KNOWLEDGE TRANSFER BETWEEN UNIVERSITIES OF APPLIED SCIENCES AND SMES: A STUDY OF INNOVATION SPACES

Marco Johannes **Wiersma**

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Table of contents

Glossary

Absorption capacity: The ability to identify, transfer, and transform new information or knowledge.

Adsorption capacity: The way knowledge is made identifiable and transferable. This concept is relatively new. Our extensive literature research only found one case study: (Beauchamp, C., & Lemay, L, 2021).

Agency: The ability of individuals or groups to exercise intentionality and to make autonomous decisions.

Array: Structured collection of related information or concept systematically organized.

Assimilation: The process of understanding new information and integrating it with existing knowledge. We refer to assimilation usually referring to agents of an organizational system.

Conscious agent (Hoffman, 2008)**:** Fundamental entities that interact with one another create what we perceive as reality. A conscious agent perceives, selects actions, and acts such that each conscious experience probabilistically leads to another, forming a dynamic loop. Agents are taken as fundamental constituents of reality, not arising from physical objects or space-time but through interactions.

Design: A complex problem-solving activity that transforms restrictions and requirements into a set of constraints and explores feasible solutions (Li & Lachmayer, 2019).

Dispositional model: Explains behavior by referring to the relationship between a system and its current situation (Vanderbeeken & Weber, 2002).

Dynamic epistemology emphasizes the role of knowledge in fulfilling practical epistemic functions, prioritizing the utility and purpose of knowledge over abstract truth conditions (Hannon, 2019). These dynamics of applied epistemology show a necessity understanding in different worlds.

Epistemic agent: Is capable of taking epistemic stances toward epistemic elements. Stances must be intentional, based on a semantic understanding of the element in question and its available alternatives, with reason, and for the purpose of acquiring knowledge (Patton, 2019).

Epistemic base: Foundational knowledge, beliefs, values, and cognitive frameworks for how an organization collectively perceives, processes, validates, and applies knowledge in its decision-making and actions. It can be shared beliefs about what information is credible, relevant, and actionable.

Epistemic closure: Used here to explain triadic and semantic closure: a mechanism of the belief system that describes how we know A from C when A affects B and B entails C, then we can know (if and only if) B from A. We can deduce new knowable truths from what we know, by applying logic.

Epistemic element: Semantic entities toward which an epistemic agent can take an epistemic stance (Barseghyan, 2018). Subcategories are used to describe the functionality of the element in a certain situation. This can be a paradigm, method, or theory aimed to be descriptive, functional and explanatory. With enough examples, it forms the base of a new ontology of epistemic elements.

Epistemic functional space: We define a space as epistemically functional when its design is based on different levels for development (states) through mutually enabling and sustaining constructs that have engineering functionality (use of knowledge) as well as epistemic functionality (legitimate and trustful knowledge).

Epistemic governance: Epistemic governance refers to the processes shaping collective perception and influencing the understanding of various situations. It focuses on the interdependency of phenomena, actors, and events that resist reductionism and linear thinking (Jalonen, 2024).

Epistemic functionality: Mutually enabling and sustaining constructs between knowledge and its function: the function of knowledge is its capacity to inform agents (for example, in decision-making and update routines). Mutual enabling means that knowledge and its function sustain each other: knowledge evolves in response to functional demands, and functional improvements depend on the evolving, context-sensitive knowledge (Schyfter, 2020).

Epistemic goals: Epistemic goals are generated in relation to particular situations of reasoning or problem-solving, and how cognitive and sociocultural perspectives on cognition that shift agents' goals within a task shifts their reasoning.

Epistemic modal knowledge: Refers to knowledge about what is possible or necessary given what is known.

Epistemic objects: Objects that are part of a continually evolving experimental system.

Epistemic situation or state: Refers to the condition or attitude of a subject (individual/agent) to a proposition or knowledge claim; Epistemic states are experienced as believed propositions (Rigo-Lemini & Martínez-Navarro, 2017) or as a set of admissible beliefs (Bochman, 2007).

Epistemic space: A conceptual framework used to represent the range of possible knowledge states, beliefs, or scenarios available to an agent or a community. When a subject can epistemically consider that *p* is possible, an epistemically possible scenario exists for the subject in which *p* occurs. Put together, epistemic scenarios constitute epistemic space.

Epistemic stance: An attitude (pragmatic/positivistic) to knowledge based on type of interaction, method or tool.

Epistemic tool: Functions in epistemic activity. A physical object or system qualifies as an epistemic tool for a specific epistemic agent if a procedure allows the tool to serve as an acceptable source of knowledge for answering a particular question using the agent's employed method. An agent is said to rely on such a tool (Patton, 2019).

Epistemic uncertainty: Epistemic uncertainty, aka system uncertainty arises from an insufficient understanding of what constitutes knowledge. This knowledge deficit is caused by various sources, e.g., understanding phenomena, processes, and characteristics. It contrasts with non-epistemic uncertainty, e.g., aleatory uncertainty, that involves variability or randomness in processes or outcomes. Unpredictable market or regional changes or random operational disruptions can affect how knowledge is absorbed and applied in practice. Another source is data measurement, related to practical issues like noise (or 'corrupt data'), incomplete or imprecise data that cause uncertainty in evaluating knowledge states, which complicates the process of accurately assessing and absorbing knowledge.

Overall, organizational and social uncertainties involve differences in organizational culture(s), trust, communication, power dynamics, and stakeholder motivations. Differences in openness, willingness to share knowledge, and internal politics can create uncertainties that impede effective knowledge transfer and absorption.

Epistemic utility: Field knowledge created with function in mind, kept in existence through use, qualified and situated by its functionality and evaluated by its functional operation (Schyfter, 2020).

Event: A debated concept used to explore social practices and historical change (Risch, 2015).

Foreknowledge: Relates to complex systems used in foresight analysis of emerging technology development (Heraud, 2017).

Functionality gap: Refers to the absence, limitation, or mismatch in the capabilities or features of a system, tool, or process needed to meet specific requirements or achieve desired outcomes. It highlights a situation where existing functionality falls short of its intended purpose or supportive needs.

Functionality of knowledge: Functional knowledge refers to the practical understanding and skills required to perform specific tasks or activities effectively, such as those needed to interact with technology or systems in a purposeful manner.

Habitus: A field with a group that shapes social actions (Bourdieu, 1990)**.**

Innovation performance: Upgrades a firm's products, services, or processes (Flor, et al., 2018).

Innovation space: Can be described in a conceptual design as a representational (Gärdenfors, 2004) or semantic model that can be used to group similarities (Gärdenfors, 2011), and in terms of activities, as defining the scope of change as a solution space. (Schmidt, 2007).

Key: The set of conventions by which a given activity, already meaningful in some primary framework, is transformed into something patterned on this activity but seen by the participants to be something quite else (Goffman, 1986)

Knowledge adsorption: A condition by which valuable knowledge is made readily available to an organization.

Knowledge base: A centralized repository of information that stores, organizes, and manages essential information related to a specific topic, product, or organization.

Knowledge-based development: Aa multidisciplinary field based upon the endogenous value-creation process of knowledge sharing.

Knowledge legitimacy: A criterion to assess knowledge quality, credibility, and salience.

Mechanism: Unobserved relations or processes that generate outcome (Mahoney, 2001).

Modal consciousness: Apparent when deliberate choices are based on experience of governing choices for situations and contexts, evaluation of methods and results of Mode 3-4, and the descriptions in terms of logical schemas based on situations. Our concept involves organizational learning and the absorption of knowledge in SMEs and UASs, where modal consciousness allows agents to act according to their awareness of the dynamic, contextual nature of knowledge. This supports advanced epistemic capabilities for managing uncertainty, experimenting, and justifying knowledge claims in innovation activities.

Modal property: Modal property is a property that is not attributed to an object in its actual state, but rather in a possible world or under different circumstances (Simmons, 1987).

Pragmatic knowledge boundary: Exists at the interface of research and practice (Makin, 2021).

Monotonic behavior: A consistent and unidirectional trend in a function, process, or system, where the output either never decreases or never increases as the input changes. Monotonic means that as people learn new information their knowledge or set of beliefs only grows and or stays the same.

Ontological uncertainty: The unintentional use of inappropriate methodologies or belief systems impacts semantic uncertainty. It arises when participants in an action attribute different meanings to the same terms, phrases, or actions. This occurs when methodological definitions lack clarity or are inappropriate for the full cognitive understanding of all participants, e.g., due to different levels of expertise (Helmholtz Uncertainty Quantification Dictionary-DE).

Reflexivity in research: Generally, reflexivity refers to the examination of one's own beliefs, judgments and practices during the research process and how these may have influenced the research (Finlay, 1998).

Routine plasticity: Tension between ostensive aspects (abstract concepts and ideal codification) and performative aspects, or the actual executions (Feldman & Pentland, 2003).

Semantic operator: A tool to represent logical operations to manipulate truth value.

Solution space: The set of potential activities that can be considered (Posthuma, et al., 2019) or on a practical level; identification of information needed on differences of actors.

Temporal dimension of knowledge exchange: A continuity established by reflecting upon the past to explore the future while continually reinterpreting the present (Dawson & Sykes, 2019).

List of Figures

List of Tables

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Mark

Abstract

The accelerating pace of technological innovation presents both unprecedented opportunities and significant challenges. The purpose of this study is to investigate the role of universities of applied sciences (UAS) in enhancing the knowledge transfer and absorption capacities of small and medium-sized enterprises (SMEs) amid epistemic uncertainty driven by rapid technological disruptions and information overload. SMEs, forming the backbone of the Dutch economy, often struggle with structural limitations in exploring, experimenting with, and assimilating new knowledge representations required by evolving paradigms such as Industry 4.0 and 5.0. Collaborative programs between UAS and SMEs create experimental innovation spaces aimed at co-creating practical solutions while simultaneously equipping students with dynamic skills to navigate complex, uncertain environments.

However, introducing new modes of knowledge production amplifies uncertainties regarding future skills and knowledge functionalities, challenging both organizational resilience and vocational education systems. By examining diverse UAS-SME interactions through an epistemological lens, this research uncovers how epistemic tensions shape knowledge processes, thereby enabling SMEs and UAS to foster joint dynamic capabilities for technologically and epistemically dynamic contexts.

Theoretical background

The theoretical background of this study draws on epistemological perspectives to examine knowledge transfer and absorption dynamics in the specific context of UAS collaborating with SMEs through student-mediated innovation spaces. Central to this research is the development of epistemic models that are continually refined through empirical observation and data-driven comparisons. These models serve not only as analytical tools but also as frameworks for enhancing awareness, engagement, and learning at both organizational and individual levels. The overarching goal is to support SMEs and UAS in recognizing, valuing, and assimilating external knowledge, thereby building necessary dynamic capabilities amid technological and epistemic changes.

Research design

This study employs a sequential exploratory mixed-methods research (MMR) design, integrating quantitative and qualitative data across multiple phases to gain a comprehensive understanding of knowledge transfer dynamics in student-mediated UAS-SME collaborations. Positioned within a post-positivist paradigm that incorporates how interactions in real-world innovation spaces shape knowledge adaptation, the MMR was chosen for its ability to combine researcher observation with participant co-creation, while acknowledging the influence of novice student learners interacting with experienced SME practitioners. The design prioritized exploratory triangulation

over explanatory causation, using descriptive quantitative analysis to complement in-depth qualitative insights from field observations and interviews. This parallel, iterative integration facilitated identification of convergence and divergence, giving a richer, contextualized picture of epistemic tensions and pragmatic knowledge trajectories in applied innovation ecosystems.

Findings

The findings show that knowledge transfer in student-mediated UAS-SME collaborations are shaped by epistemic tensions between pragmatic, operationally embedded trajectories and desired pathways toward higher abstraction and structural integration. These patterns underscore the distinctive practice-oriented nature of UAS-SME ecosystems, which complement the dynamics of research university collaborations with larger firms, and indicate that maximizing effective transfer requires aligning innovation space methods with contextual constraints and exploratory goals.

Innovative value

This study introduces an epistemological lens to analyze knowledge transfer dynamics, extending beyond traditional absorptive capacity models. By focusing on student mediation as the primary mechanism, it bridges the literatures on education, innovation, and epistemology.

Scientific value

This study advances dynamic modal epistemology (DEL) as a framework for knowledge transfer in UAS-SME collaborations, extending beyond traditional absorptive capacity models focused on acquiring and exploiting existing knowledge. The research uses modal semantics to research set-theoretic variance across actor ensembles and shows how unawareness of negative introspections (e.g., necessarily false beliefs) create more rigid trajectories in knowledge absorption.

Value for practice

For SMEs, recognizing locked-in negative beliefs encourages the introduction of variance (e.g., diverse teams, cross-firm networks, student inputs), creating new knowledge functionalities that improve responsiveness to information flows without disrupting existing routines. UAS practitioners can apply this pedagogically by designing projects that challenge modal rigidities through heterogeneous epistemic environments (e.g., living labs or solution experiments), enabling students to revise beliefs through experience in open collaboration and mutual learning with SMEs.

Preface

"To know that we know what we know and to know that we do not know what we do not know is true knowledge."—Nicolaus Copernicus

The absorption of knowledge enables organizations and their agents to enhance their knowledge base and thus make effective and efficient progress in improving their performance in innovative ways.

However, absorption of new knowledge contains uncertainties that require a *certain* set of ideal conditions to be integrated in both the system that supports existing knowledge and facilitates its functionalities for its agents. Arranging these conditions includes the reconstruction of acquired beliefs on existing knowledge, their purpose and thus the threat they pose to both core tenets of knowledge and its optimal use by organizations and agents. Approaching knowledge from a dynamic epistemological perspective helps to understand how knowledge changes over time, in actions and in multi-agent environments. In that sense the stances for absorption are both pragmatic and epistemic.

Core tenets of knowledge in small and medium enterprises (SMEs) comprise a mix of tacit, explicit, experiential, and procedural knowledge. They are linked to the approaches a SME takes to the discovery of knowledge in its day-to-day operations. Such knowledge is often built up from social capital rather than from formalized legitimation processes. Core tenets of knowledge are constantly being adapted and centered around daily innovative practices related to products and services. Human agents embody this knowledge, in the process creating informal learning processes that are strongly connected with the functionalities they serve and thus become deeply embedded in the organization's day-to-day practice. New technologies can quickly make knowledge obsolete, impacting the core tenets of a SME's knowledge and practices and creating gaps in skills. Artificial intelligence (AI) is disrupting existing traditional processes, thereby increasing the need for new knowledge and skills.

