validation – encouraging entrepreneurs to "get out of the building"[3] – the scientific approach emphasizes a more deliberate process for the decision of which experiments to run (Spina et al., 2020) and for the later incorporation of feedback (see also the discussion in Zellweger & Zenger, 2021).

As elaborated by Felin et al. (2024), the Lean startup approach is built on the assumption of information asymmetry between the entrepreneur and the customer: the latter are assumed to possess information and knowledge that the entrepreneur needs to access and incorporate into new products and services. To the contrary, the scientific approach emphasizes the idea of *beliefs* asymmetry, which plays a key role in directing awareness and attention toward highly specific, possibilities within one's surrounding. Finally, compared to the Lean start up approach, the scientific approach is inherently *generative* (Felin et al., 2017, 2024), in that entrepreneurs using a scientific approach are not just focused on representing their environment but also on *creating* sources of value.

The differences between these two approaches imply that their effectiveness can reasonably vary depending on the context in which the decision is made. For example, in contexts characterized by a high financial cost of experimentation, the development of a theory can play a crucial role in reducing the space of solutions and, therefore, the cost of experimentation (Camuffo et al. 2023b). The same is valid for contexts characterized by high levels of uncertainty, for instance in which past data is not available or radical solutions are proposed. In these settings, experimentation without a clear theoretical framing could provide confusing outcomes (e.g., Camuffo et al., 2023b). Vice versa, in contexts with more structured problems, existence of past evidence, and a clearer definition of the problem space, a Lean startup approach could be appropriate.

3. Designing tools to apply the scientific approach

Having discussed the implications and core principles of a scientific approach to decision making, in this section we describe a set of tools developed to put them in practice. Particularly, we focus on tools developed for entrepreneurs dealing with strategic decisions under uncertainty, such as the one related to the launch of a novel venture. In this context, we derive a set of design principles that explicitly connect the core principles of the scientific approach with the essential features that these tools should possess to effectively implement them.

An important premise is that many entrepreneurs are not familiar with formal scientific methodologies nor with concepts such as theories and hypotheses or causal reasoning and probabilistic terms.[4] Ultimately, successfully guiding entrepreneurs to adopt and apply a scientific approach requires tailored strategies that solve these challenges while making sure the approach fits the unique needs of decision-making in entrepreneurship.

To address these practical challenges, we introduce a set of tools and methods designed by a large team of researchers[5] to facilitate the practical application of the principles of the scientific approach to decision-making. The tools introduced in the following section are all based on original work. These tools were designed for entrepreneurs' own use, with the purpose of facilitating the application of the scientific approach to their decision-making processes. Although a teacher may introduce these tools to entrepreneurs, for instance in the context of an entrepreneurship course, the entrepreneur remains the intended primary user.

Ultimately, by closely observing the needs and challenges faced by entrepreneurs, we identified key elements necessary for the successful application of the scientific approach. Building on these observations, we derived and describe in this paper specific *design principles* through a process aimed at balancing potentially competing objectives: 1) maintaining academic rigor and accurately translating the prescriptions of

[3] This definition has been coined by Steve Blank, in several interviews, lectures and speeches. For instance: https://www.inc.com/steve-blank/key-to-success-getting-out-of-building.html

[4] For instance, Eric Ries, the founder of the Lean Startup movement, highlights in his own blog the difficulty in developing and running hypothesis-testing with Minimum Viable Products despite the latter being designed to simplify validation activities (Ries, 2010b)

[5] In addition to the authors' team, this group includes Arnaldo Camuffo, Alfonso Gambardella, Francesca Bacco, Daniele Battaglia, Claudia Frosi, Diego Jannace, Teppo Felin, Danilo Messinese

the literature, and 2) designing intuitive and user-friendly layouts.[6]

3.1. Theory: tools, methods, and design principles

We build on the literature on *theory-based* approaches (Camuffo et al., 2023b; Ehrig & Schmidt, 2022; Felin & Zenger, 2009, 2017), which defines a theory as a way to clearly explain *why* a business idea should be successful, through a connection of the main elements defining the idea and their interactions with environmental contingencies. In the language of Camuffo et al. (2023a, 2023b), these elements are called *attributes*. Attributes are then connected through each other via *causal links*, and entrepreneurs make explicit their prior *beliefs* or subjective probabilities of the extent to which an explicated causal structure is "true". This cognitive process allows the entrepreneur to identify the first-order principles that lead to her business idea creating value and unveil the mechanisms potentially leading to startup success.

Translating this process into practical and actionable tools is not straightforward: while the concept of theory is well known to scientists, an entrepreneur might not necessarily be familiar with it (or with this terminology). Thus, translating this concept into actionable tools demands framing it as something concrete and easily relatable to entrepreneurial practice.[7] One potential solution is to nudge entrepreneurs to think of a theory as a logical *story* that explains the determinants of value of the business idea. In creating this story, entrepreneurs are encouraged to explain why each *attribute* – that is, an element of the problem or of the solution having an uncertain future realization (A. Camuffo et al. 2023b) – is relevant to the story and how *attributes* are causally connected. To be effective, entrepreneurs' stories should 1) be articulated in a clear and logical way; 2) consider potential alternatives; 3) be based on logical facts and/or previous evidence; and 4) be as modular as possible.

As an illustration, consider the case of Emily, developing a business that creates and sells a sustainable and ethical fashion clothing line. She starts by developing a theory about the market and the reasons why customers would be interested in her business. She creates a story that explains her intuition behind the idea: many people are concerned about the impact of fast fashion on the environment and the poor working conditions in the fashion industry, but they struggle to find affordable and stylish sustainable clothing options. Emily's business will fill this gap by offering a wide range of sustainable, ethically made clothing at an affordable price point. She also identifies key determinants of her business' success, such as the availability of sustainable and ethically sourced materials and customers' willingness to pay for sustainable and ethical fashion. These *attributes* are key to Emily's theory: customers' concerns about the impact of fast fashion and the scarcity of sustainable clothing options are causal antecedents to customers' willingness to pay, which ultimately determines the overall success of the idea jointly with the *attribute* related to the availability of ethically sourced materials. Emily also considers an alternative theory: that customers are indeed interested in sustainable and ethical fashion but are not willing to pay a premium for it. In this case, Emily's business should focus on finding ways to offer sustainable and ethical clothing at prices that are competitive with fast fashion. In doing this exercise, not only Emily clearly outlined the causal chain behind the value of her business idea, but also developed alternative pathways to follow that hinge on different representations of the problem.

Emily's example showcases how *attributes* are unfolded in a hierarchical fashion, like tree branches, and are connected to each other in an a-cyclical way. The example also shows that, through theoretical reasoning, Emily was able to be "parsimonious" in the choice of relevant attributes: only few and key ones were selected by Emily as important determinants of her business proposition. Emily also thought in probabilistic terms, realizing that if some of the attributes were realized, the probability of her idea being successful was likely to increase. Finally, Emily was able to identify alternative attributes and alternative causal links, paving the way for potentially new solutions or alternative patterns of development.