The Dutch government has recognized the importance of helping SMEs to increase their capacity to absorb knowledge through partnerships with universities of applied sciences (UASs). In 2015, the Advisory Council for Science, Technology, and Innovation (*Adviesraad voor Wetenschap Technologie en Innovatie*) addressed this issue, emphasizing the crucial role of UASs as knowledge partners for SMEs. To facilitate and support these collaborations, the government has launched and carried out various initiatives, including offering what it calls "knowledge vouchers" and subsidies for projects involving cooperation in research and development. These changes are having an impact on vocational education at UASs, which are becoming more and more involved in research and are also emerging as knowledge providers who will prepare future actors in SMEs.

The question is how can we understand multi-layered, dynamic, and highly differentiated epistemic SMEs in such a way that we can increase their capacity to absorb knowledge? This study analyzes how UASs and SMEs co-develop the absorption of knowledge strategies to enhance their mutual capacity for identifying, transferring, and applying knowledge. This entails considering the dimensions of absorption and the development of organizational methods and processes to continually reconfigure the dynamic capabilities of SMEs. In addition to adopting the dynamic capability view and resource-based views, we analyze how epistemological theories can contribute to a deeper understanding of these absorption processes. In contrast to approaches that focus on resources and capabilities, this approach focuses on the particular characteristics of applied knowledge and its relation to human agents when it comes to the absorption of knowledge. Changes in the functions of knowledge and in the management of skills and tasks particularly affect small SMEs with few employees.

The reconstruction of beliefs

The likelihood that knowledge produced by UASs will be absorbed by SMEs and vice versa will be low if the absorption processes are not tailor-made. UASs have little experience in creating tailor-made absorption processes. Since SMEs differ considerably in their pragmatic cultures and use a mix of tacit and explicit knowledge, research is needed on methods to integrate new knowledge.

The creation of value in most SMEs is still based on economic rather than on epistemic values, and that affects how these SMEs know what they know. Our model suggests that a major condition for epistemically driven change is the reconstruction of beliefs and the codification of knowledge. To accomplish this, there has to be a connection between how knowledge is constructed and how this construction is understood: a modal tie. This modal tie requires new frameworks to integrate economic and semantic knowledge in SMEs, meaning the understanding of knowledge and its consequences in different domains and disciplines, and the corresponding values that are needed in order for SMEs and UASs to absorb the knowledge each other produces.

CHAPTER 1

Introduction

Chapter 1. Introduction

This first chapter describes how this study contributes to enhancing the knowledge absorption capacity of small and medium enterprises (SMEs) in times of increasing epistemic uncertainty. The chapter is laid out as follows:

1.1 Background

1.2 Government initiatives

1.3 The changing role of UASs

1.4 Research methods

1.5 Main research question and chapter outlines

1.1 Background

In the context of Industry 4.0, collaboration between universities of applied sciences (UASs) and SMEs has become crucial for enhancing their capacity to absorb knowledge amidst rapid technological and epistemic shifts. Industry 4.0 has revolutionized knowledge ecosystems through the large-scale integration of systems and information. Interconnected organizational networks have given rise to efficient, application-oriented, knowledge-production processes (Nowotny, et al., 2003).

However, the accelerated pace of technological advancement confronts SMEs with significant challenges in producing and applying knowledge. These challenges in organizations are marked by significant uncertainties about the knowledge and applications that require development. These uncertainties stem from rapid technological advances and the interconnected organizational networks, which generate diverging and sometimes conflicting streams of information, thereby complicating the integration of knowledge within SMEs (Teece, et al., 1997). Succeeding and surviving in the Industry 4.0 era requires a problem-solving attitude that faces a range of scientific, societal and, most importantly, epistemological perspectives.

This problem-solving orientation is characterized as sustainability science (Caniglia, et al., 2021), since it aims to create knowledge that is both scientifically rigorous and societally relevant. Therefore, it has a high degree of trans disciplinarity among the actors in science, politics and, increasingly, UASs. The emergence of new technologies demands ongoing updates to knowledge and skills, and these in turn create further epistemological uncertainties. Many SMEs lack the necessary human-resource and knowledge-management systems to absorb critical external knowledge effectively into their operations (Lisboa, 2015; ATWI, 2018; Shaw, et al., 2024).

This limited absorptive capacity restricts their ability to develop new insights, thus intensifying pressure on existing exploitation activities while constraining the potential for exploration and innovation. Without the capacity to maintain or expand newly acquired knowledge, SMEs risk suffering from knowledge inertia.

Another challenge SMEs face is the heterogeneous and often tacit nature of produced knowledge. While this tacit knowledge can accelerate entrepreneurial innovation and help reduce R&D costs (Chesbrough, 2003), both its absence of codification and transformation processes present challenges. In these contexts, innovation frequently stems from recombining different pieces of existing knowledge (König, et al., 2011), a process that is predominantly embodied in human agents rather than in formalized knowledge systems or repositories. Also, SMEs typically prefer to collaborate with clients and customers, rather than UASs or colleges (Corral de Zubielqui, et al., 2015).

This preference underscores the need for UASs to develop more effective strategies for engagement and knowledge transfer with SMEs, and to stress the practical, applicability and relevance of their research to SMEs operations and innovations. In conclusion, while the potential benefits of the mutual transfer of knowledge between UASs and SMEs are substantial, realizing them requires overcoming significant challenges related to the knowledge produced, the knowledge transfer mechanisms, and the preferences of SMEs in collaborative partners. Future research should focus on developing effective models of engagement that can bridge these gaps and enhance the impact of UAS-SME collaboration in regional innovation ecosystems (OECD, 2011).

Collaboration issues

The SMEs' preference for collaborating with clients rather than academic institutions (Corral de Zubielqui, et al., 2015) suggests a potential mismatch in epistemic frameworks between academia and industry. This potential misalignment could lead to uncertainty in determining what constitutes valuable knowledge and how it should be shared, absorbed and applied. Additionally, the rapid pace of technological change introduces temporal epistemic uncertainty (Scharmer & Kaufer, 2013), as knowledge that is relevant today may quickly become obsolete. Taken together, these factors contribute to a state of epistemic uncertainty in UAS-SME knowledge ecosystems that challenge traditional models for sharing and transferring knowledge that needs more adaptive and context-sensitive approaches to achieve collaborative innovation.

Recognizing this challenge, policymakers promote collaborations between SMEs and UASs. These partnerships aim to establish innovation spaces, multi-level, multi-modal, multi-nodal, and multi-agent systems of systems that forms a 21st-century innovation ecosystems (Carayannis & Campbell, 2009), where SMEs can engage with UAS students and researchers to co-create knowledge, develop novel strategies, and enhance adaptability to changing environments (Carayannis & Campbell, 2021). However, these collaborative spaces often lack established frameworks for understanding how knowledge is absorbed, resulting in epistemically ill-structured situations where knowledge is uncertain or inconsistent (Spiro, et al., 1988; Wu & Shen, 2016).

Navigating such complex environments requires specific skills, including an ability to resolve inconsistencies in information and create structured representations to clearly identify potential solutions. These skills are particularly valuable for SMEs that operate in dynamic sectors characterized by knowledge ambiguity.

The epistemological complexity involved in defining and conceptualizing the ability to absorb knowledge is further compounded when this ability requires meta-knowledge, knowledge of the environment in which the knowledge is used, and knowledge on how and by whom this knowledge is applied (Woodill, 2021). This meta-cognitive dimension is a type of consciousness necessary to develop critical epistemic values. We conceptualize it as a type of epistemic consciousness focused on the distinct modality of knowledge needed for the advancements that effectively reduces epistemic uncertainty.

The problem of epistemic uncertainty

This study concentrates on processes that facilitate the absorption of new knowledge. A key prerequisite is the extent to which new knowledge is consistent with pre-existing knowledge. We can draw a distinction between organizational absorption of knowledge — integration into systems—and assimilation by human agents operating in or outside organizational systems. When it comes to human agents, both individual and collective attitudes influence the ways in which epistemic certainty about new knowledge is achieved and the extent to which individuals or groups can get or actually have access to new knowledge. The lack of certainty often leads to rejecting or postponing absorption of the knowledge. Assimilating new knowledge typically requires a change in prevailing attitudes, a shift in the justificatory system through which human agents legitimize such knowledge, or both (Suchman, 1995; Brew, et al., 2018).

The goal of this research is to develop and refine epistemic models through empirical observation and data-driven analysis, focusing on understanding how conscious awareness of epistemic processes influences continuous knowledge absorption terms of identification, transfer and application. The research aims to enhance frameworks that support awareness, engagement, and learning at both individual and organizational levels. Ultimately, this research seeks to empower SMEs and UASs in the co-development of knowledge absorption strategies thereby building the dynamic capabilities needed to thrive amid ongoing technological and epistemic changes.

Creating epistemic certainty requires significant effort and a strong commitment from human agents. For SMEs, it often entails financial costs and risks. The legitimization of knowledge also demands a return on investment (efforts), whether through exploring experiences, or gathering information. Our study demonstrates that epistemic doubt—uncertainty about knowledge—manifests differently for SMEs and UASs, and that doubt influences both their ability and willingness to accept the risks associated with integrating new knowledge.

The processes of absorption, legitimation, acceptance, and ultimately use of knowledge can be personal and systemic, formal and informal, based on experienced knowledge or propositional knowledge or any combination of the above (Sjödin, et al., 2019). Consequently, we find distinct differences in the manifestation of absorption processes, caused by the subjective experiences of agents, system characteristics, and environmental dynamics that affect how we accept the degrees of certainty that ultimately allow agents and systems to adopt new knowledge.

Successful absorption of new knowledge thus requires research into the specific knowledge engineering practices and knowledge modifications of each particular organizational and personal system. This dissertation argues that uncertainty about recently acquired knowledge increases when that knowledge requires changes to the core tenets of existing knowledge and its processes and, most significantly, routines.

New knowledge thus generates new uncertainties and a new phase of epistemic validation is required before the newly acquired knowledge can be applied with confidence. Newly acquired knowledge also tends to influence previously established beliefs, frameworks, and routines constituted by prior knowledge. This dynamic exchange between new and existing knowledge and how this exchange is orchestrated depends on characteristics of the SMEs involved.

Many SMEs face this uncertainty about new routines and capabilities. Their current knowledge, skills, and applications prove increasingly inadequate to deal with the dynamics of the evolving knowledge environment. This inadequacy gives rise to new implicit and explicit demands for knowledge. However, in the face of continual environmental changes, the strategy regarding new goals and knowledge requirements often remains uncertain. Perhaps SMEs' current strategies are proving insufficient so that other measures are called for (Furman & Teodoridis, 2019; Cockburn & Sterns, 2019; Mize, 2020; Bles Van Der A, et al., 2019). This epistemic uncertainty often results in knowledge inertia, postponing absorption.

Limits to the ability to measure or interpret change in an organization, known as aleatory uncertainty (e.g., those resulting from a greater increase in information), amplify epistemic uncertainty. Reducing epistemic uncertainty requires research into the justification, application and usability of the to-be-absorbed knowledge. Reducing epistemic uncertainty can also be achieved by experimenting with the new knowledge in the organization. However, small enterprises face a considerable challenge on this score, since they have limited capacity in both time and human resources and lack the capability to experiment and/or explore. The pursuit of epistemic certainty through experimentation and exploration introduces financial risks, particularly for resource-constrained SMEs. (Carayannis, et al., 2021). Our findings show that when companies lack control over maintaining or adjusting new knowledge, associated risks are often avoided by preserving the status quo (inertia).

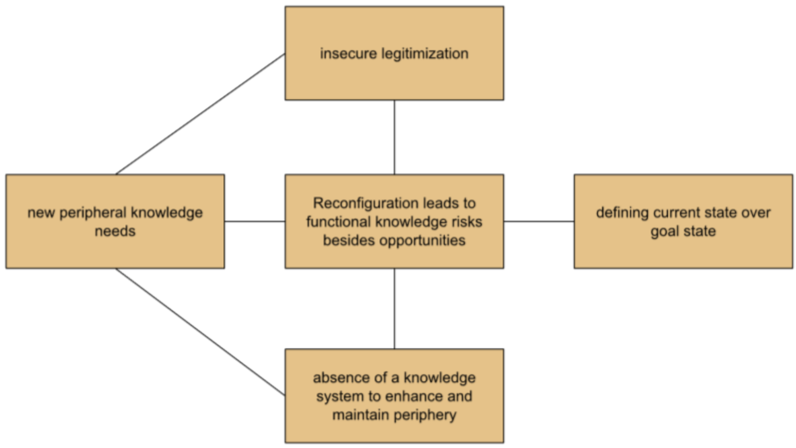

Figure 1.The introduction of peripheral knowledge

Figure 1 shows how new knowledge needs require a comparison of current states with desired goal states.

Enhancing the capacity to absorb knowledge

Given the high degree of heterogeneity among SMEs and the presence of epistemic uncertainty, the capacity to absorb knowledge can be enhanced only by developing functional knowledge specific to individual organizations (Cohen & Levinthal, 1990; Barney, 1991; Teece, et al., 1997; Burt, 2004). This development increases self-sustainability in the face of systemic changes (Battersby & Bailin, 2018). Functional knowledge refers to the practical understanding and skills required to perform specific tasks or activities effectively, such as those needed to interact purposely with technology or systems (Szulanski, 2000).

Developing organization-specific functional knowledge requires students to develop epistemic modal knowledge, with a view to continually developing and adapting functional knowledge to the needs of a particular organizational-epistemic system (Bendixen, 2016; Malmqvist, et al., 2015). Epistemic modal knowledge enables students to navigate complex, dynamic organizational-knowledge ecosystems and to recognize, analyze, and respond to the unique epistemic requirements. It enables them to make epistemic stances under uncertainty in a range of organizational contexts. Such stances involve choices on gathering and interpreting information from different sources. Judging the stance further requires knowledge on how uncertainty about new knowledge is reduced in the process of knowledge absorption. Students should also know the requirements for integration in the existing knowledge base, and how users evaluate new knowledge. All of this requires mature human-resource management (HRM).