We provide below a brief description of three specific tools that were employed in some of the empirical research on the scientific approach to decision-making and in entrepreneurship education.[8]

The first tool is the *story tree* canvas. To implement the design principles of *Attribute identification* and *Causal logic*, the canvas starts with three questions that help entrepreneurs define the main *attributes* of their theory: 1) what problem or phenomenon are you observing? 2) why is that happening? and 3) what could you do about it?. By answering these questions, entrepreneurs start forming a preliminary mental representation of the causal links behind the value generated by their business idea, both on the problem and solution sides. After answering these questions, the *story tree* guides the entrepreneur through three steps. The first step is to decompose the story into different building blocks, i.e., *attributes*, that identify elements of the problem with uncertain realizations: in doing so, entrepreneurs select the most relevant ones, and discard those that are less relevant in the spirit of developing a parsimonious (*Design principle 3*) but complete representation of the problem (Felin et al., 2020). The second step is the identification of causal roots and mechanisms, in the spirit of identifying the assumptions behind each of the *attributes*. This thought process allows the entrepreneur to clearly define why *attributes* have been included, and whether it is reasonable to make assumptions over them or if there are first-order principles that should be investigated more. Finally, entrepreneurs are encouraged to create causal connections between *attributes*, to create a structured causal chain that in principle explains why the business should be successful.

Importantly, there are no pre-defined blocks that form the *story tree*: entrepreneurs can avoid standard representations of the problem and focus only on specific *attributes* according to the stage of development in which the business idea is. For example, an early-stage entrepreneur might focus solely on the exploration of market needs and user problems, thus drafting a *story tree* exclusively focused on this type of investigation. Moreover, entrepreneurs can be encouraged to develop more than one *story tree*, to have different representations of the same problem (*Design principle 4*).

As an example, drawing from the MiMoto case detailed in Spina and Fronteddu (2022), we describe how the MiMoto founders developed their idea for a network or electric scooters that can be rented per minute through an app. The founders started to reflect on their own experience living in Milan (Italy) and thought it would be valuable to offer a network of easy-to-access electric scooters because pollution and traffic are two big problems for commuters. They then identified four main categories of *attributes*, related to the problem and the solution offered. For instance, under the problem category, they identified three main *attributes*: long commuting times, pollution, and lack of mobility alternatives. For each of them, they identified potential antecedent attributes: traffic causes longer commuting times, gas-powered vehicles generate toxic emissions, and issues with public transportations and limitations of bike usage are causing a lack of alternatives to cars. Finally, they causally connected these *attributes* to potential "end" *attributes* of the story, like those related to the ideal customer or to the potential offer.

The *story tree* could also be thought of as a simplified version of a second tool that can be leveraged to represent entrepreneurs' theories in

[6] Whereas these tools were not developed following a design science approach, the process followed is consistent with its key steps and we emphasize the key similarities. We thank the Editor and one of the Reviewers for recognizing and suggesting this association.

[7] One tool intended to help entrepreneurs in the development of a theory is the Value Lab. See Felin et al., (2021, 2024).

[8] More details or canvases for the theory-related tools are available upon request.

a more precise and schematical way: direct acyclic graphs (DAGs) or causal graphs. The latter are ways to represent causal chains of attributes and define (subjective) probabilities over the realization of such *attributes* and causal links. In this sense, decision makers can be nudged to think about their problem framing by identifying key *attributes* and causal links, that can then be represented graphically using DAGs. This tool answers to all four design principles, albeit in a less user-friendly fashion. Moreover, in this more sophisticated tool, decision makers can also be nudged to make explicit subjective probabilities over the assumed connections, which will become the subject of the empirical testing (Camuffo et al., 2023a, 2023b).

A third tool that can be used to develop a structured theory is the *theory map*. It can be used when entrepreneurs have already completed other canvases proposed by other approaches, such as the BMC or Lean canvas and particularly responds to the first three design principles outlined above. Starting from the problem representation in the latter canvases, entrepreneurs are nudged to consider the BMC as the starting point of their business story: the BMC allows the decomposition of the theory into multiple elements (*attributes*), even if pre-defined and potentially limited. The *theory map* can be thought a set of questions directly related to the other canvases' elements (e.g., *why* would potential users face the problem described in the BMC and *how* is this related to the proposed solution?), that prompts the entrepreneur to identify key attributes and their causal connections. By answering these questions while considering different attributes simultaneously, the tool encourages more thorough and holistic thinking about the problem. It does so by causally connecting elements that are virtually separated in the canvas, being it the standard BMC or the Lean canvas. In simpler terms, the *theory map* prompts entrepreneurs to think about the reasons why *attributes* have been added, why they are important for the business proposition, and whether elements are causally connected with each other. This thought process allows entrepreneurs to identify unnecessary or redundant attributes and to focus on the most important assumptions that could be subject to further testing.

All three tools were developed by the scientific approach research team to address the need for better problem framing before gathering evidence and to streamline the theory development process. The *story tree* was conceived as a template to simplify the identification of key *attributes* and *causal links*, with initial questions serving the purposes of "softening" the somehow impersonal process of creating schematic structures with little text description. The application of DAGs to strategy problems is designed as to address needs of more sophisticated decision-making processes, where the need of explicitly stating probabilities (and related computations) is more marked. Finally, the *theory map* was conceived with the aim of enhancing the existing tools developed by the Lean Startup movement, making the process of theorization more straightforward, while also establishing a connection with more widely recognized instruments.

Regardless of the differences behind these tools, they can be reconducted to a common set of design principles and their overarching goal is to help entrepreneurs to think in terms of causal chains of *attributes* that explain the potential success of their business idea, as to parsimoniously identify assumptions and beliefs that need to be tested (Jannace & Camuffo, 2023). Finally, these tools can also easily be used in conjunction with other existing tools and canvases, such as the templates for *customer journeys* or *customer personas*. For instance, the initial identification of the reasons for targeting specific customer segments can be done using the *story tree*, followed by the development of *customer personas* for a more complete representation of those targets. Additionally, the *customer journey* could be built on the causal connections created in the *story tree* or in DAGs, to deepen the process of investigation and theorization by further decomposing its attributes.

By abstracting from the three tools described above, we derive a set of design principles that should guide the development of effective theory-building tools:

Design principle 1 (Attribute identification): For entrepreneurs to identify key attributes and associated beliefs relevant to their current stage of business development, tools should promote a modular approach to theory-building, allowing for flexibility and adaptability of the theory over time.

Design principle 2 (Implement causal logic): For entrepreneurs to systematically identify causal connections between the key attributes, tools should guide them through a structured process that helps establish clear cause-and-effect relationships and associated beliefs.

Design principle 3 (Encourage parsimony): For entrepreneurs to maintain a focused and manageable scope of analysis, tools should facilitate the elimination of less relevant attributes or causal relationships, ensuring an effective and targeted approach to theory development.

Design principle 4 (Alternative scenarios consideration): For entrepreneurs to identify potential alternative attributes or causal paths that could lead to different outcomes or strategies for the business, tools should enable them to systematically compare and evaluate alternative scenarios and contingencies.

3.2. Hypotheses: tools, methods, and design principles

Once the theory has been developed, the scientific approach encourages entrepreneurs to start the development of **hypotheses**. According to the second principle stated in Section 2, hypotheses should be derived directly from the theory and can be defined as short statements that describe what happens under specific conditions. Specifically, entrepreneurs create hypotheses about *attributes'* realizations or on the existence of specific *causal links*, as to find validation for the overarching theoretical framework they created and update their initial beliefs.

Following the scientific approach, entrepreneurs are encouraged to develop their hypotheses focusing on the theorical variable of interest, as opposed to thinking immediately about their empirical operationalization. The goal is to encourage them to maintain their focus on their theories and related hypotheses, without limiting their thought process to solely what can be empirically measured. The method in which constructs are empirically measured is a later-stage question, and empirical constraints are explicitly considered in the evaluation of results, as we will elaborate on in the later sections. Again, the rationale for this approach is that developed hypotheses should closely align with the underlying theory, potentially testing mechanisms or causal relationships.