1.2 Government initiatives

The Dutch government has set up several initiatives to promote collaboration and partnerships between UASs and SMEs, emphasizing fostering knowledge development in SMEs (OECD, 2016; SME Action Plan (MkB-Actieplan); European Commission, 2019). The SME Action Plan addresses challenges to human capital, innovation, financing, and digitalization. It promotes public-private sector (PPS) partnerships in vocational education and applied sciences, aiming to link SMEs with educational institutions to foster skills development and knowledge exchange. The Knowledge and Innovation Covenant (*Kennis- en Innovatieconvenant*; Rijksoverheid, 2023) encourages practical application of knowledge outcomes to help SMEs access research results from UASs and other institutions, thus improving their innovation capacity and knowledge absorption. These policies have catalyzed the evolution of the role of UASs in addressing societal challenges and contributing to economic and knowledge development.

The relationship between UASs and SMEs extends beyond mere problem-solving; it offers multiple benefits, including lower R&D product costs and optimization of products and processes. Significantly, it creates opportunities for the extraction of knowledge from various networked organizations (Nowotny, et al., 2003; (Helbig, 2013). Collaborative activities localized on campuses generate knowledge spillovers, which are widely recognized as effective catalysts for innovation (Bogers, et al., 2012). The collaboration between SMEs and UASs in research-related activities facilitates the creation and dissemination of knowledge. The pragmatic, incremental research conducted at colleges offers SMEs the advantage that they can accumulate knowledge gradually through experimentation, enhanced data monitoring, and the use of novel instruments, products, and processes. This approach enables iterative feedback in knowledge production (OECD, 2016; European Commission, 2019; Abramovsky, 2023; Pape, et al., 2025; Shaw, et al., 2024, and Du, 2021).

The vast diversity in size, sector, and maturity among SMEs requires tailored knowledge transfer and absorption strategies, but current government programs often apply broad approaches that may not fit all SME profiles.

Epistemic gaps influence HRM practices

Industry 4.0 has fundamentally reshaped the integration of systems and information at scale, thus enabling the emergence of networked organizations and ecologies characterized by efficient, differentiated modes of knowledge production (Alonso, et al., 2024; Nowotny, et al., 2025). SMEs are increasingly embedded in these knowledge-intensive networks. SMEs often face acute knowledge-exploitation pressures in highly volatile and competitive markets, where the ability to apply and validate information in real time is a necessity rather than an option. This leaves little or no room for exploration. Effective knowledge management becomes essential for coordinating internal and external human resources and for managing data as a strategic lever for organizational learning and the realization of adaptive capacities.

Due to exploitation pressures, transforming knowledge in SMEs is inherently experimental, often necessitating systemic change and reconfiguration of human roles. The creation of new knowledge introduces conjectures, which naturally include tentative ideas or hypotheses that may serve as potential pathways for organizational learning. However, solving these conjectures requires balancing the costs of experimentation against the expected epistemic and economic benefits. SMEs have to cultivate the capabilities and strategies that will enable them to identify and exploit economic opportunities from both internal and external sources (Teece, et al., 1997). Intangible capabilities such as tacit knowledge, technical skills, organizational routines, and strategic relationships are critical assets for sustaining competitive advantage (Porter, 1985; Eisenhardt & Martin, 2000).

Contemporary societal challenges continue to reshape the configuration of intangible capabilities and associated human capital in organizations. New environmental and market contexts demand relationships and systems that reinforce epistemic infrastructure and enhance the dynamic capabilities of organizational agents (Szulanski, 2000; Bogers, et al., 2012; Roco, 2016, and Aas & Breunig, 2024). In short, SMEs lack effective methods or tools to process, synthesize, and extract meaningful insights from this vast pool of information, characterized as information overload that affects their management (Gross, 1964).

SMEs lack frameworks and tools that their agents can use to capture and apply information meaningfully—i.e., by finding, selecting and weighing information against existing knowledge and experience. These processes are often supported by different forms of knowledge management and HRM used to identify what knowledge is needed and to allow access to new knowledge.

When more information is available, and when knowledge and new skills are required based on environmental dynamics, organizations face a deficit in knowledge integration or assimilation, which translates to a reduced capacity to absorb knowledge. Missing representations of knowledge has an enormous impact on how SMEs define their development strategies. Ineffective or replaceable knowledge functionalities and applications entail high costs and risks. The difficulties involved in managing an organization’s capabilities and tools leads to a contingent approach to managing knowledge (Aas & Breunig, 2024).

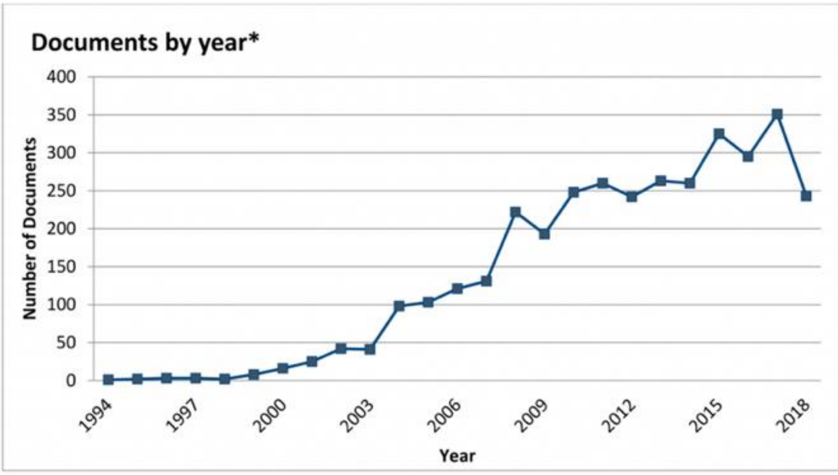

Figure 2. Growth trajectory in the knowledge-management and sustainability literature (Sanguankaew & Vathanophas Ractham, 2019)

If organizations are incapable of producing, finding, transferring, or transforming the information that is required for their core processes, there will be a gap in epistemic functionalities. Knowledge is epistemic in the sense that it and its functions are 'mutually enabling and mutually sustaining constructs' (Schyfter, 2020). An epistemic functionality gap arises when knowledge cannot be constituted, or when it is unambiguous and sustainable and enables a relation with a required function (Teece, et al., 1997; Eisenhardt & Martin, 2000).

1.3 The changing roles of UASs

In contemporary knowledge-driven societies, regional social and economic development has become increasingly dependent on local innovation ecosystems. These ecosystems are often characterized by physical and social proximity stakeholders who are engaged in the production, transfer, and application of knowledge (Etzkowitz & Ranga, 2013). UASs have become relevant actors in regional innovation processes, expanding their traditional roles to encompass what is often termed the 'third mission' of higher education institutions (Pinheiro, et al., 2015). Complementing the established missions of education and research, this third mission involves participating in regional development and addressing the challenges posed by the evolving knowledge economy (Barrioluengo, et al., 2016; Champenois & Etzkowitz, 2017). UAS engagement in these activities represents a significant shift in both their institutional identity and operational focus.

SMEs have gained importance as critical partners for UASs in regional innovation ecosystems. SMEs serve multiple functions in UAS relationships: as recipients of knowledge, as mediators facilitating knowledge circulation, and as platforms for learning from experience that offer opportunities for future professionals to engage in applied research (Pinheiro, et al., 2015; Mäenpää, et al., 2016; Tödtling, 2006; Weert de & Leijnse, 2010). This symbiotic relationship is increasingly recognized as a cornerstone of regional innovation.

Central to the efficacy of these ecosystems is boundary spanning. Key actors in these systems play a crucial role in identifying, extracting, and applying new knowledge from diverse networks (Cohen & Levinthal, 1990; Velde & Wittman, 2012; Lundberg, 2013, and Hasanefendic, et al., 2017). Boundary-spanning activities are essential for facilitating knowledge flows across institutional and disciplinary boundaries, enhancing the absorptive capacity of organizations and overall innovative potential of the region (Wilhelm & Dolfsma, 2018).

The research context

The Dutch government has formulated missions in top sectors that deal with challenges of the future (agriculture, water and food, chemistry, the creative industries, energy, life sciences, and health, high-tech systems and materials, the water maritime sectors, horticulture, and starting materials and logistics). The plan is to strengthen the economy through innovation, capitalize on opportunities, improve human capital and invest in scientific research. It also fosters innovative designs and products in the relationships between UASs and SMEs.

As a result, UASs and SMEs have joined various entities, including Triple Helix, Communities of Practice, Learning communities, Field labs and Living labs, as well as special projects and various PPS partnerships. In these spaces, UASs and SMEs aim to do pragmatic and incremental research, which may offer SMEs the opportunity to experiment and accumulate knowledge (Delfmann & Koster, 2012; Windesheim, 2013; European Commission, 2019; AWTI, 2019; Vereniging Hogescholen, 2018 and Gijsbertse, et al., 2020). Knowledge sharing between UASs and smaller SMEs is key in terms of the need for, and the absorption of knowledge that is generated by collaborative research (Delfmann & Koster, 2012; WRR, 2013; ATW, 2014; ATWI, 2015; Vereniging Hogescholen, 2015; ATWI, 2015; Rathenau Instituut, 2016, and ATWI, 2018).

The nexus of higher education and economic growth

UASs (in Dutch: '*hogescholen*') are vocational universities. They arose when the system offering bachelor's and master's degrees along the lines of the Anglo-American system was introduced in former polytechnic schools. The intricate relationship between UASs and SMEs is the subject of extensive scholarly discourse. UASs still have a strong academic approach to knowledge production and aim to provide knowledge to SMEs (Windesheim, 2013; ATWI, 2015; Rathenau Instituut, 2016; European Commission, 2019) and to train future professionals for complex profession-oriented knowledge challenges (Vereniging van Hogescholen, 2021; Gijsbertse, et al., 2020). SMEs are recognized as important providers of knowledge to UASs and of great value to the vocational training of students as future professionals (Pinheiro, et al., 2015; Mäenpää, et al., 2016; Tödtling, 2006; Weert de & Leijnse, 2010; Bogers, 2012; Barrioluengo, et al., 2016; ATWI, 2015, and Delfmann & Koster, 2012).

The role of UASs in innovation

Innovation transcends institutional and disciplinary boundaries. This leads to collaboration between SMEs and UAS, starting with product development and extending to broader social dimensions, including education and the formation of human capital (Etzkowitz, et al., 2013; Ranga, 2011). The practice-oriented pedagogical approach UASs take positions them as significant contributors to innovation, particularly through strategic partnerships with SMEs (Weert de & Leijnse, 2010; Pasternack, 2013; OECD, 2016).

Different approaches based on models for collaborative relationships

The Rotterdam University of Applied Sciences (RUAS) aims to research various models of knowledge that can increase the exchange and sharing of knowledge (Gijsbertse, et al., 2020). Currently, the policies that RUAS pursues are based on Triple Helix models, learning-community models, and boundary-spanning processes in several projects, Living labs, Field labs, and PPPs (Bergvall-Kåreborn, et al., 2015). All these approaches model knowledge-sharing processes closely related to the absorption of knowledge. However, there are critical and distinct differences in goals, available finance and, most importantly, the research needs of SMEs in terms of knowledge realization.

The Triple Helix model conceptualizes the relation between academia, industry, and government. It has gained significant traction in innovation studies (Leydesdorff & Etzkowitz, 1998; Leydesdorff & Ivanova, 2016). It can serve to foster collaboration between UASs and regional SMEs in shared frameworks. Learning communities are more flexible than helices and can exist at various scales, from small groups to large organizations. They often involve peers or colleagues in similar fields or educational institutions, focusing on micro-level interactions and individual growth.

Such communities improve learning rather than the absorption or exchange of knowledge. For example, PPS collaborations emphasize network-governance features more than principal-agent aspects. This approach gives stakeholders autonomy to set own goals and activities, aimed at experimentation (Moerman, 2020).

Boundary-spanning and innovation spaces in the Triple Helix

Knowledge often remains siloed within specific organizational or community boundaries, with practitioners operating inside distinct epistemological frameworks (Riege, 2005). The challenge of traversing institutional boundaries remains difficult (Etzkowitz & Leydesdorff, 2000). Key actors, such as students and human agents in SMEs, play a crucial role in identifying, extracting, and applying new knowledge from diverse networks (i.e., in boundary spanning) (Cohen & Levinthal, 1990; Lundberg, 2013). Boundary-spanning activities facilitate knowledge flows across institutional and disciplinary boundaries, thereby potentially creating absorptive capacity (Haas, 2015). In Triple Helix theory, the aim of boundary spanning is to facilitate the permeation of institutional limits to enable effective collaboration.

Intermediaries play a critical role in orchestrating interactions among stakeholders, mediating discussions, and negotiating contracts (ATWI, 2015; Stam, 2014; Lin & Hu, 2017). Smaller SMEs face difficulties in boundary spanning, as they lack the financial and human resources to participate (Son, et al., 2018). These SMEs also have limited expertise navigating complex relationships, and few structured processes for absorbing knowledge (Tongerloo, 2021).

The Triple Helix approach looks past the increasing complexity and differences in capacity of SMEs. As a result, it does not address how new functionalities are epistemically constructed for different types of SMEs and their knowledge needs. The approach does not stress self-sustainability in mitigating risks for systems when revisions of tasks and skills involve possible costs in support systems, new process requirements, and organizational change.

There remains a critical need to study more nuanced and effective partnerships (Delfmann & Koster, 2012; McCann & Ortega-Argilés, 2014; Hasanefendic, et al., 2017). Triple Helix theories focus on collaboration between academia and industry. Little attention is paid to the innovation spaces that can serve as an interface between UASs and SMEs (Szulanski, 2000). These spaces are designed with innovation in mind, and address regional challenges. Innovation spaces can serve as an arena where entrepreneurial universities engage with industry and government partners to capitalize on scientific knowledge and support economic development (Chalmers, 2011). The proximity and ongoing dialogue in these spaces facilitate the dynamic flow of tacit and explicit knowledge, enhancing the capacity of all parties to absorb, adapt, and apply new insights rapidly (Etzkowitz, et al., 2008).

A quick look at SME differentiation and the resulting challenges for UASs

In 2024 there were 426,810 SMEs in the Netherlands: businesses with 2–250 employees. The SME sector is divided into micro-enterprises (2-10 employees), small enterprises (10-50 employees), and medium-sized enterprises (50-250 employees). The majority of SMEs are businesses with fewer than 50 employees. In 2024 there were approximately 258,000 micro-enterprises and 113,810 small businesses and about 55,000 medium-sized enterprises (MkB Statline, 2024; CMS MkB, 2024; MkB servicedesk, 2024). Besides size, there are differences in characteristics. SME differences lead to the following challenges:

- Strong differentiation creates a complex landscape for research and policymaking on the absorption of knowledge. General policies may fail to address the specific challenges faced by different groups in the SME population.
- Smaller and less-resourced SMEs may lack the financial, technological, or human capital needed to recognize, absorb, and apply new external knowledge effectively.
- There is a need for models based on types of SMEs' capacity to absorb knowledge, recognizing the considerable heterogeneity in how firms acquire, assimilate, and exploit external knowledge (Zahra & George, 2002; Cohen & Levinthal, 1990).
- Differences in management skills, expertise, and organizational learning capabilities across SMEs mean that some are better positioned to integrate external knowledge, while others struggle due to limited internal know-how or absorption capacity.