To develop tools that help entrepreneurs developing hypotheses, we describe the rationale behind key design choices we made and elaborate on the then-derived design principles. First, as previously mentioned, hypotheses are effective when coherent with the formulated theory. The comprehensive work that entrepreneurs do to develop their own representations of the business problem enables them to identify their priors over a set of key *attributes* and causal connection, which they ultimately translate into testable statements that allow for testing the theory as a whole. Second, each hypothesis should be focused on testing one and only one *attribute* or *causal link* of the theory at a time. Crafting a hypothesis such as "Women in large cities prefer taking the taxi over the bike, and do so because of the comfort regardless of the highest price paid" would be less informative than breaking it down into two statements: "Women in large cities prefer taking the taxi over the bike" and "Higher comfort is the main decision driver when choosing which means of transportation to take". This is because testing the two statements separately enables the entrepreneur to identify whether both, none, or only one of them is supported. This would not be possible when testing both statements jointly. This is closely connected to the subsequent *evaluation* phase, and to the potential update of the theory following experimental results. Crafting simple hypotheses that focus on only one specific element of the theory has three main advantages: 1) it simplifies the definition of the relevant empirical test to conduct, thanks to the higher clarity of the research questions and constructs; 2) it increases the precision of findings' interpretations; 3) it allows to distinguish between hypotheses on potential mechanisms versus direct effects.

Third, developed hypotheses should be precise and falsifiable. "Precise" means that key concepts are defined precisely and there is no ambiguity about which elements are being inquired. "Falsifiable" borrows Karl Popper's logic of conjectures and falsifications (Popper, 1959, 2002), which is the fundamental basis of the deductive approach in scientific reasoning. Each statement should be formulated in a way that can be directly answered with a "True/False" response, in line with the principle of theory falsification. Finally, as a result of the theory development effort, entrepreneurs are encouraged to prioritize hypotheses. Indeed, some elements of the theory and related hypotheses are more crucial than others in addressing the problem under investigation. By focusing on the most important hypotheses first, entrepreneurs can ensure that they are testing the most critical elements of their theory. With a well-developed theory and the set of testable hypotheses, the entrepreneur is ready to move to the second pillar of the scientific approach.

Overall, this leads to the following set of design principles:

Design principle 5 (Theory integration): For entrepreneurs to ensure alignment between the theory's attributes/causal relationships and the proposed hypotheses, tools should enable a seamless derivation of hypotheses from the theoretical frameworks, maintaining coherence and consistency throughout the process.

Design principle 6 (Hypothesis simplification): For entrepreneurs to develop hypotheses that focus on only one element at a time, tools should incorporate features that help break down complex theories into singular, well-defined statements.

Design principle 7 (Hypothesis falsification): For entrepreneurs to develop hypotheses that can be effectively tested, tools should incorporate features that help them in stating falsifiable statements.

Design principle 8 (Hypothesis prioritization): For entrepreneurs to effectively prioritize their hypotheses, tools should include mechanisms to compare and rank hypotheses based on their importance to the overall theory and their potential impact on decision-making.

3.3. Evidence: tools, methods, and design principles

The second pillar of the scientific approach is the *action-based* one. It consists of two main components: the *evidence-gathering* process, in which decision makers progress to gather feedback through different techniques such as MVPs or interviews, and the *evaluation* of empirical results, in which they react to the feedback obtained. As emphasized in the previous section, entrepreneurs use the theory and hypotheses developed in the first pillar as a guide to conduct tests and gather evidence that they then reconduct back to the theory before it is translated into revised action.

The type of evidence that entrepreneurs can gather depends on the stage of development of their business idea and the specific aspects that require validation. Validation is the process of testing the feasibility of a business idea by collecting evidence and evaluating the extent to which a "product-market fit" is achieved (Moore, 2014) – the point at which a product or service satisfies a specific market or customer need. It is the process of ensuring that a product or service is desirable, viable, and feasible in the market and that it addresses a specific customer problem or need efficiently and effectively. Using one of the common classifications in the field of entrepreneurship (Ries, 2011), this validation process can be broken down into three main components: problem validation, offer validation, and solution validation (Ries, 2011). Problem validation is the process of testing the existence and size of a problem that the business idea aims to solve. Offer validation is the process of testing the attractiveness of the proposed solution or offer to the target market. Solution validation is the process of testing the feasibility and scalability of the proposed solution. The principles of the scientific approach can be employed to rigorously explore and refine all aspects of entrepreneurial validation efforts. For instance, a theory can be built on solution-related problems, and hypothesis addressing uncertain elements of such theory can be developed as to address the solution validation phase.

Generally, different paths can be taken for different validation purposes. For example, the creation of structured customer interviews and questionnaires can be good instruments for the problem validation phase, while creating an MVP and devising A/B tests might be more useful for the offer and solution validation one. Regardless of the evaluation phase and the evidence gathering technique that is employed, the scientific approach to decision-making emphasizes the importance of adhering to best practices in research methods (e.g., Creswell & Creswell, 2018) both when gathering evidence to test hypotheses as well as when conducting more exploratory interviews to refine theories or to gather a better sense of the market environment. Therefore, the key principle is to adopt a rigorous and systematic approach when designing and conducting any phase of the search process. For example, when conducting exploratory research through interviews, entrepreneurs should prepare structured interview plans and questions, rather than engaging in merely unstructured conversations with potential customers. Therefore, even in the initial, more exploratory phases, the recommendation is to adhere to an interview script and predefine the key topics for discussion. As an additional example, when running a customer survey, entrepreneurs should ensure that the survey questions are well-crafted and that the sample size is large enough to provide statistically significant results. Additionally, they should take steps to minimize bias and ensure that the data collected is accurate and reliable. By following these principles, entrepreneurs can increase their confidence in their findings and make more informed decisions based on the evidence gathered. Table 1 provides an overview of the main options available to gather evidence, including illustrative examples of some of their application across the different phases.

Considering evidence gathering related to hypothesis testing, one key aspect is to identify a clear relationship between the hypotheses being tested and the chosen empirical measurements. Fig. 2 represents an application of this idea using the example of MiMoto presented in the previous section. MiMoto decided to use a questionnaire as their evidence-gathering technique to conduct hypothesis testing. Therefore, they needed to ensure that their hypotheses were clearly connected to the questions in the questionnaire, from which they could derive clear measures.

Starting from the general and testable hypothesis derived from the theory and relevant attributes, the entrepreneur operationalizes the main concepts to be tested and develops a set of questions with a list of possible answers.

In the example in Fig. 2, MiMoto founders are testing the assumption that people are often stuck in traffic when commuting. To do so, they asked potential customers a specific question ("In an average week, how often do you happen to be stuck in traffic?") with specific possible answers to test the idea that traffic is a relevant problem for professionals. It is important to note that, as in any research setting, the choice of questions and answers that constitute part of the survey is discretionary to the entrepreneur.[9] Obviously, the quality of the decision-making process will also depend on the choice of suitable questions and answers that do not introduce biases. So, an important question is how to support entrepreneurs to in these choices. The answer is not

[9] For example, another entrepreneur who is testing the same hypothesis, could ask a different question (e.g., "On a scale from 1 to 7, how pervasive do you think the traffic problem is in your city?") or, given the same question and answers as in Fig. 2, a third entrepreneur could decide to focus on the share of respondents choosing only the option ">5 days per week".

Table 1
Evidence gathering techniques.

	Interviews	Questionnaires	Prototype testing	A/B testing
Short description	One-to-one conversations to gather in-depth insights about a phenomenon directly from customers or other stakeholders	A series of - mostly closed-form - questions to gather insights and obtain validation from larger groups	The process of validating prototypes of a product or service (for example with an MVP)	An experimental comparison of alternative versions of a product/service to determine which one performs better
Application examples	*Theory development*: Exploratory inquiry of customers and markets. *Problem validation*: Validate mechanisms underlying customer problems and needs.	*Problem validation:* Validate customer problems and needs. *Offer validation:* Validate product feature's attractiveness on a larger scale.	*Offer validation:* Validate the attractiveness of the solution's most important features. *Solution validation:* Validate the feasibility of such features.	*Offer validation:* Evaluate the attractiveness of alternative features of the solution. *Solution validation:* validate the feasibility of alternative features; potentially study causal mechanisms.