- Our research shows that deploying standard knowledge or boundary objects is difficult due to SME differences. Standard knowledge and boundary objects are not tailored to SME practices and are thus difficult to integrate with their knowledge bases.
- Heterogeneous SMEs often have varying innovation objectives and operational contexts, which complicates targeting and customizing research knowledge to meet their diverse needs. A one-size-fits-all approach to knowledge transfer is ineffective.
- Most smaller SMEs, particularly micro-enterprises, often lack research infrastructure, have limited time, and may have little experience with collaboration.
- Accessibility of data for UAS students and lecturers may be affected by low HRM maturity and lack of HR strategies in smaller SMEs. Data is required to reduce epistemic uncertainty (Kiureghian & Ditlevsen, 2009; Hüllemeier & Waegeman, 2021; Walters, et al., 2023).
- SME domains affect the modes of knowledge absorption. Manufacturing SMEs may adopt other knowledge absorption strategies than service-oriented ones. Regional factors, innovation ecosystems and policy support also influence absorption capacity.
- Differing levels of social capital, networks, and trust relationships among SMEs impact their ability to access and absorb knowledge. Isolated or less connected SMEs may face barriers in knowledge flow and collaboration with research institutions.
- Last but not least, the practicality of SMEs may affect the changes to belief required for epistemic advancement. It also creates dualism between the systems of justification of new knowledge used by UASs and SMEs (Quanbeck, 2024).

Limitations to and opportunities for epistemic changes

Small and micro-enterprises have a significant impact on the regional and national economy of the Netherlands. New technologies change the functional knowledge needed to operate. Especially smaller SMEs lack ongoing development of knowledge about knowledge (Helbig, 2013). Collaborating with UASs can enhance this type of knowledge, which can in turn change both domain knowledge in the knowledge base of SMEs and the configuration of tasks and skills. This collaboration can increase the capacity of SMEs to absorb knowledge. The significant variations among SMEs in organizing and storing functional knowledge can explain this. Many SMEs are not inclined to formally represent or codify functional knowledge. As a result, outside parties cannot easily observe or influence functional knowledge that is available by external parties, at the level of both individual agents and organizations. (Nonaka &

Konno, 1998). The inability to perceive and interpret existing tacit, weak, or unstructured knowledge, as well as to distinguish between epistemic contexts hinders a specific context-rich approach. SMEs lack the reflexivity and associated beliefs required for less-structured knowledge.

When it comes to knowledge absorption processes, it is essential to align new knowledge with the prior beliefs of the agents involved. In situations of epistemic uncertainty, prior beliefs and representations of knowledge are suboptimal for new functional knowledge. New formal representations need to be created that recognize new knowledge functionalities, including skills and associated applications. Maintaining this knowledge becomes challenging due to the absence of a codified system for functional knowledge. Providing context-related knowledge is crucial for the independent use and maintenance of that knowledge. When understanding of the possibilities of the new knowledge is missing, SMEs find it challenging to accept its application. And when SME agents' capabilities must be (re)configured informally, it requires tailor-made objects or processes, and questions may remain about the long-term implications and maintenance of newly absorbed knowledge.

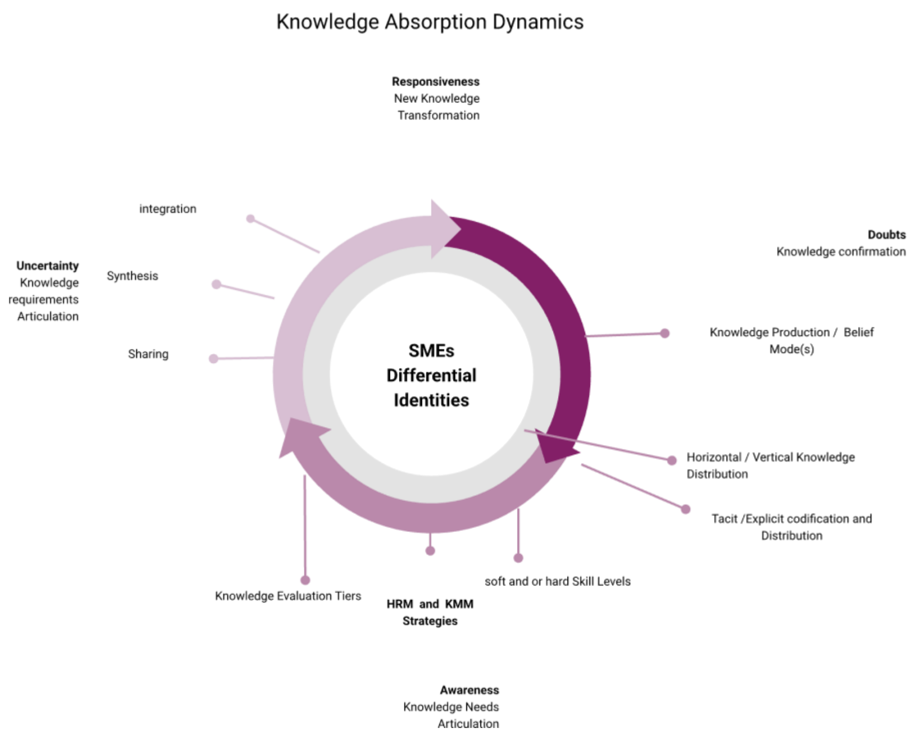

Figure 3. The continuous circle of responses to uncertainty

Requirements for epistemic capacity
Developing contextual, practical knowledge requires such critical thinking and the ability to engage in meta-cognitive activities to identify suboptimal knowledge. However, agents must have access to this knowledge in order to create new representations of it. A lack of knowledge about different types of knowledge may make these inaccessible. And a lack of experience with knowledge that is differently structured may cause uncertainty and the rejection of new beliefs (Mize, 2020). Making new representations of knowledge requires students to modify knowledge functionalities to suit the needs and capabilities of human agents and the capacities of SMEs' knowledge systems. Modification involves changing existing functionalities that may affect agents' core knowledge processes, routines, and beliefs.

As a result, new technologies create both knowledge boundaries and economic and business risks for the transformation of knowledge. Figure 3 represents how the needs of SMEs for knowledge vary in accordance with technological and epistemic changes and consequently uncertainty.

Collaborative learning in modal awareness
Through collaborative exploration, UASs and SMEs create a clearer picture of the effect of emerging technologies related to types of knowledge, its justification and possible applications, required skills for human agents, and ultimately the conditions for integrating new concepts to respond to these changes. The stages of modal awareness and responsiveness are crucial to epistemic advancements. Research shows that experimentation creates the new approaches needed to respond to uncertainties regarding the reorganization of knowledge and skills, to determine, and act on, the needs of agents and systems for knowledge.

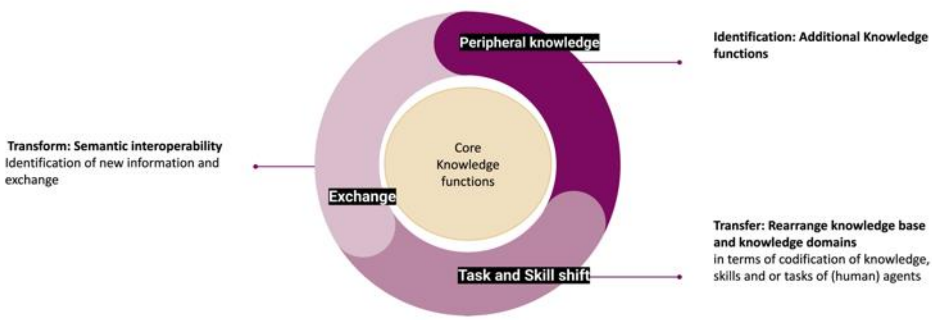

Figure 4. Absorption of knowledge and the effect on semantic interoperability

Our research reveals that a lack of awareness regarding the effects of different knowledge modalities significantly impacts the absorption of knowledge processes. Knowledge modalities, in this context, are the diverse ways in which individuals acquire, process, and retain information. Our findings indicate the presence of semantic boundaries that hinder the identification and transformation of knowledge presented by UASs to SMEs. The lack of attention to the ways various cultures and belief systems influences the use of knowledge is particularly problematic. Moreover, the semantics used in research often diverge from the more pragmatic knowledge base typical of SMEs. This divergence particularly affects the ability of SMEs to absorb knowledge from UASs.

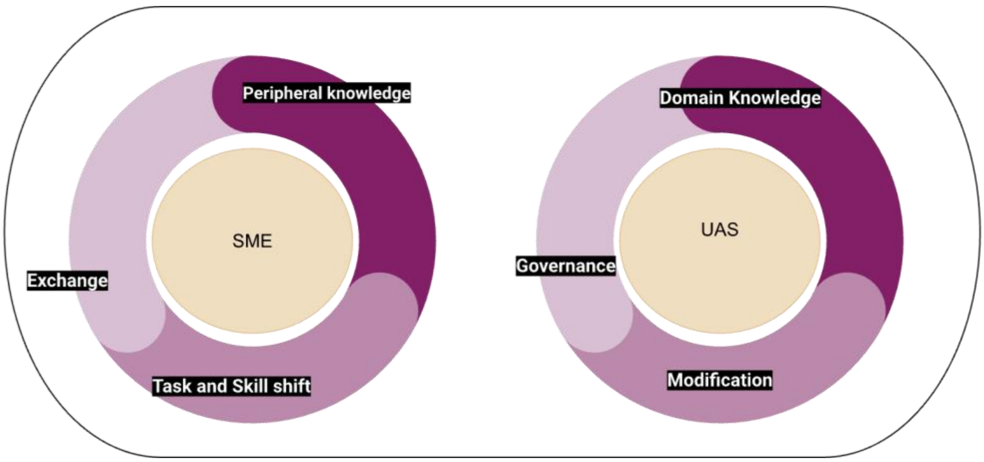

Figure 5. Internal transfer circles in separate knowledge-based systems.

Figure 5 illustrates how external knowledge needs to be adapted to suit different contexts. This adaptation process involves at least three steps: identify, transfer and transform external knowledge. When these processes lack principled support mechanisms to finally establish such functionalities as experiential representations and successful knowledge absorption, the result is a weak structural framework for maintaining changes in routines and reconfiguring skills derived from peripheral knowledge. This research underscores the importance of developing a nuanced understanding of knowledge modalities and their impact on the absorption of knowledge, particularly in the context of UAS -SME collaboration. It highlights the need for sophisticated approaches to the transfer of knowledge that can account for cultural variations, and the pragmatic knowledge needs of SMEs. Such an understanding could make processes related to the absorption of knowledge significantly more effective and could contribute to more robust innovation ecosystems.

How knowledge gets modified is the subject of the research field of knowledge management (Weggeman, 1997). The idea is to meet the current and future needs of knowledge workers (Bergeron, 2003; Zhixiong & Yuanjian, 2010; Bottini & Doeller, 2020). Less attention is paid to how UASs and SMEs modify their knowledge for that purpose. Thus, modified knowledge is poorly represented and hard to evaluate. The reflexivity required for building and enhancing knowledge is absent, and that affects knowledge symmetry, that is, the degree to which all stakeholders have access to the same knowledge. In smaller SMEs, we found that this affects the absorption and distribution of knowledge. Our findings highlight the need for knowledge flows, based on knowledge-management principles, between UASs and SMEs, as presented in Figure 5. Such flows bridge the gap between theoretical constructs and practical knowledge rooted in actual applications.

From awareness to consciousness of different modalities of knowledge

Awareness of the different ways individuals and organizations perceive, process and acquire new information is crucial in learning problem-solving contexts. Our research shows that new functionalities of knowledge introduce uncertainty. A functionality is effective when it generates certainty of a maximal response of taken actions (Peirce, 1902). A response is maximal when it has a high degree of predictability in repeated responses, allowing human agents to act with confidence. When a response changes, for instance, when part of the stimulus or action is replaced by automation, the input difference may be indirectly composed. Individual contributions of input become more uncertain if the response is effective but more efficient in time and or costs. When such efficiency is increased in the output, this can serve as a stimulus for organizations (or individual agents) to retain the newly composed functionality.

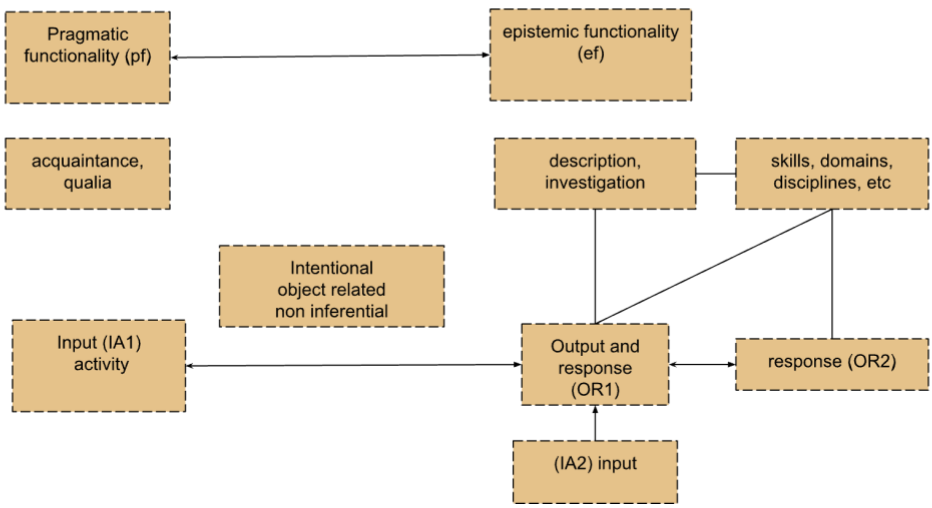

Figure 6. Pragmatic perspective as a foundation for epistemic functionality

Figure 6 Models how pragmatic knowledge serves as foundation for epistemic knowledge and vice versa. An epistemic functionality acts as an understandable description of an enabling construct necessary for a distinct functionality. However, if input IA2 takes place under new information the activities, output and response affect OR1 and consequently OR2, OR3, etc. This makes IA1 compound (has a relational functionality with OR1 and IA2), and temporary uncertain in terms of a loss in the degree of intentionality. Although output of OR1 can have higher effectivity or efficiency this distinction requires different representations of epistemic states or cognitive states. We found for example that novice learners lack an ability to articulate distinct goals in objects they use (often denser in descriptions e.g., concepts or propositions) and consequently new judgments and expressions for output in R2 (‘and what to do and know next’). Inexperienced learners require more instructions. Our research also shows that with more experience learners the intentionality is more robust.

Acquisition (judgments) and assimilation (new beliefs) of knowledge to be functional require consciousness of different modes of knowing in a multi-agent environment. The dynamic integration (learning to switch between stances based on different modes) helps to reduce uncertainty of compound functionalities. This involves knowledge engineering based on epistemic doubts and uncertainties.

Our research demonstrates that acceptance of a composed functionality in SMEs is influenced by several factors. When new tasks need corresponding instructions, this requires agents to draw distinctions in known activities to achieve optimal efficiency of the new input. Determining which substitution of knowledge or even redundancy of human agent activities depends on environmental factors, the organization’s access to new technologies, and how they can be incorporated in existing functionalities.

New functionalities of knowledge processes or applications can introduce uncertainty for organizations and human agents. This uncertainty increases when organizations engage in traditional activities with a high risk of being transformed into composite functions. Modal uncertainty can also arise when expressions are assigned to activities, resulting in task ambiguity that generates financial risks. When SMEs are uncertain about expressions associated with the effectiveness or efficiency of new tasks, adaptation becomes harder for both the organization and its agents. This distinction reflects the difference that “knowledge that is known by description is ultimately known by acquaintance” (Russel, 1912). In other words, these descriptions are non-reductive to the activities (uncertain).

Our research shows that this knowledge differs in the expression needed for effective exchange within or between organizations. Knowledge by description is often derived from automated processes and it requires propositional knowledge to assess its response. Related expressions or descriptions are difficult to translate in terms of reduction to knowledge by acquaintance. In many smaller SMEs, knowledge is continuously in use, meaning that the space and time between activities and responses is maximized. Exchanging space and time to explore new activities with a limited group of employees carries financial risks. Our research indicates that SMEs build their knowledge with the help of customers or suppliers who are closely connected to the processes and products. This reflects the dynamic and often tacit nature of knowledge management in SMEs, which impacts their ability to adapt and innovate effectively. This finding has led to research on how the use of metaphysical knowledge can contribute to greater acceptance of uncertain knowledge and the associated consequences for organization development. In the preliminary study, the concept of epistemic consciousness, phenomenologically understood as the relationship between experience and learning, or specifically focused on the intentionality of consciousness through the use of objects, proved insufficient to contribute effectively to the exploration of metaphysical concepts in UAS-SME relations to affect knowledge absorption.

Particularly in smaller SMEs, these concepts constitute a significant risk, also related to the intensity of the knowledge absorption process, which occurs in various, often sequential phases and dimensions that can correspond to the specific characteristics of an organization. This calls for an exploration of how innocent (Bartolotti, 2020) or naïve students can sufficiently distinguish between epistemic and pragmatic stances both within and outside of their own knowledge and vocational education domains (Kuhn, et al., 2000). Additionally, there is the task of developing new knowledge and making this knowledge identifiable, transferable, and readily usable by others.

Our research questions whether and how a metaphysical exploration of new functionalities can contribute to the development and incorporation of new knowledge, with particular attention to acceptance, description, and acquaintance. This requires the exchange of knowledge through experiments on how new and uncertain functionalities relate to their maximal response and distinct reductions (actions) in descriptions across different environments with existing knowledge and beliefs. Doing so, it becomes possible to integrate propositional knowledge, which is strongly connected to acquaintance, with pragmatic knowledge derived from these experimental representations and their associated actions. The epistemology of modality helps us to understand how modal truth gives a better understanding of different real worlds and situations. The importance of the research is to understand how consciousness of modal knowledge can enhance the ability to absorb knowledge and reduce constant uncertainty across a diverse range of SMEs.

1.4 Research methods

We used a mixed-methods research design (Tashakkori & Teddlie, 1998) to investigate and collect quantitative and qualitative data to create a more complete picture of events and situations (Brewer & Hunter, 2006).

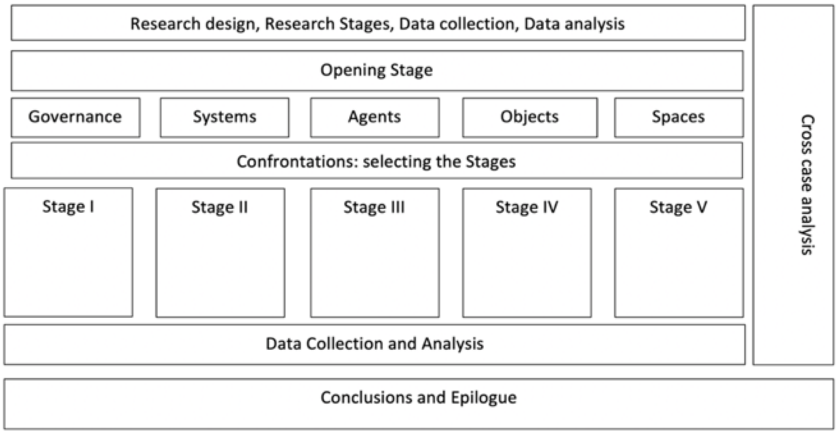

Figure 7. The mixed-methods research canvas

The design is convergent/parallel (Creswell, et al., 2003) over a long period, enabling the use of different interpretations to address the different problems. MMR design covers multiple stages for collecting, analyzing, and synthesizing information. The choice of design aims to contribute to epistemological descriptions of spaces, protocols, and instruments. It also aims to develop knowledge and information management between UASs and SMEs in unstructured and/or uncodified environments. We believe that the relationship between pragmatic and epistemological viewpoints can be better understood by both positivist and pragmatic approaches (Harrison, 2013).

There are several reasons for choosing MMR design. There is no suitable knowledge-management model for the mutual absorption of knowledge by UASs and SMEs. Also, innovation spaces are broadly defined and mostly used in academic contexts. For example, there is a difference between helix innovation spaces and public and private innovation spaces. Some field labs and learning communities are not formally defined as such. Since this study aims to analyze the absorption of knowledge in differentiated contexts and domains, it requires analyzing types of knowledge and their boundaries. It examines how the behavior of individuals can be influenced by various factors. It explores the behavior of various students and agents, their routines, and their interactions. Therefore, we observe and describe the behavior of students and agents in terms of roles and maturity, and the ability to absorb and engineer knowledge. Syntheses of qualitative and quantitative methods are helpful for policy- and decision-making, so that we can address the (epistemic) governance of these spaces (Mays, et al., 2005 ; Sirriyeh, et al., 2012). The convergent parallel design, covering multiple stages for collecting, analyzing, and synthesizing information, enables us to apply different interpretations and merge our findings.

Significance of the research

Paradigm changes affect the way we—conscious human agents— learn to create the fundamental constituents of knowledge (Hoffman, 2008). The human agent of the future will need to be able to respond to epistemic uncertainties that affect their position to add different types of value to its knowledge functionalities. However, constant fast change requires the agent to consider the reliability of existing knowledge and consequently the ability to revise and adapt the knowledge needed to respond. High dynamic changes in SMEs create constant epistemic uncertainty that threatens the existing and future dynamic capabilities of human agents. This uncertainty makes the organizational-knowledge base less adaptive and responsive to change.

This research analyzes how human agents in SMEs can integrate new information into their routines to respond dynamically to change. It requires epistemic models as tools for agents and SMEs that show necessary (non-native) responsiveness from agents and SMEs. Our study analyzes how UASs and SMEs can contribute to the development of these models.

Conscious moves

On a pragmatic level this study explores how both agents and students can make conscious moves, which involve navigating specifically between the epistemological and pragmatic dimensions of knowledge. The study analyzes how different practices can make coherent and reliable future representations of knowledge that enable agents to be more adaptive. It analyzes how these changes affect awareness of the effect of existing routines on new knowledge needs in SMEs. Examining the conditions that epistemically govern how we can experiment and create such models allows us to describe a topology of knowledge interfaces between UASs and SMEs.

Our model of an innovation space allows us to experiment with various epistemic and real-world dimensions, including most of the learning concerns models for constant coupling of functionalities of agents in smaller SME systems and the ability to influence their activities. The aim is to develop self-sustainability in absorption as a result of what we conceptualized as modal consciousness. This concept aims to understand different absorption dynamics and necessary knowledge modification methods to determine the effective channels for identification, transfer, and transformation aimed at self-sustainability of human agents in different contexts.

Modifying knowledge relates to possible engineering for an uncertain goal state. The research aims to uncover how knowledge flows between UASs and SMEs and how different flows can be codified to build on knowledge in engineering processes. The study aims to contribute to the understanding of the absorption of knowledge processes under conditions of epistemic uncertainty and provide practical insights for organizations seeking to enhance their absorptive capacity with UASs.

1.5 Main research question

Our research investigates the epistemic relationship between UASs and SMEs and analyzes the dynamics of the absorption of knowledge between the two entities. The study aims to address the following primary research question:

How can UASs and SMEs co-develop the absorption of knowledge strategies to enhance their mutual capacity for identifying, transferring, and applying knowledge under epistemic uncertainty?

This leads to the following sub-questions:

1. How can UASs and SMEs share knowledge about tools and instruments for continual advancements in dynamic capabilities under epistemic uncertainty? This sub-question examines how UASs and SMEs can continually learn in terms of awareness of how to integrate different types of knowledge from different sources.
2. What differences among SMEs affect the dynamics of the absorption of knowledge and how does this in turn affect the ability of UASs and SMEs to develop strategies together?

This sub-question studies how the effects of different modalities of knowledge affect the creation and sharing of new knowledge between the different knowledge systems of UASs and SMEs. It explores how UASs and SMEs reason about present and future knowledge needs and how this affects the sharing and integration of knowledge in each system.

3. What is the effect of pragmatic and semantic boundaries of co-development and knowledge exchange processes between UASs and SMEs?
This sub-question explores the effect of agents, contexts, and situations in UASs and SMEs and the integration of the absorption of knowledge strategies. It focuses on how human agents can consciously make epistemic advances in various semantic and pragmatic realities.
4. What design of an innovation environment or innovation space contributes to the effective and efficient mutual absorption of knowledge by UASs and SMEs? This sub-question integrates the previous questions and presents models for representations of knowledge.

Chapter outlines

Chapter 1 introduces the question of maintaining the knowledge function and explores how emergent technologies affect knowledge from an epistemological viewpoint. We focus on how these technologies disrupt the relationship between agents and their access to knowledge sources. Vocational education will eventually prepare the agents of the future to work and learn in highly differentiated, complex, and uncertain environments (SMEs). These agents will require new ways to find meaning and understanding, but most importantly, become conscious of the use of knowledge. The research focuses on models that can develop representations of knowledge and value co-created by UASs and SMEs through the absorption of knowledge. This approach aims to bridge the gap between vocational institutions and the practical needs of businesses in a fast-evolving technological landscape.

We seek to understand how to prepare future professionals for the challenges they will face in increasingly complex work environments. The chapter sets the foundation for exploring the intersection of knowledge management, emerging technologies, and the evolving needs of both educational institutions and businesses.

Chapter 2 conceptualizes the integration of various perspectives to uncover the complex processes involved in SMEs' absorption of knowledge. It explores how knowledge can be produced and exchanged in both SME and UAS systems. Both rely on the application of knowledge to optimize knowledge-production functions, allocate human resources, and constantly rearrange future capabilities. The epistemological contribution and benefit of participation consists of knowledge that is functionally credible and contextually relevant. We argue that a function of knowledge has both epistemic and economic value. This value increases when new knowledge synthesizes with transient knowledge in both UASs and SME knowledge systems.

A conceptual model for aligning this type of knowledge requires a substantive approach to knowledge-management and engineering principles and practices. This approach concerns various conceptualizations of how knowledge can be produced, shared, and finally absorbed. By examining these processes, we aim to develop a comprehensive understanding of the knowledge flow between academic institutions and businesses, focusing on the practical application and the creation of value in both environments. The chapter explores the mechanisms by which knowledge transforms from theoretical concepts to practical applications, and how this transformation can be optimized to benefit both UASs and SMEs. This serves as a foundation for developing strategies to enhance the absorption of knowledge and utilization in real-world business contexts.

Chapter 3 describes the research design and methodology. We studied several types of SMEs in terms of capabilities and capacities, representations of knowledge, and the boundaries that affect identification, transfer and transformation of new knowledge. We studied students' design processes and compared several collaborative projects including PPPs, consortia, living labs and field labs to determine their effectiveness. We observed the behavior of students in various knowledge environments that affected their abilities. The chosen environments were based on the literature and strategies of the RUAS for collaboration with SMEs. We collected data on types of SMEs, their agents in boundary positions, and their research capabilities.

Chapter 4 presents our findings, based on the case studies, and offers recommendations for sharing and absorption of knowledge and levels of knowledge engineering.

Chapter 5 describes the findings of our cross-case analysis.

Chapter 6 discusses the key findings.

Chapter 7 concludes the dissertation with suggestions for further research.

CHAPTER 2

Theoretical Framework

Chapter 2. Theoretical Framework

This chapter discusses the theoretical framework on which the study is based. Our problem-solving areas concern differences between UASs and SMEs in their representations and production modes of knowledge. These differences provide different types of barriers and boundaries for knowledge integration and consequently affect access to each other's knowledge bases to explore new epistemic requirements.

The aim is to enhance our understanding of the dynamics of constant knowledge creation processes and provide epistemic models of SMEs, their agents and how to adapt to these evolving societal challenges and technological demands.

The chapter explores how conscious behavior can lead to more adaptive agents and thus to new knowledge systems. Furthermore, we discuss how the capacity to employ the logic of reflexive reasoning can be realized within agents' existing routines in each system.