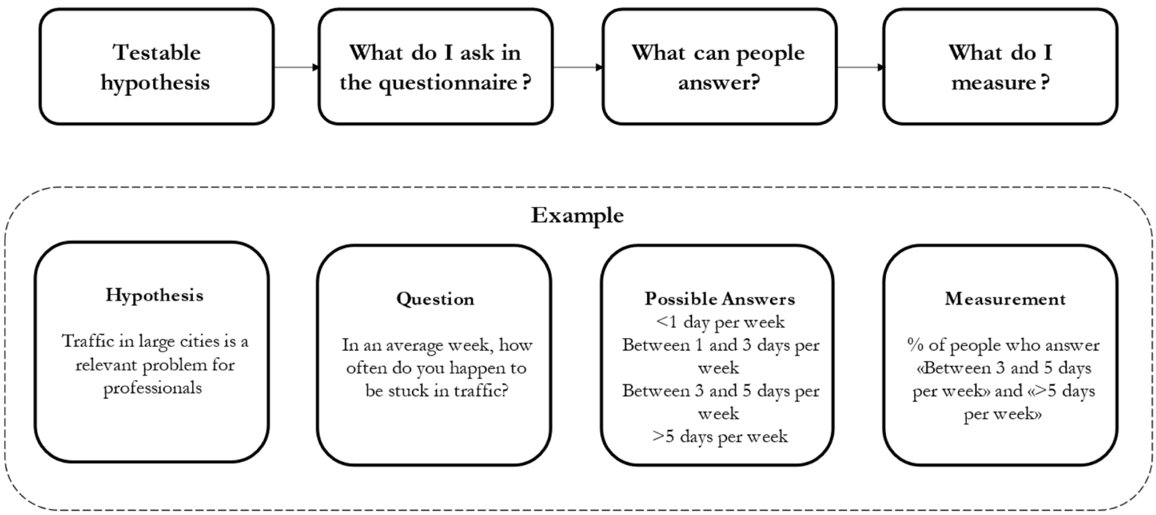

Fig. 2. – Connecting hypothesis to measures (with example).

straightforward. Indeed, unless there are common measures used in previous research or established by practitioners (such as relevant Key Performance Indicators, for instance) or scholars, it is up to the entrepreneur to identify the best measure and argue for its reliability. In our experience, a few safeguarding mechanisms are helpful. First, it is important to encourage entrepreneurs to establish a *clear link* between what is being tested and its measure. Second, measures have to be defined *ex-ante*, that is before results are collected. This pre-determined approach reduces the chances that the chosen measure is influenced by the results and allows for the avoidance of bias in the analysis and interpretation of the data. This procedure is in line with best practices in scientific research, where pre-registration is often used to ensure transparency and avoid confirmation bias (e.g., Simmons et al., 2011; Wicherts et al., 2016). Third, it is important that entrepreneurs absorb specific elements of the scientific culture, such as pre-testing phases that can be conducted with friends or peers, offering comments to potentially improve the quality of questions and measures. These suggestions can be applied irrespective of the specific evidence gathering technique chosen as entrepreneurs are prompted to clearly define the measurable outcomes ex-ante, whether it is the result of a randomized experiment, or a metric related to the MVP.

Finally, when using any of the evidence gathering techniques described above, entrepreneurs are encouraged to determine the relevant population to investigate and draw a potentially representative sample to study. It is important that entrepreneurs have clarity about *what type of* users or customers is their model targeting and reflect on *how well* the sample they chose is representative of this population. Assuring that the sample collected represents the potential customers of the final product or service is crucial to obtain evidence that aligns with the theoretical reasoning and that enables to obtain information that are relevant to the specific decision-making problem.

In this sense, the scientific entrepreneur is encouraged to engage in a *due diligence* of the available sample, *before* conducting the evaluation of the results. Two elements are deemed to be particularly important when conducting this exercise. First, entrepreneurs following the approach are taught to verify if they have a reasonable sample size to obtain informative results. The appropriate sample size might differ according to the type of test conducted and to the reference population. While interviews or MVP testing could produce informative insights with a small sample (such as of 10–15 respondents), questionnaires and precise hypothesis validation exercises should be conducted with larger samples, ideally composed of hundreds of respondents if the type of business/market size allows it.[10] Second, entrepreneurs are invited to verify if the sample is representative of the population they want to investigate. This implies that the first element entrepreneurs should scrutinize are the characteristics of the gathered sample. As stated above, this is a crucial step since it allows them to understand how informative the results could be. While random sampling from the overall population of potential customers could not be a feasible sampling strategy for most of the entrepreneurs, especially if at early stages or with limited resources, it is also true that non-random techniques could lead to samples that are a good small-scale representation of the population being studied. Hence, we elaborate the following set of design principles, particularly relevant to rigorously test hypotheses:

[10] As in scientific research, the size of the sample is strictly related to the size of the targeted population. An entrepreneur operating in a mass market might need a larger sample than an entrepreneur operating in a niche market, to obtain representative results.

Design principle 9 (Clear Operationalization): For entrepreneurs to collect relevant data for hypothesis testing, tools should guide entrepreneurs in translating the variables mentioned in the hypotheses to specific measures.

Design principle 10 (Appropriate technique selection): For entrepreneurs to choose the most appropriate validation techniques, tools should provide explicit categorization of techniques based on their suitability for different phases of validation (problem, offer, solution) and the type of insights they are best equipped to provide (quantitative vs. *qualitative).*

Design principle 11 (Sample representativeness): For entrepreneurs to identify an appropriate sample, tools should allow them to check whether the sample that is used for gathering evidence, is representative of the target population under study.

3.4. Evaluation: tools, methods, and design principles

The *sample due diligence* is critical also for the last phase of the scientific approach: **evaluation**. Evaluation means conducting an objective analysis of the test results, based on reliable measurements and on the definition of prior expectations. Within the scientific approach to decision-making, the evaluation phase plays a pivotal role in bridging action and cognition. During this phase, the feedback obtained from the testing stage is reviewed in comparison to the originally envisioned theory.

Equipped with their hypotheses to test, entrepreneurs have already defined precise empirical measurements in the previous phase. Going back to the example from the previous section, MiMoto founders decided to consider the share of people being stuck in traffic at least three times per week as their main measure. This choice aims to establish a *clear link* between the measure and the hypothesis and to define the measure *ex-ante*, which shows that entrepreneurs have several degrees of freedom when making fundamental choices on what to test and how. However, they should also determine the results they would expect to be able to support their hypotheses *before* analyzing the data. The entrepreneur defines in advance what outcome would correspond to a positive assessment on the validity of the hypothesis. For instance, in the MiMoto example, what is the entrepreneur's expectation regarding the share of respondents being stuck in traffic that will lead him or her to considers the hypothesis "Traffic in large cities is a relevant problem for professionals" supported? We refer to this value as a *threshold*, which is a predetermined value used in hypothesis testing to determine whether a null hypothesis should be rejected or not. The threshold is the outcome that the entrepreneur would ideally expect so that he or she can consider the hypothesis supported if he or she had the chance to investigate the entire population described by the theory. The threshold aspect is also consistent with later developments in the Lean Startup practitioners' literature (Maurya, 2016). Defining outcomes in advance is key to avoid cognitive biases such as the confirmation bias (Kozyrkov, 2019): the decision-maker has to form expectations on the results he/she would expect to falsify her hypotheses, before looking at the actual data. Otherwise, the risk is to "*perceive facts in light of what they already believe […] If you're free to move the goalposts after you find out where the data landed, then that's exactly what you'll do, unconsciously*" (Kozyrkov, 2019). It follows that a key point in applying the approach is that entrepreneurs identify a "threshold" before looking at the data: this allows the entrepreneur to interpret data in the most honest way, and to gather insights that are relevant to the hypothesis testing phase. Such a threshold is not "objective": ultimately, even threshold setting is subject to one own's theory, beliefs, experience, and cognitive traits.