The chapter is laid out in the following sections:

2.1 Introduction

By “constant changing of the epistemic landscape,” we mean ongoing efforts to study how semantic waves create epistemic changes that shape our knowledge systems. These efforts are characterized by prior knowledge that provides us with other knowledge and reduces epistemic uncertainty. The absence of such epistemic certainty affects the status of our present knowledge and disables agents in their progress and actions. Certainty is propositional and can manifest itself through actions (Wittgenstein, 1953/2006). Knowledge of actions makes us aware of how we know what we know. This is a type of coherent evidentialism that pairs actions or phenomena with epistemic justifications (Hüllemeier & Waegeman, 2021). Being aware of how this works, either through pragmatism or rationalizations makes us less innocent or intuitive agents (Bartolotti, 2020). However, this knowledge can make us aware, but sometimes not innocent just merely naïve in the sense of not directly willing to change or make efforts to make epistemic advancements (Kuhn, et al., 2000).

This type of unwillingness or monotonic behavior on the part of agents can also be a sign of an inability to make sense of the structure of the new beliefs that come with based on new situations or events (Spiro, et al., 1988).These clear structures are well-defined and or have received explicit codifications as support mechanisms. Such structured codes help to define corresponding behavioral and social patterns for agents in organizational or communal environments (Nonaka & Takeuchi, 1995). But even if agents know how knowledge, its systems, and its effects are constituted, that is not a precondition for epistemic advance (Jonassen, 1997; Roux, et al., 2006; Bendixen, 2016). So how do we deal with uncertainty as a result of technological or epistemic changes?

This question concerns the role of human agents, their environments and the knowledge systems that shape how we define what we do not know, and how we decide which choices will make epistemic advancements responsive to the effects of uncertainty that limit access to new knowledge. In other words, how can agents be constituents of knowledge (Hoffman, 2008) using a form of auto epistemic logic—that is, reflexive reasoning about self-knowledge, about changes in the epistemic landscape of Industry 4.0 and its effects on both the agent’s environment and routines.

2.1.1 Consequences of new technologies

Government policy on innovation has shifted toward an entrepreneurial-discovery framework, emphasizing the development of knowledge-based assets in specific regions where private industries, public sectors, and governments collaborate on environmental and societal challenges (Bogers, et al., 2012; Helbig, 2013). Knowledge develops in these settings through the production of highly local and contextualized rationalities in SMEs (Laursen, et al., 2011; Nooteboom, et al., 2005) that have epistemological implications for the distribution of knowledge (Nowotny, et al., 2003; Nonaka & von Krogh, 2009).

The mutual exchange of knowledge between UASs and SMEs is considered a key element in innovation for knowledge-driven economies. However, new technologies affect labor markets and consequently lead to new developments in knowledge functionalities, including applications and skills. A new paradigm challenges practical and epistemic advances. This requires experimental methods, especially when rapid change in epistemic stages requires adaptations to knowledge systems and agents' functionalities.

Siloed knowledge production is inefficient at addressing these challenges. Crossing institutional and knowledge boundaries requires transdisciplinary production modes that involve different types of stakeholders. The complexity and interconnectedness of Industry 4.0 demand an integrated and adaptive approach for knowledge systems and knowledge functionalities.

Capabilities are strongly related with apriority in knowledge. Apriority or foreknowledge at a substantive level can be pragmatic, or may take the form of schemas that shape understanding in problem-solving or are epistemic in the sense of reasoning on knowledge (Nooteboom, et al., 2005). These schemas create different levels of consciousness based on available methods to reflect, reasoning capabilities and the tools and availability to respond to different knowledge needs. Available methods and sources to respond can make agents aware of the effect of changes to routines and enable them to acquire additional information or knowledge based on the type of routines or functionalities used.

In epistemology, epistemic spaces (Chalmers, 2011) consist of various types of experiments related to modal logic that enable agents to carry out metaphysical and pragmatic experiments on possible representations of knowledge. These spaces aim to develop a priori possibilities in both functionality and epistemic statements that can help explain the requirements of new paradigms. An experimental modal space can serve as a dynamic environment where traditional boundaries are blurred, enabling innovative approaches whose effects can be monitored. The concept of this is particularly relevant to developments in different legitimation concepts (Maton, 2013; Maton, 2020) of knowledge domains, its grammar (Gärdenfors, 2017) and its effect on beliefs (Mize, 2020) and knowledge distribution (Bernstein, 1999) as we discuss later. By focusing on this critical knowledge, the model seeks to anticipate and adapt to new developments, thus enhancing the dynamic capabilities of both academic institutions and businesses. The approach aligns with current theories of knowledge management and organizational learning currently addressed in gray literature on the specific needs of UAS-SME collaborations resulting from rapid technological changes (see also Chapter 1).

2.1.2 The science of integration of knowledge

"Each field (discipline) is the site of a specific legality (a nomos), a product of history, which is embodied in the objective regularities of the functioning of the field and, more precisely, in the mechanisms governing the circulation of information, in the logic of the allocation of rewards, and in the scientific habitus produced by the field, which are the condition of the functioning of the field." (Bourdieu, 2004).

The science of knowledge integration as a final phase of knowledge absorption is still a nascent field. Integration of knowledge involves overcoming different types of knowledge boundaries and barriers that affect how different types of knowledge, their domains, disciplines and practices can merge. When knowledge is epistemically uncertain, in contrast to aleatoric uncertainty, reasoning on knowledge, its definitions its distinct descriptions to constitute and justify information is required (Löf, 1996). This reasoning process has a long history in epistemology, especially in the legitimation of these definitions. Legitimation is the difference between the presence of intensions and extensions in representations of knowledge (Carnap, 1937). This idea of intensions and extension is the basis for semantic externalism (Putnam, 1975) and has been developed into the model of conversion to different situations in which the agent uses descriptions of knowledge in terms of codifications (Rattan, 2006). In a more modern variant, it is understood that absence of these descriptions leads to contextual understandings without the necessity to develop capacities for semantic interoperability (Valente & Marchetti, 2005). As a result, highly contextualized knowledge has difficulties in accessing external sources.

Knowledge of epistemic dynamics can help to understand how agents from UASs and SMEs gain access to relevant environments and knowledge systems, and integrate diverse epistemic and practical dimensions of knowledge. The environments and agents of SMEs and UASs may generate distinct beliefs and values that contribute to the development of new functionalities. Agents must be aware of experimental approaches to access external information sources and their own capability to extract, transfer and convert this information to representations of functionalities.

However, as Chapter 1 explains, especially smaller or micro-SMEs have limited capability and capacity to develop the necessary steps to make effective changes in their routines and system. This limitation affects risk assessment of the possibly necessary epistemic advancements. Key risks may include financial and epistemic costs to maintain newly produced knowledge, such as acquiring new skills as a result of changes to the agents' routines and behavior. Also, the selection and involvement of individual agents places significant demands on organizational capacity, making it crucial for SMEs to understand how the organization can benefit from individual agents' contributions, weighed against the financial and epistemic risks.

2.1.3 Dynamics of epistemology

This study uses a dynamic epistemological approach. The subfield of applied epistemology deals with the application of knowledge. Both applied epistemology and epistemic modal logic support the structuring of knowledge by providing different reasoning modalities. Epistemic modalities reason on the basis of modal arguments rather than personal arguments that relate to epistemic uncertainty or ambiguity. Understanding the various epistemic modalities provides information on the legitimation of arguments for different realities. Thus, the epistemology framework is necessary to understand the new functionalities of knowledge in different epistemic systems and environments.

Since we focus on integration and assimilation, this affects the alignment of knowledge codifications in diverse epistemic systems. A critical aspect is the necessary conversion and dissemination of codification in terms of identifiability or semantic interoperability between different knowledge-production modes.

Codification requires semantic representations in what is called different worlds. And to be both effective and legitimate in these different worlds (Lewis, 1986) codes must facilitate the semantic interoperability levels between UASs and SMEs that overcome or bridge semantic knowledge barriers. That makes it easier to integrate or assimilate new knowledge functionalities, for example in the description of skills.

When successful, this recombination can have many advantages, such as effective epistemic communities or ecologies of systems that share social ontologies and beliefs based on semantic interoperability. Also, knowledge is more easily transferred, trusted and accepted in semantic environments. It reduces economic costs, since transformation of knowledge involves experimenting with necessary changes in systems, and the roles or routines of human agents. Semantic and epistemic knowledge boundaries can further act as conjectures for continuous learning (Akkerman & Bakker, 2012). The developments of objects in terms of processes provide possibilities to exchange ideas in a less negotiable manner as it would be in a competitive environment (Star, 1989; Carlile, 2002; Pöyry-Lassila, et al., 2013). Trusted actors are more eager to learn from the experimenting process and share acquired new meanings and values (Hakkarainen, 2009; Akkerman & Bakker, 2012).

Objects can be considered as coordinating mechanism of knowledge (Cohen & Levinthal, 1990; Roux, et al., 2006) if they effectively influence the transfer and absorption of new knowledge by reducing its ‘tackiness’ or ‘stickiness’ (Cohen & Levinthal, 1990; Zahra & George, 2002; Tushman, 1977; Szulanski, 2000). This requires codifications that can function as foreknowledge in innovation processes.

Objects can show degree of difference in practices and routines (Abraham, et al., 2015) and semantic differences in concepts developed in experiments that affect the translation of knowledge into differentiated practices. Skills description may, for example, help describe different levels of skills that may strongly relate to existing tiers in HRM practice, often not present in smaller SMEs.

2.1.4 The common interest in the absorption of knowledge between UASs and SMEs

Absorptive capacity consists of potential and realized components, which differentially influence exploratory and exploitative capabilities. This study aims to provide insights into modifying knowledge based on the differences in SMEs, the capabilities of agents and capacities in knowledge systems. The research focuses on the complex nature of epistemic uncertainty in relation to the effective absorption of knowledge, such as incompleteness, inconsistency, and ambiguity. Epistemic uncertainty on a pragmatic level is often more an incapacity in time or tools of SMEs and their agents to represent, model and identify new knowledge as a result of technological changes.

Relatively little is known of how SMEs absorb knowledge despite their enormous impact on the economy (Forth & Bryson, 2018). As a result, absorption capacity has been and still is intensively researched. Most studies use the concepts of Cohen and Levinthal (Cohen & Levinthal, 1990) and Zahra and George (Zahra & George, 2002). As defined by Cohen and Levinthal (Cohen & Levinthal, 1990) the absorption of knowledge capacity refers to an organization’s ability to identify, assimilate, and apply new external knowledge to enhance learning and innovation. This dynamic capacity is shaped by a complex interplay of factors, including the organization's cultural dimensions, which influence the willingness and ability to share and identify critical knowledge; the characteristics of key actors (Hustad & Bechina, 2012; Gao & Nee, 2018), such as their skills, education, and experience (Beauchamp & Lemay, 2021; Kousgaard, et al., 2105), which determine the level of recognition and utilization of external knowledge bases.

The organization's prior knowledge enhances the ability to make sense of external inputs and adapt them for practical application and determines learning capabilities of the organization. Structural factors such as organizational size and product diversity, as well as the organization's interaction with its external environment, influence this prior knowledge. Absorptive capacity is often cumulative and path-dependent, evolving through exploratory, transformative, and exploitative learning processes (He & Taohuang, 2018). It affects epistemic and practical dimensions in identifying, valuing, acquiring, assimilating, transforming, and eventually using the exploitation of knowledge.

Clearly, the development of absorptive capacity is a complex process linked to various internal and external networks. However, when successful, absorptive capacity creates strong organizational and individual learning capabilities and enhances an organization's innovation performance and ability to maintain competitive advantage in dynamic environments.

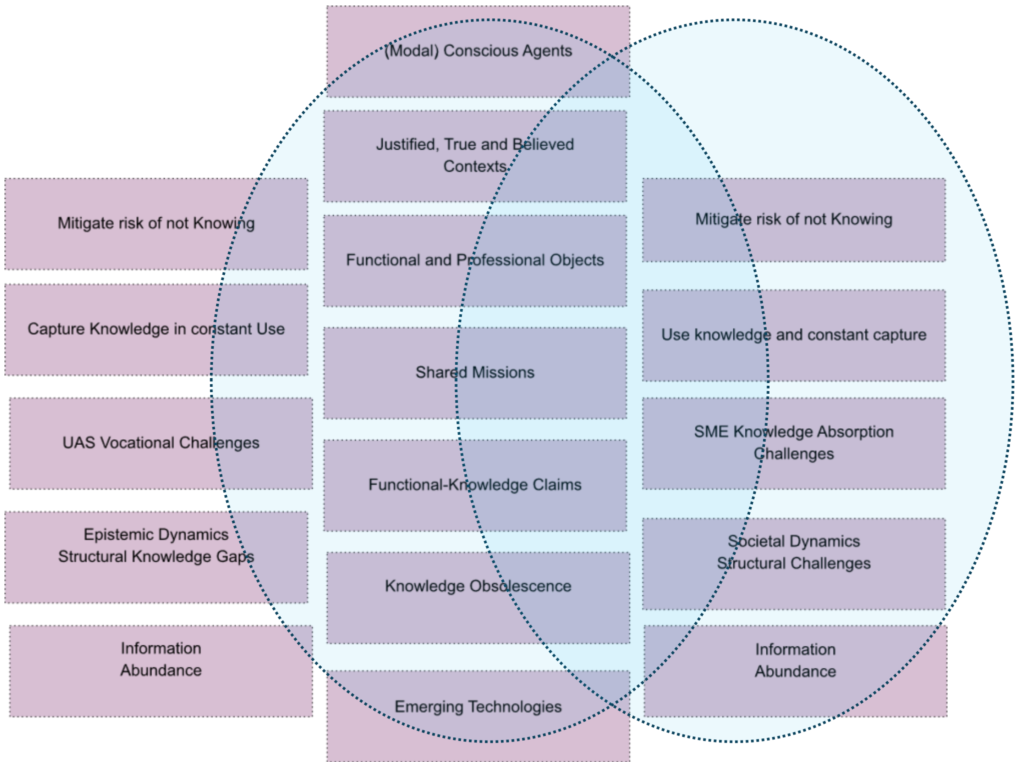

Figure 8. Main interests of UASs and SMEs in relation to knowledge absorption

Figure 8 represents the possible overlaps in boundaries and disparities between UASs and SMEs. Both UASs and SMEs face similar difficulties in aligning their knowledge base with rapidly changing needs. These changes involve new professional disciplines, expert knowledge domains and changing demands in necessary skills. This requires constant revisions of curricula, teaching and research methodologies (Abramovsky, 2023; OECD, 2016; ILO, 2022). The fading traditional disciplinary boundaries in Industry 4.0 and 5.0 poses a significant challenge for both SMEs and UASs.

UASs and SMEs also have distinct knowledge-production modes and representations of knowledge, each creating unique practical and epistemological boundaries for the absorption of knowledge. Beyond traditional absorption boundaries, these individual epistemic systems have more divergent knowledge objectives. In UAS (educational in general) settings, epistemic systems are often linearly organized and structured in distinct (categorical) phases. Conversely, SMEs function as individual micro social systems, utilizing diverse sources for absorption through varied procedures, patterns, and mostly interpersonal influences that impact (uncoded) epistemic outcomes and their legitimacy.

Thus, the disparities between UASs and SMEs in knowledge-management practices are significant. SMEs often adopt a temporary or short-term approach to organizational learning and rarely develop explicit knowledge-management policies. They tend to rely on informal procedures and tacit knowledge stored predominantly in managers' and employees' minds. In contrast, UASs traditionally have a formal and explicit knowledge infrastructure. These knowledge-management approaches create both challenges and opportunities for knowledge exchange rather than absorption between UASs and SMEs. Understanding these distinctions is crucial for our research and designing effective epistemic tools that can bridge the epistemic gap between these entities.

Overlap in barriers mainly relates to redundancy of information and sharing of information. Agents may be in boundary positions but are ineffective at knowledge transfer since they rely on the same resource that creates structural holes in the information transfer (Burt, 2004; Kalish & Robbins, 2008; Soda, 2009) that facilitates interactions.

2.1.5 An overview of boundaries

Industry 4.0 integrates systems and their information in efficient, multi-modal, networked environments that contain socially distributed and application-oriented differentiated knowledge-production modes (Nowotny, et al., 2003). SMEs increasingly have to participate in these environments to identify, acquire and recombine new information and critical knowledge effectively. However, lacking human resources, most SMEs are relatively unprepared for this.

Studies show that small SMEs tend to overcome the constraints of their size by accessing external sources (Grandinetti, 2016). However, most SMEs have little experience in knowledge management or the skill models needed to use new external information effectively. As a result, they lack the key recombinatory capabilities, also known as response capabilities, which create (low cost) learning processes (with epistemic benefits) that permit SMEs to continuously align their knowledge and skill base with external technology bases and contexts (Loree, et al., 2011).

New policies to address this problem often involve roadmaps experimenting with the collaborative capacities and capabilities of SMEs. The concept of experimental roadmaps aligns with the broader trend of creating innovation ecosystems.

(Mazzucato, 2018; ATWI, 2018; European Commission, 2019). These roadmaps serve as catalysts for the co-creation of knowledge and the development of practical solutions. Also, roadmaps facilitate the transitions toward more adaptive organizational structures (European Union, 2018; Masood & Sonntag, 2020).

In our preliminary research, we found two reasons that affect the participation of smaller SMEs. First, although novelty barriers can act as conjectures for learning and may have preemption effects in innovation for SMEs, these conjectures always involve epistemic and thus financial costs. For most smaller SMEs, the costs are often too high. The second reason lies in the cause of the matter: lack of capacity and capability affect necessary absorption capacity, mostly in transfer and transformation. Additionally, the risks associated with new reconfigurations and routines pose challenges for the processes and agents involved.

The environmental boundaries that lead to responses in space and time

A plethora of literature shows that most SMEs often lack sufficient dynamic capabilities and capacities to rearrange internal and external competencies (Teece, et al., 1997; ATW, 2014; WRR, 2013; Biesta, 2015; Champenois & Etzkowitz, 2017). Most SMEs lack key agents that have the time to identify or experience to transfer external information (Kleijn, 2012). Effective key agents create ambidextrous capacity (Connelly & Kelloway, 2001; O'Reilly & Tushman, 2007) that achieve strategic renewal and optimize exploitation (Dedehayir & Seppänen, 2015). Secondly, differences in the action logic between agents in the field and students affect the time they have to develop (Korstanje & Moerman, 2015; Russel & Novig, 2020).

In collaborative research, SMEs seek direct solutions, whereas knowledge institutes focus on developing knowledge building in their students' specific domains. This impacts on the interactions between SME agents and the research conducted by UASs, and vice versa (AWTI, 2015). It requires dynamic research articulations that make sense to the actors involved (Kracht & Kornai, 2015). Also, the type of environment—discrete or continuous process—affects the ability to identify, transfer and eventually transform knowledge (Zahra & George, 2002; Russel & Novig, 2020). Discrete environments require distinct steps to isolate (individual) actions and its changes as a result of new information. Continuous environments involve processes with overlapping and interdependent flows of information.

Boundaries in terms of distinctions of knowledge emerge when agents are confronted with high novelty problems they cannot solve with existing ideas and require new information and sources of innovation (Carlile, 2002). Knowledge boundaries are confrontational since they affect self-sustaining mechanisms, routines, and beliefs (Broniatowski & Mageee, 2017). They emerge when new sources have different representations, codifications and meanings and require transformation and translation in different syntactic and semantic scripts of behavior (Carlisle, 2002; Star, 2010).

Syntactic Semantic and pragmatic knowledge boundaries

Syntactic boundaries are the least complex of translations in knowledge boundaries between UASs and SMEs that involve, for example, lexicons in systems used by agents. Most syntactic boundaries concern specific technicalities of procedures, tasks descriptions and or roles. In our preliminary research, we found varying data types in education and practice. They are not considered complex since they are usually described explicitly and have degrees of execution ability.

Semantic knowledge boundaries affect translation between agents because ambiguity and identifiability result from interpretations formed in their own domains (Gärdenfors, 2011). Pragmatic boundaries concern the agents' embedded or prior knowledge (Broniatowski & Mageee, 2017) their interpretations or their institutional beliefs and different routines (Carlisle, 2002; Star, 2010; Jacoby, 2001; Tsoukas, 2009; Chu, 2014).

Different boundaries also relate to the epistemic costs and benefits between SMEs and UASs. SMEs face time constraints due to their daily operations and limited resources and tend to prioritize overcoming pragmatic boundaries, which is often most difficult for inexperienced learners. Also, SMEs generally have limited HR resources to articulate the differences in these boundaries, which is necessary for effective exchange initiatives.

Knowledge-in-use, habitus and habituals

SMEs depend on knowledge that is in use. This knowledge functions in real time (Carayannis, et al., 2021) and often has discrete, deterministic environments and routines. Any change in these evokes financial, operational and behavioral risks. Change can also cause tension between representations of present and future knowledge that agents may access to form discrete, deterministic environments. This tension is also rooted in differences between UASs and SMEs in their modal vocabularies and the logical consequences that affect knowledge integration.

We assume that the semantics of knowledge objects aims at adding necessary information in routines and that dynamic capabilities cause most of the tensions between different systems. Objects of knowledge are organized in different semantic environments.

The epistemic environment of SME agents is a personal state of consciousness based on reflective experience, embedded in (mostly symmetrical) routines that reason on and respond to their routines. The production of more informal objects of knowledge, which conflict with tacit knowledge, as discussed by Polanyi (Polanyi,1967) and Nonaka

& Takeuchi (Nonaka & Takeuchi,1995), is thus an obstacle between formal and informal systems.

Converting knowledge to other environments requires more than conversion methods (Bendixen, 2016). Tacit, uncodified and informal knowledge is highly context-specific, pragmatic logic. It is carefully fabricated along horizontal distributions of knowledge (Bernstein, 1999; Luhmann, 1990; Leydesdorff & Ivanova, 2016). Its legitimation takes place through actions, a mix of referents rather than references. For example, suppliers, customers, clients and colleague take roles as external source of information and legitimation. This makes sense since different formal and social relations have other information and legitimation sources. Higher differentiation of external sources also requires an increase in the type of conversions between different systems, agents and practices.

Especially the different maturity of SME agents is important both in defining sources as primitive constituents (Hoffman, 2008) and their capability to convert pragmatic knowledge (Nonaka & Takeuchi, 1995; Beauchamp & Lemay, 2021). Converting different types of knowledge affects the identification in absorption processes.

2.1.6 Conclusion

This section highlights the importance of human agents having access to alternative environments when the current epistemic and practical environment fails to provide enough information for the actions and responses they request. However, access from UASs to SMEs and vice versa require distinct relationships. Accessing the ability to consciously navigate between the epistemic and practical dimensions is, by far, a natural process. On a substantive level it involves the flow of knowledge between trusted, relevant partners.

So, what are the contributive, complementary roles and tasks of relevant partners that provide access to each other’s world to gain mutual benefit? Also, could epistemic uncertainty in future knowledge needed in both worlds provide the chance for new types of collaboration between the different systems, each with expertise in their own dimensions?

This is characteristic of the underlying difficulty to integrate unknown and unfamiliar knowledge between UASs and SMEs in general and particularly in Industry 4.0 with its epistemic uncertainties. It shows the diffuse boundaries of new dynamic epistemic and pragmatic environments. The dynamics influence the existing and future functionalities of knowledge where human agents must have continuous access to multi-agent environments. In this study we analyze how the absorption of knowledge can reduce epistemic and pragmatic uncertainty through effective absorption of knowledge between practical and epistemic worlds.

2.2 The concept of modal consciousness to model SMEs

The efficient and effective exploitation of new external information to solve problems is a process of refining existing capabilities by incorporating acquired and transformed information into its operations (Zhixiong & Yuanjian, 2010). This refinement modifies knowledge acquired through exploration or search processes (Miwa & Takahashi, 2008). In education we find modification in terms of modified instructions in explicit and formal representations of knowledge, such as curricula.

Most SMEs depends on their agents to integrate necessary additional information into their core tenets of representations of knowledge (Gallivan, et al., 2003). A core of knowledge with embedded tacit knowledge requires higher financial and epistemic costs to systematically adapt routines for constant knowledge acquisition. If not done systematically, the acquisition risks adding less value to the system (Shariq, 1999; Shoham, et al., 2012). The risk is to create knowledge transfer without distinctly recognizing the need for new processes, organization and instructions on using that information (Bostrom & Sandberg, 2009). Cognitive artifacts, such as plans, diagrams and schemes can support agents to identify, complement and transfer the information (Sutton, 2010). The conversion needs and requirements using artifacts have low cost but also add relatively little value to learning capabilities. Learning based on developing knowledge depends on learning to organize different knowledge needs (Vigotsky, 1978). Multi-modal learning facilitates knowledge development by establishing requirements for future representations (Bottini & Doeller, 2020). Human capability is crucial in contributing information for future knowledge (Hoffman, 2008).

Modal logic and reasoning on boundaries

Modal knowledge is concerned with reasoning about knowledge, specifically about the laws for how we how gain information and knowledge (Kment, 2021). Modalities explain how different semantic boundaries constitute knowledge and its production modes. Modal logic involves understanding the multiplicity of perception modes (Soboleva, 2019). Based on the literature we assume that narrowing perceptions of semantics affects the identification of future necessary or possible knowledge.

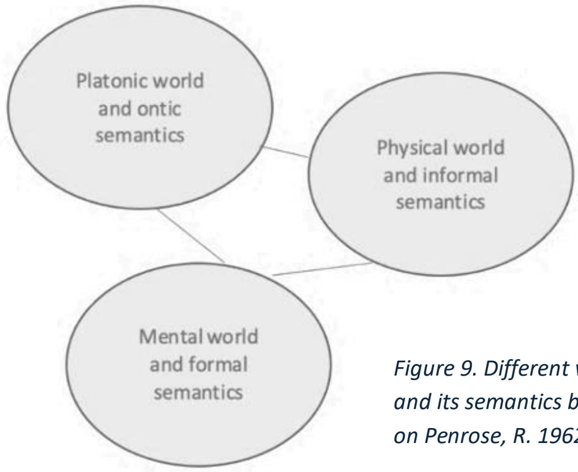

Figure 9. Different world and its semantics based on Penrose, R. 1962

The requirements of agents' awareness in system functionalities

Awareness of different knowledge-production modes requires knowledge of the semantics and modes that make distinct functionalities of knowledge. The disciplinary mode with its strict boundaries focuses on inquiry and academic research. The pragmatic context mode is driven by societal needs, and accountability takes place through the needs of the environment.

If organizations are unsure of developing capabilities and future knowledge, it is generally unclear what type of production mode will follow. The current mode is pluralistic, meaning that it is both individual and networked, theoretical and contextual (Nowotny, et al., 2003; Carayannis, et al., 2021). Our concept of modal consciousness is a rooted in epistemic fluency, which involves the development of diverse perspectives essential for professionals operating in a technologically rich environment (Trede, et al., 2019).

Modal consciousness specifically refers to the awareness of various capacities and capabilities related to the system's absorption of the necessities and capabilities as a consequence of the epistemic uncertainty. It emphasizes epistemic progress in terms of capturing new concepts that are necessary, possible or sometimes contingent for smaller SMEs in multi- modal, diverse networks and contexts. Modal consciousness extends beyond the traditional understanding of epistemic fluency by focusing on a meta-cognitive awareness of how different knowledge systems and contexts influence the integration of knowledge and information.

Modal consciousness involves the capability (of systems, agents) to modify different kinds of epistemic semantics needed for multi-agent interoperability in universally coded networks. The emphasis on progress reflects the need for both students and professionals to navigate the changing epistemic landscape, where knowledge is increasingly distributed between human capabilities and technological systems. This awareness enables professionals to effectively integrate knowledge from various sources. It enables agents to adapt to new epistemic environments and apply integrated knowledge to address complex, multifaceted problems described as grand societal challenges. By focusing on the conscious recognition of different absorptive capacities of agents in SMEs, modal consciousness provides a framework for understanding how SMEs and their agents can enhance their ability to legitimize, model, and codify knowledge for diverse contexts. This awareness is crucial to overcome syntactic, semantic and pragmatic knowledge boundaries between disciplines and domains.

Translating modal consciousness to management practices

Agents operating across various knowledge systems should utilize the new technological functionalities and applications created by developing modal consciousness. Our study found that these functionalities and applications require constant maintenance and revision.

Constant revision mostly affects SMEs with routine-based capabilities. The dispositional context requires absorption derived by human agents sensing, reconfiguring and transforming systems (Russel & Novig, 2020) that require different types of learning (Hoffman, 2008).

We conceptualize modal consciousness as a necessary condition for human agents to develop distinct technological, epistemic and sustainable functionalities of knowledge in response to ongoing technological developments.