In this phase, the entrepreneur is nevertheless encouraged to reflect once again on the representativeness of the sample. As discussed, entrepreneurs are encouraged to identify a representative sample, but this is not always possible. Short a perfect sample, they are encouraged to be aware of the biases of the sample and take them into account in setting their expectations on the findings. For instance, what if the scooter-sharing entrepreneurs were constrained to gathering data only on middle-aged professionals as opposed to younger professionals? This is where the *sample due diligence* plays a key role: the threshold can be adapted to the sample (i.e., if entrepreneurs understand when to be conservative with their thresholds), before looking at the empirical results on the specific measure. Suppose that MiMoto founders selected a threshold equal to 60 %, and that this threshold was met by the actual answers, but these answers were obtained from individuals in their middle age as opposed to their target of younger professionals. In this case, one way forward would be to adjust their threshold according to their own beliefs about the respondents. For instance, if they believed middle-aged professionals are more likely to get stuck in traffic than young professional, for instance due to their specific travelling time, they would increase their threshold to have a higher rejection bar for their hypothesis. This process of setting the threshold and modify it according to the sample available *before* looking at the results is what we call an "objective evaluation" of the evidence gathered. These remarks can be summarized in the following last set of design principles:

Design principle 12 (Thresholds definition): For entrepreneurs to objectively assess testing results, tools should guide the pre-definition of acceptable outcomes (thresholds) with reference to the measures defined in the evidence phase.

Design principle 13 (Iterative refinement): For entrepreneurs to incorporate in their assessment any available information on possible limitations associated with the methodology used for evidence collection, tools should allow for a substantiated cautious adjustment of thresholds.

To guide entrepreneurs in this seemingly complex process, one tool that can be used is the *hypothesis canvas*, shown in Fig. 3. The goal of this canvas is to provide a visual representation of the evidence and evaluation phases, connecting them with the theory and hypothesis ones, thus helping entrepreneurs to "visualize the process" and making it less susceptible to biases. This tool encompasses most of the design principles outlined above.

The *hypothesis canvas* provides a high-level overview of all the components of the scientific approach, with an emphasis on the measurement part. In the two blocks in the upper part, entrepreneurs state the aspect of the theory relevant for testing and the related hypotheses under empirical investigation (*Design principle 5: Theory integration*). In the two central blocks, they are encouraged to list the technique chosen for data gathering and the measures used to test the hypotheses (*Design principles 9, 10: Clear operationalization; Appropriate technique selection*). Importantly, while entrepreneurs can select the evidence-gathering technique they find most suitable, the canvas encourages them to clearly specify both the chosen technique and the method of signal collection. For instance, this could be through a targeted survey or interview question, or an A/B test, with the entrepreneur also nudged to detail the specific metric to be collected. In the left-hand side block at the bottom, entrepreneurs make explicit their initial beliefs, that is the threshold *as if* the whole population of targeted customers was available (*Design principle 12: Thresholds definition)*. Up to this point, the canvas can be completed even before collecting data, adhering to the principles of defining measures *clearly* linked to hypothesis and declaring outcomes *ex ante*.

Once the data is available, the entrepreneur evaluates whether the sample is appropriate or not in terms of size and representativeness and decides whether to increase or decrease the threshold (listed in the *threshold* box – *Design principles 13: Iterative refinement*). At this point, the empirical analysis of the results can begin, and the entrepreneur indicates the result from the data in the last block on the right-hand side at the bottom of the canvas, deciding whether the tested hypothesis was rejected or supported. A decision can then be made based on the results of this comprehensive and objective evaluation.

But what if some crucial hypotheses are not supported? What if the evidence gathered is inconclusive? Entrepreneurs are encouraged to

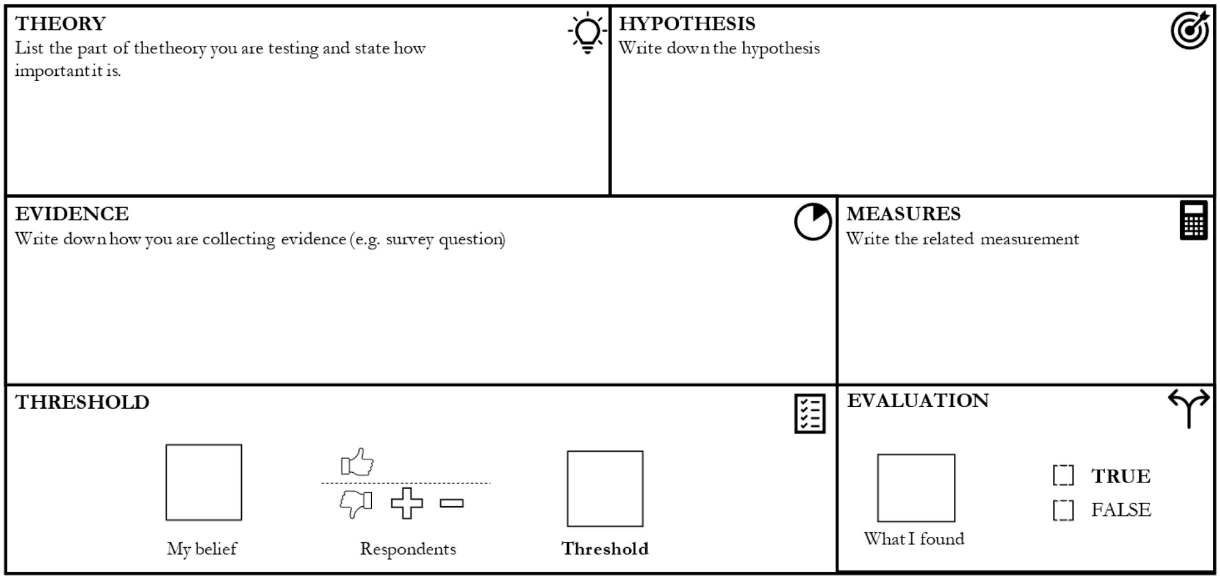

Fig. 3. – The hypothesis canvas.

think about their theory and testing phases in the spirit of Popper's philosophy of science: they can "*learn that they are wrong, […] whereas they cannot learn that they are ultimately right*" (Ehrig & Schmidt, 2022: 1289). If the entrepreneur believes the data is reliable and the theory is sound, negative results provide a negative signal about the plausibility of the theory. For instance, if a crucial hypothesis is not supported by evidence, this could lead to the termination of the project or to the development of an alternative explanation for the phenomenon under observation, where the entrepreneur tries to understand potential alternative explanations. Provided the theory development has been done carefully, the entrepreneur might already have an explanation in mind (an *alternative* theory), turning the negative results into a potential positive signal of the plausibility of an alternative explanation. Furthermore, negative or inconclusive results may arise from initially targeting the wrong customer segment, prompting entrepreneurs to explore the potential applicability of the theory in different markets. The scientific entrepreneur is encouraged to be open to potentially discomforting results, and, if needed, to revise assumptions and theories. The theoretical reasoning underlying each test may support alternative explanations and inform about alternative pathways or being a clear negative signal leading to an earlier termination of the entrepreneurial project. This step of comparing results with the original theory is important. Without theoretical reasoning, just relying on empirical results might lead to biased interpretations, and to a myopic search (Gavetti & Levinthal, 2000). Scientific entrepreneurs are also encouraged to interpret results bearing in mind their limitations, such as that they might come from a limited sample and that additional rounds of data collection might lead to different results – in this way, scientific entrepreneurs do not treat results from investigations with customers as an "absolute truth".

4. Practical development of tools and future research

The previous section described some of the tools developed to put in practice the prescriptions of the scientific approach, and the subsequently derived design principles that could also inform future research on this topic. The development of some of the tools mentioned in this article took place in the context of RCTs conducted by the scientific approach research team. The RCTs were conducted in different time periods, and each of them provided an opportunity to observe and learn the way in which a scientific approach to entrepreneurial decision-making can be implemented in practice. The research team organized business support programs lasting for several months. The programs included two components: an initial idea validation training course, and monthly events of general interests. During the training course participants were randomly assigned into either a treatment group, which received training incorporating the scientific approach, or a control group, which received comparable training but without the scientific approach. To offer actionable resources for entrepreneurs to adopt and utilize the scientific approach, a range of tools were introduced in these training sessions. These tools were exclusively available to participants randomly assigned to the "scientific approach" training.

The tools described in previous sections were not subjected to a conventional design-science validation cycle but underwent validation rounds both before and during the RCTs. In designing the training programs, the research team pre-tested the tools for entrepreneurs through iterative development cycles. For example, in creating the hypothesis canvas detailed in Section 3.4, multiple ideation cycles were conducted before finalizing the initial draft. After achieving a first working version for each tool, validation rounds were carried out by soliciting feedback from third parties tasked with adopting the tools and providing feedback on usability. For instance, research assistants – Master's level students with an interest in entrepreneurship – were asked to act as entrepreneurs attending the acceleration program and to provide feedback on which aspects of the tools were not clear and needed refinement. Alternatively, tools were circulated among scholars and practitioners for feedback on both their theoretical rigor as well as their practical, intuitive application to real-life decision-making. A subsequent validation phase involved instructors from the business support programs. They were asked to apply the tools to mock scenarios and offer feedback. These comprehensive validation efforts aimed to ensure the tools were as effective as possible in facilitating entrepreneurs' application of the scientific approach.

Overall, results from the first RCTs indicate that the training was effective in increasing the level of scientific intensity applied by entrepreneurs in their decision-making process (see Camuffo et al. 2024 for more detail). Although specific validation tests for each tool were not conducted, these results represent a *prima facie* validation of the design principles elaborated in this article as being conducive to the practical application of a scientific approach.

Future research could conduct controlled experiments to evaluate the effectiveness of these tools in enhancing understanding and application of theoretical concepts. Additionally, longitudinal studies could be employed to examine the long-term impact of implementing these tools on learning and attrition outcomes for different participants. Furthermore, comparative studies across different disciplines or industries could shed light on the generalizability and adaptability of these tools across varied contexts.

5. Discussion and conclusion

The goal of this article was to provide a comprehensive set of design principles that researchers can use to develop tools that would allow a practical but rigorous application of the scientific approach to entrepreneurial decision-making (Berglund, 2021; van Aken, 2004), based on the growing body of research showing its economic effectiveness.

The paper started with an analysis of what the scientific approach to decision-making is, reviewing the recent body of theoretical and empirical literature. Despite the presence of research emphasizing the benefits of following a scientific approach to decision-making (e.g., Agarwal et al., 2024; Camuffo et al., 2020, 2024), its application to practical decision-making might still be seen as challenging due to the lack of familiarity of entrepreneurs with these contexts.

First, following the scientific approach involves engaging systematically in two distinct but complementary phases: theory development (*cognition-based*) and experimentation (*action-based*). In the first phase, the goal is to create a better framing of the decision problem, for instance about a business idea under development, based on the selection of key *attributes* of the decision problem, on the *causal links* between them, and on making subjective *beliefs* explicit. This more structured representation enables entrepreneurs to have a clearer framing of the assumptions behind their value creation process, considering causal roots and potentially alternative explanations. Building on this theory, decision makers develop testable hypotheses on the most important and uncertain aspects of the theory. Hypotheses are then tested in the second phase dedicated to experimentation. Entrepreneurs gather evidence to falsify hypotheses and do so complying with prescriptions drawn from best practices in research methods. Results are then evaluated in relation to the original theory before a decision is made. Focusing on these phases, we derive the key principles characterizing the application of a scientific approach to decision making.

Next, we present a set of original tools and templates that were used during the RCTs deploying training courses for entrepreneurs. While we do not provide an exhaustive list of tools, we provide illustrations of tools that can: a) help developing and refining entrepreneurs' theories and subsequent hypotheses, since theory-development plays a pivotal role in the proposed scientific approach; b) help entrepreneurs in connecting their theory and hypothesis to empirical validation techniques and evaluate results in an objective way. In describing these tools, we derive a set of design principles that can guide researchers in developing novel ways to facilitate the practical application of the theoretical prescriptions of the scientific approach. Table 2 summarizes the thirteen design principles that we derived in this paper, linking them to the components of the scientific approach.

It is important to note that in the sections above we emphasized some design principles more prominently than others when describing key tools and methodologies. This is in line with the illustrative as opposed to exhaustive approach we take in this article. Indeed, the described tools might incorporate only some of the design principles summarized in Table 2. For instance, the Story Tree or the Theory Map are primarily intended for the theory-building phase and are thus primarily related to the first four design principles, with less or no emphasis on the subsequent activities of data gathering and reviewing collected evidence. However, we emphasize that it is essential for a comprehensive application of the approach that all design principles are incorporated across the overall set of tools presented to entrepreneurs.

Overall, this exercise sets the stage for a reflection on the type of decisions where the application of a scientific approach could provide a tangible added value. While it is outside the scope of this article to deeply explore these contingencies, the approach has been designed to

Table 2
Summary of design principles.

#	Short name	Description	Component
1	Attribute identification	For entrepreneurs to identify key attributes and associated beliefs relevant to their current stage of business development, tools should promote a modular approach to theory-building, allowing for flexibility and adaptability of the theory over time.	Theory
2	Implement causal logic	For entrepreneurs to systematically identify causal connections between the key attributes, tools should guide them through a structured process that helps establish clear cause-and-effect relationships and associated beliefs.	
3	Encourage parsimony	For entrepreneurs to maintain a focused and manageable scope of analysis, tools should facilitate the elimination of less relevant attributes or causal relationships, ensuring an effective and targeted approach to theory development.	
4	Alternative scenarios consideration	For entrepreneurs to identify potential alternative attributes or causal paths that could lead to different outcomes or strategies for the business, tools should enable them to systematically compare and evaluate alternative scenarios and contingencies.	
5	Theory integration	For entrepreneurs to ensure alignment between the theory's attributes/causal relationships and the proposed hypotheses, tools should enable a seamless derivation of hypotheses from the theoretical frameworks, maintaining coherence and consistency throughout the process.	Hypothesis
6	Hypothesis simplification	For entrepreneurs to develop hypotheses that focus on only one element at a time, tools should incorporate features that help break down complex theories into singular, well-defined statements.	
7	Hypothesis falsification	For entrepreneurs to develop hypotheses that can be effectively tested, tools should incorporate features that help them in stating falsifiable statements.	
8	Hypothesis prioritization	For entrepreneurs to effectively prioritize their hypotheses, tools should include mechanisms to compare and rank hypotheses based on their importance to the overall theory and their potential impact on decision-making.	
9	Clear Operationalization	For entrepreneurs to collect relevant data for hypothesis testing, tools should guide entrepreneurs in translating the variables mentioned in the hypotheses to specific measures.	Evidence
10	Appropriate technique selection	For entrepreneurs to choose the most appropriate validation techniques, tools should provide explicit categorization of techniques based on their suitability for different phases of validation (problem, offer, solution) and the type of insights they are best equipped to provide (quantitative vs. qualitative).	

(*continued on next page*)

Table 2 (*continued*)

#	Short name	Description	Component
11	Sample representativeness	For entrepreneurs to identify an appropriate sample, tools should allow them to check whether the sample that is used for gathering evidence, is representative of the target population under study.	
12	Thresholds definition	For entrepreneurs to objectively assess testing results, tools should guide the pre-definition of acceptable outcomes (thresholds) with reference to the measures defined in the evidence phase.	Evaluation
13	Iterative refinement	For entrepreneurs to incorporate in their assessment any available information on possible limitations associated with the methodology used for evidence collection, tools should allow for a substantiated cautious adjustment of thresholds.	

tackle decisions about *strategic problems*, namely those that are unstructured and uncertain in a Knightian sense (Knight, 1921). Engaging in theory building can particularly lead to a competitive advantage in settings where data and experience are limited – what A. Camuffo et al. (2023b) call "low-frequency, high-impact" decisions. In addition to entrepreneurs launching a novel value proposition, this category might include managers introducing an innovative product or service. Hence, the approach presented in this article and some of the tools (for instance, DAGs) could successfully be implemented by a broader variety of decision makers.

A second point worth mentioning is the influence of entrepreneurs' heterogeneity and subjectivity in the application of a scientific approach to decision-making. While the article outlines clear and objective steps that the entrepreneur *is encouraged to* follow when making decisions under uncertainty, certain steps within the process are inherently shaped by the entrepreneur's own priors, beliefs, and previous decisions, which are heterogenous. Just as researchers following a protocol still have many "degrees of freedom" – for instance in term of how to collect data, which analytical techniques to use or which thresholds to adopt – so do entrepreneurs who use a scientific approach. Entrepreneurs' heterogeneity and subjectivity characterizes all phases of the application, from the elaboration of the theory and belies to the empirical design choices and the identification of a threshold for test success. Yet the tools presented in this article reflect the intention of providing some guidance for translating in practice the insights from the literature in this area, thereby addressing the "relevance" problem often faced by academic discourse (van Aken, 2004)

Lastly, we believe that the design principles outlined in this article could be thought also as basis for thinking about the design of entrepreneurial education. While defining principles for effectively designing teaching activities is beyond the scope of this article, we believe this is a promising path for future research.

CRediT authorship contribution statement

Andrea Coali: Writing – review & editing, Writing – original draft, Project administration, Conceptualization. **Elena Novelli:** Writing – review & editing, Writing – original draft, Supervision, Conceptualization. **Anusha Sirigiri:** Writing – original draft, Conceptualization. **Chiara Spina:** Writing – review & editing, Writing – original draft, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

No data was used for the research described in the article.

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References

Agarwal, R., Bacco, F., Camuffo, A., Coali, A., Gambardella, A., Msangi, H., Sonka, S. T., Temu, A., Waized, B., & Wormald, A. (2024). Does a theory-of-value add value?. In *Evidence from a Randomized Control Trial with Tanzanian Entrepreneurs (SSRN Scholarly Paper 4412041)*. https://doi.org/10.2139/ssrn.4412041

Agrawal, A., Gans, J. S., & Stern, S. (2021). Enabling entrepreneurial choice. *Management Science, 67*(9), 5510–5524. https://doi.org/10.1287/mnsc.2020.3920

Berglund, H. (2021). Entrepreneurship as design and design science. *Journal of Business Venturing Design, 1*(1–2), Article 100012. https://doi.org/10.1016/j.jbvd.2022.100012

Bingham, C. B., & Davis, J. P. (2012). Learning sequences: Their existence, effect, and evolution. *Academy of Management Journal, 55*(3), 611–641. https://doi.org/10.5465/amj.2009.0331

Bingham, C. B., & Eisenhardt, K. M. (2011). Rational heuristics: The 'simple rules' that strategists learn from process experience. *Strategic Management Journal, 32*(13), 1437–1464. https://doi.org/10.1002/smj.965

Blank, S. (2013). Why the Lean Start-Up Changes Everything. *Harvard Business Review*. https://hbr.org/2013/05/why-the-lean-start-up-changes-everything.

Bonabeau, E. (2003). Don't trust your gut. *Harvard Business Review*. https://hbr.org/2003/05/dont-trust-your-gut.

Camuffo, A., Cordova, A., Gambardella, A., & Spina, C. (2020). A scientific approach to entrepreneurial decision making: Evidence from a randomized control trial. *Management Science, 66*(2), 564–586. https://doi.org/10.1287/mnsc.2018.3249

Camuffo, A., Gambardella, A., & Pignataro, A. (2023a). Framing strategic decisions in the digital world. *Strategic Management Review*.

Camuffo, A., Gambardella, A., & Pignataro, A. (2023b). Theory-driven Strategic Management Decisions. In *CEPR Discussion Paper, DP17664*.

Camuffo, A., Gambardella, A., Messinese, D., Novelli, E., Paolucci, E., & Spina, C. (2024). A scientific approach to entrepreneurial decision-making: Large-scale replication and extension. *Strategic Management Journal*. https://doi.org/10.1002/smj.3580

Coali, A., Gambardella, A., & Novelli, E. (2024). Scientific decision-making, project selection and longer-term outcomes. *Research Policy, 53*(6), Article 105022. https://doi.org/10.1016/j.respol.2024.105022

Creswell, J. W., & Creswell, J. D. (2018). *Research design: qualitative, quantitative, and mixed methods approaches* (5th edition). SAGE Publications, Inc.

Csaszar, F. A., & Laureiro-Martínez, D. (2018). Individual and organizational antecedents of strategic foresight: A representational approach. *Strategy Science, 3*(3), 513–532. https://doi.org/10.1287/stsc.2018.0063

Csaszar, F. A., & Levinthal, D. A. (2016). Mental representation and the discovery of new strategies. *Strategic Management Journal, 37*(10), 2031–2049. https://doi.org/10.1002/smj.2440

Csaszar, F. A. (2018). What makes a decision strategic? strategic representations. *Strategy Science, 3*(4), 606–619. https://doi.org/10.1287/stsc.2018.0067

Davenport, T. H., & Bean, R. (2018). Big companies are embracing analytics, but most still don't have a data-driven culture. *Harvard Business Review*. https://hbr.org/2018/02/big-companies-are-embracing-analytics-but-most-still-dont-have-a-data-driven-culture.

Davenport, T. H. (2009). How to design smart business experiments. *Strategic Direction, 25*(8). https://doi.org/10.1108/sd.2009.05625had.004
Ehrig, T., & Schmidt, J. (2022). Theory-based learning and experimentation: How strategists can systematically generate knowledge at the edge between the known and the unknown. *Strategic Management Journal, 43*(7), 1287–1318. https://doi.org/10.1002/smj.3381
European Business Review, E. (2021). *Evolution of decision making: how leading organizations are adopting a data-driven culture*. November 14. The European Business Review https://www.europeanbusinessreview.com/evolution-of-decision-making-how-leading-organizations-are-adopting-a-data-driven-culture/.
Felin, T., & Zenger, T. R. (2009). Entrepreneurs as theorists: On the origins of collective beliefs and novel strategies. *Strategic Entrepreneurship Journal, 3*(2), 127–146. https://doi.org/10.1002/sej.67
Felin, T., & Zenger, T. R. (2017). The theory-based view: Economic actors as theorists. *Strategy Science, 2*(4), 258–271. https://doi.org/10.1287/stsc.2017.0048
Felin, T., Koenderink, J., & Krueger, J. I. (2017). Rationality, perception, and the all-seeing eye. *Psychonomic Bulletin & Review, 24*(4), 1040–1059. https://doi.org/10.3758/s13423-016-1198-z
Felin, T., Gambardella, A., & Zenger, T. (2021). Value Lab: A tool for entrepreneurial strategy. *Management and Business Review, 1*(2). https://papers.ssrn.com/abstract=3956189.
Felin, T., Gambardella, A., Novelli, E., & Zenger, T. (2024). A scientific method for startups. *Journal of Management*. https://doi.org/10.1177/01492063231226136, 01492063231226136.
Felin, T., Gambardella, A., Stern, S., & Zenger, T. (2020). Lean startup and the business model: Experimentation revisited. *Long Range Planning*. , Article 101889. https://doi.org/10.1016/j.lrp.2019.06.002
Gans, J. S., Stern, S., & Wu, J. (2019). Foundations of entrepreneurial strategy. *Strategic Management Journal, 40*(5), 736–756. https://doi.org/10.1002/smj.3010
Gary, M. S., & Wood, R. E. (2011). Mental models, decision rules, and performance heterogeneity. *Strategic Management Journal, 32*(6), 569–594. https://doi.org/10.1002/smj.899
Gavetti, G., & Levinthal, D. (2000). Looking forward and looking backward: Cognitive and experiential search. *Administrative Science Quarterly, 45*(1), 113–137. https://doi.org/10.2307/2666981
Harms, R., & Schwery, M. (2020). Lean startup: Operationalizing lean startup capability and testing its performance implications. *Journal of Small Business Management, 58*(1), 200–223. https://doi.org/10.1080/00472778.2019.1659677
Jannace, D., & Camuffo, A. (2023). Curbing the addition bias: Scientific approaches and propensity to subtract in entrepreneurial ideas. *Academy of Management Proceeding, 2023*(1).
Kahneman, D., Lovallo, D., & Sibony, O. (2019). A structured approach to strategic decisions. *MIT Sloan Management Review*. https://sloanreview.mit.edu/article/a-structured-approach-to-strategic-decisions/.
Knight, F. (1921). *Risk, uncertainty and profit*. University of Illinois at Urbana-Champaign's Academy for Entrepreneurial Leadership Historical Research Reference in Entrepreneurship.
Koning, R., Hasan, S., & Chatterji, A. (2022). Experimentation and start-up performance: Evidence from A/B testing. *Management Science*. https://doi.org/10.1287/mnsc.2021.4209
Kozyrkov, C. (2019). The first thing great decision makers do. *Harvard Business Review*. https://hbr.org/2019/06/the-first-thing-great-decision-makers-do.
Leatherbee, M., & Katila, R. (2020). The lean startup method: Early-stage teams and hypothesis-based probing of business ideas. *Strategic Entrepreneurship Journal, 14*(4), 570–593. https://doi.org/10.1002/sej.1373
Levitt, B., & March, J. G. (1988). Organizational learning. *Annual Review of Sociology, 14*, 319–340.
Maurya, A. (2016). *Scaling lean: mastering the key metrics for startup growth* (Illustrated edition). Portfolio.
Moore, G. A. (2014). *Crossing the chasm, 3rd edition: marketing and selling disruptive products to mainstream customers* (3rd edition). Harper Business.
Nickerson, J. A., Silverman, B. S., & Zenger, T. R. (2007). The `problem' of creating and capturing value. *Strategic Organization, 5*(3), 211–225. https://doi.org/10.1177/1476127007079969
Novelli, E., & Spina, C. (2024). Making business model decisions like scientists: Strategic commitment, uncertainty and economic performance. *Strategic Management Journal*. https://doi.org/10.1002/smj.3636
Ott, T. E., & Eisenhardt, K. M. (2020). Decision weaving: Forming novel, complex strategy in entrepreneurial settings. *Strategic Management Journal, 41*(12), 2275–2314. https://doi.org/10.1002/smj.3189
Ott, T. E., Eisenhardt, K. M., & Bingham, C. B. (2017). Strategy formation in entrepreneurial settings: Past insights and future directions: Strategy formation in entrepreneurial settings: Past and future. *Strategic Entrepreneurship Journal, 11*(3), 306–325. https://doi.org/10.1002/sej.1257
Popper, K. R. (1959). *The logic of scientific discovery* (p. 480). Basic Books.
Popper, K. (2002). *Conjectures and refutations: the growth of scientific knowledge* (2° edizione). Routledge.
Ries, E. (2010a). The five whys for start-ups. *Harvard Business Review*. https://hbr.org/2010/04/the-five-whys-for-startups.
Ries, E. (2010b). *Lessons learned: good enough never is (or is it?)*. September https://www.startuplessonslearned.com/2010/09/good-enough-never-is-or-is-it.html.
Ries, E. (2011). *The Lean Startup: How Today's Entrepreneurs Use Continuous Innovation to Create Radically Successful Businesses*. Crown.
Shepherd, D. A., & Gruber, M. (2021). The lean startup framework: Closing the academic–practitioner divide. *Entrepreneurship Theory and Practice, 45*(5), 967–998. https://doi.org/10.1177/1042258719899415
Simmons, J. P., Nelson, L. D., & Simonsohn, U. (2011). False-Positive Psychology: Undisclosed Flexibility in Data Collection and Analysis Allows Presenting Anything as Significant. *Psychological Science, 22*(11), 1359–1366. https://doi.org/10.1177/0956797611417632
Spina, C., & Fronteddu, A. (2022). *A scientific approach to creating a new business: MiMoto* (INSEAD Case Study). https://publishing.insead.edu/case/a-scientific-approach-creating-a-new-business-mimoto-0.
Spina, C., Camuffo, A., & Gambardella, A. (2020). Founders, apply the scientific method to your startup. *Harvard Business Review*. https://hbr.org/2020/11/founders-apply-the-scientific-method-to-your-startup.
Thomke, S. H. (2020). *Experimentation works: the surprising power of business experiments*. Harvard Business School Pr.
van Aken, J. E. V. (2004). Management research based on the paradigm of the design sciences: The quest for field-tested and grounded technological rules. *Journal of Management Studies, 41*(2), 219–246. https://doi.org/10.1111/j.1467-6486.2004.00430.x
Walsh, J. P. (1995). Managerial and organizational cognition: notes from a trip down memory lane. *Organization Science, 6*(3), 280–321. https://doi.org/10.1287/orsc.6.3.280
Wicherts, J. M., Veldkamp, C. L. S., Augusteijn, H. E. M., Bakker, M., van Aert, R. C. M., & van Assen, M. A. L. M. (2016). Degrees of freedom in planning, running, analyzing, and reporting psychological studies: A checklist to avoid p-Hacking. *Frontiers in Psychology, 7*. https://www.frontiersin.org/articles/10.3389/fpsyg.2016.01832.
Zellweger, T. M., & Zenger, T. R. (2021). Entrepreneurs as scientists: A pragmatist approach to producing value out of uncertainty. *Academy of Management Review*. https://doi.org/10.5465/amr.2020.0503. amr.2020.0503.
Zellweger, T. M., & Zenger, T. R. (2022). Entrepreneurs as scientists: A pragmatist alternative to the creation-discovery debate. *Academy of Management Review*. https://doi.org/10.5465/amr.2022.0163