Using this concept, we aim to analyze differences between UASs and SMEs that affect distinct, coherent representations of the various contexts that make generalization (extensions over a longer range and time period) difficult. To develop the capabilities (future) human agents must be able to integrate knowledge describing or codifying the epistemic functionalities that enable mutual sharing of knowledge through absorption processes. We conceptualize epistemic functionality as a tool in modal logic to develop semantic representations of new functionality needs in response to epistemic uncertainties that require foreknowledge. Such foreknowledge can be realized by experiments, scenarios and or simulations. It requires constant reflexive responses to act as continuous learning mechanism.

Consciousness of modal states or consciousness, reason and descriptions of knowledge

The ability to reason on different modal states and representations of knowledge is essential in a society in which knowledge systems differentiate at high speed.

Modal epistemologies are aimed to describe how knowledge is constituted (Becker & Zhao, 2023) and especially concern the relationships between agents and their beliefs. Advancements in modal logic is an aspect of applied epistemology in terms of defining (future) epistemic functionalities of agents that contribute to different models of possible worlds.

A layman representation of our conceptual model is as follows: (modal) consciousness can be represented as awareness of the different possibilities in knowledge modification necessary to reduce uncertainty in the functionalities of a knowledge system.

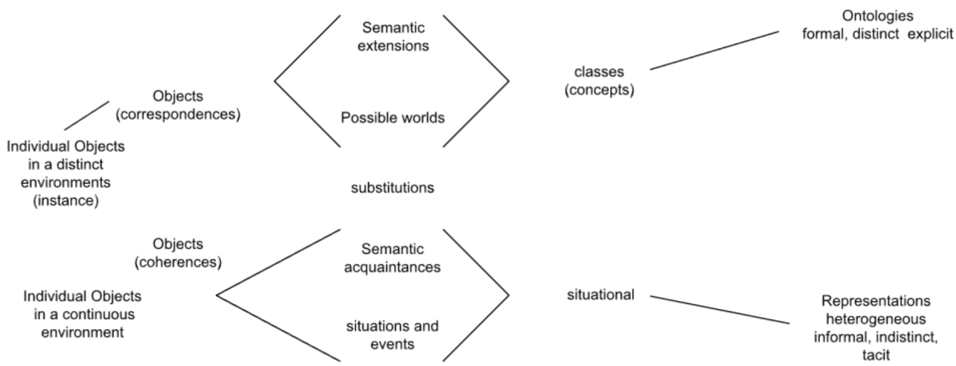

Figure 10. Translations of objects of knowledge and its translations in terms of expressions in ontologies situations and consequently representations

Figure 10 shows how the semantic architecture assigned to situations and events in terms of SMEs as epistemic environments (distinct and formal) is primarily related to types of production, marketing, and similar attributes in SMEs.

This suggests that current ontologies do not sufficiently capture the complex, semantically rich nature of knowledge systems and processes involved in absorptive capacity across different domains. More nuanced and domain-specific expressions are needed to improve understanding and modeling of knowledge transfer in these contexts to provide distinct functionalities of knowledge in terms of skills and or applications

The main challenge is to find or engineer semantics that both capture and identify a possible translation for additional epistemic functionalities in SMEs. It concerns knowledge of the differences on various levels and integrating representations and functional requirements in codes (technological, social, economic) needed for problem-solving. Knowing about integrating semantics and pragmatics enables agents to reason about an actual situation and act on it.

Absorption processes requirements

The above shows that evolving ontologies require constant relating to real-world semantics in terms of production modes. Successful implementation is an equivalent or a distinct epistemic functionality of knowledge in terms of 'sameness' in both worlds.

2.2.1 Modal logic

Modal logic has an important effect on deciding what knowledge is and how it can be constituted. As illustrated in Figure 11 (below), we can take various routes to constructing and constituting knowledge. Although the schema shows clear boundaries between various concepts and notions, it is crucial to recognize that these boundaries are less strong or rigid in reality. The schema highlights distinctions between epistemic reasoning, which allow agents to reason on what is known as possible states or worlds. It shows the types of reasoning and instruments UASs use in certain situations. Epistemic uncertainty can be reduced by adding information that reduces lacking or incomplete knowledge. For highly differentiated SMEs, the schema emphasizes that finding instruments also relates to future epistemic states and environmental characteristics. For agents, it involves size, education and experience and most importantly access to different external sources. For students, the differences in complexity also affect the level of their prior knowledge of particular situations and contexts.

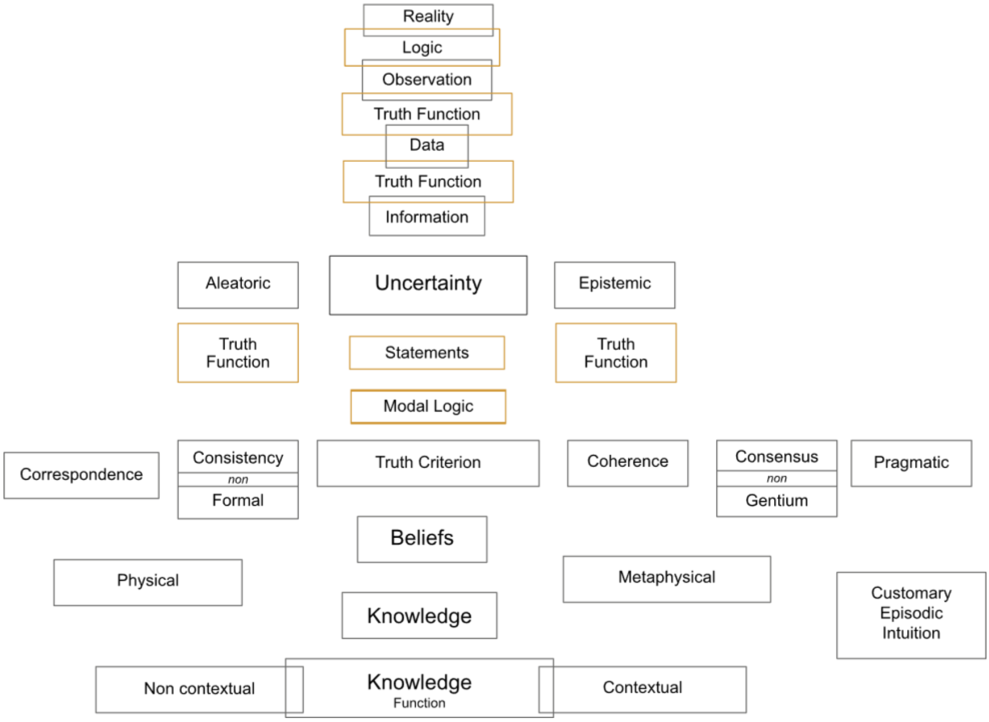

Figure 11. The expanding knowledge labyrinth

Ill-structured situations as concepts for integration and modification

Ill-structured environments contain complex problems, have ambiguous knowledge and poor semantic codification. Because agents have multiple views on the knowledge required (Spiro, et al., 1988) they find it difficult to choose what is needed. Systems face difficulties in designing and developing experimental epistemic objects. Thus ill-structuredness is often diverse in terms of availability of instructional systems. This refers to various forms of conceptual complexities and case-to-case irregularities. These environments require new theories of learning to avoid oversimplifications that make it hard to constitute knowledge (Bendixen, 2016). We aim to study if these cause indistinctions or inconsistencies in the students' approach to create links between cause and effect that describe what is needed for (a.) possible solutions and (b.) epistemic functionalities of objects needed for the situation. Creating objects of knowledge requires reasoning (Pöyry-Lassila, et al., 2013) that expands existing ideas and have constructs that aim to integrate new ideas. This trialogical process involves the role of technology (Hakkarainen, 2009). It is a discontinuity of earlier knowledge-production modes (Nowotny, et al., 2003; Lee, et al., 2014; Fox, 2011). It requires non-instructive, non-formal learning in different environments.

Modal logic expands classical logic by introducing operators for necessity and possibility, thereby enabling a more nuanced representations of (prior) knowledge and beliefs of agents as well as students in different contexts. Modal logic employs reasoning about beliefs in relation to various modes of truth across different contexts.

Confrontation with novelty questions the beliefs or legitimization of agents and students working in collaboration. A new situation can be experienced as threatening rather than inviting and may consolidate earlier beliefs (Luhmann, 1986). In our research we also can study whether the levels of beliefs of agents or students affects changes in their relationship (Bartolotti, 2020; Kienhues, et al., 2016).

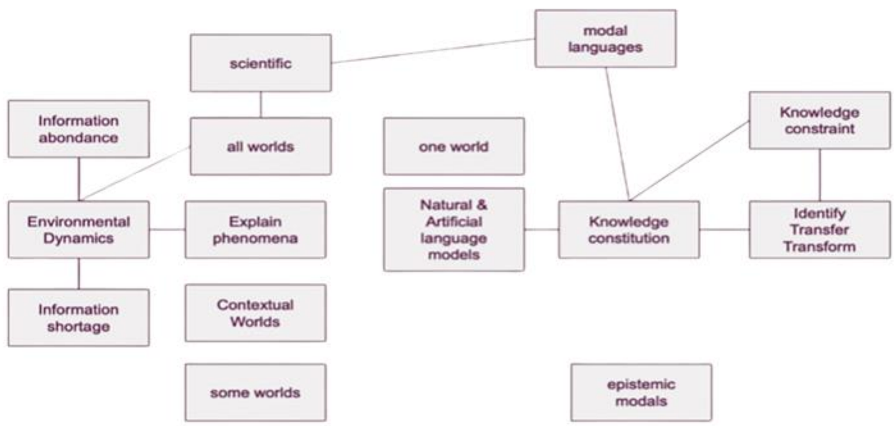

Figure 12. Different routes to the construction of knowledge

The framework of modal logic aims to represent and reason on objects based on multi-modal environments, including time, knowledge, belief, and obligation as key elements crucial to understanding complex epistemological concepts.

Epistemic modality refers to future states and how various costs and risks reach that state in terms of possibilities, contingencies and necessities based on epistemic constraints and exiting core tenets of knowledge. This means that a claim on solutions (how) and necessary functionalities (who and what) is a given epistemic constraint**.**

2.2.2 The applicability of modal logic: Reflexivity, transitivity and symmetry of knowledge

The applicability of modal logic lies in reasoning on knowledge systems and representations of SMES and their future states. Modifying knowledge based on the current and future states enables students and agents to explore and experiment with necessary or possible distinctions between semantic and technological functionalities that Industry 4.0 requires.

Reasoning on different possible worlds requires an awareness on the effect of the semantics used, for example in the designs of students. Semantics of concepts may be described formally or informally. As a result, these descriptions require translations to technologically functional (in terms of skills) to address real (or true) world problems. Using colloquial or personal semantics can affect distinctions in the description of the needed functions and consequently extensions over situations. On a substantive level this requires an SME to make a knowledge representation of present and future knowledge and skills.

Apart from inadequately describing skills and their effect on what a knowledge system needs from a human agent, semantics are difficult to code. Inferences and comparisons between SME characteristics, a used concept for present solutions, become ambiguous.

When the syntax and semantics of a real-world function (skill O) can access other systems, as a result of higher information and knowledge integration, that function is transitive. It can be used to identify and extract information and assess its transformation potential in that same syntax or semantics.

For example, if an object of knowledge with description x: *O* (x) holds in one world, it must hold in all worlds accessible from that world, and thus all worlds accessible from all those worlds, and so on. Here we know that $\Box O \rightarrow \Box O$ means transitivity: if something, or object (x) is true it remains necessarily true in all accessible worlds, both transitive and reflexive. Transitivity is essential for a hierarchy, for example in statements. If something is true in a statement, the consequences of that statements are also true. The reflexivity relates to the way particular agents in System A have access to their own knowledge domain or knowledge on that object in a goal state. This enables us to discern several levels or tiers on the absorption capacity of individual agents, and their relation to the requirements of knowledge system to respond to the dynamics of Industry 4.0

Particularly for our research, it means that both students and agents have access to each other’s knowledge base or repository. This symmetry also affects the knowledge distribution in terms of its density and gravity.

Lately much attention has been paid to contingency models, reasoning on their effect in organizations and descriptions of functionalities that give a better understanding of how to deal with contingencies in organizational processes and innovation readiness.

In summary, by integrating modal logic with the process of knowledge absorption, we gain a more comprehensive understanding of the semantic requirements of interactions between different types of knowledge belief systems, and contextual factors that affect knowledge identification, transfer and transformation as well as constant revision.

2.2.3 Integrating modal logic with substantive knowledge-management processes and designs

Modal logic provides a formal framework essential in professional contexts for reasoning about necessity, possibility and contingency. This distinction is crucial for making informed decisions and evaluating the strength of different knowledge claims on applications for new situations. If there is a distinct functionality of skills and knowledge, applying modal logic to professional situations enables agents in the field discern to reason and respond to problems (Bianconi, et al., 2014). Using different modal operators for research projects, students can become aware of the differences and learn to reason to modify knowledge based on different environments.

Modal logic helps students to differentiate between personal, social, and professional reasoning. Professional reasoning is based on experience and meta-cognitive elements. Understanding the varying contexts of SMEs in terms of the capabilities and capacities of their agents supports the integration of knowledge as a type of epistemic situationism (Cavusgil, et al., 2002; Swink, 2006; Fairweather, 2017; Azzam, et al., 2020). Semantic and pragmatic knowledge barriers between UAS and SMEs especially affect novice learners, who are unaware that, for example, tacit knowledge is a part of a knowledge-production mode. Modal logic teaches students to reason on distinct situations and the capabilities needed to be epistemically functional.

Modal relationships

We conceptualize the difference between UASs and SMEs as an experimental innovation space. We use the topology of the space to explore modifications of knowledge to model various SMEs, their characteristics and epistemic states (Lewis, 1986) on the absorption of knowledge, and their knowledge needs. We aim to model contextualities in a quadrant (as a semantic guidance) to determine the efficiency of making inferences from coherent situations.

Our framework conceptualizes the interrelated mechanisms that shape the topology of innovation space between UASs and SMEs collaboratively addressing shared dynamics by constantly producing temporally distinct epistemic functionalities: epistemic governance; polymodality of SMEs; and characteristics, objects and agents. On a substantive level, for different types of SMEs these mechanisms involve converting information and producing knowledge in semantic and pragmatic languages to codify distinct epistemic functionalities.

We argue that these mechanisms reduce tension between semantics and pragmatics used in each system needed for distinct epistemic functionalities. Using knowledge mode (3/4) for production requires an array type topology (see Figures 13 and 14).

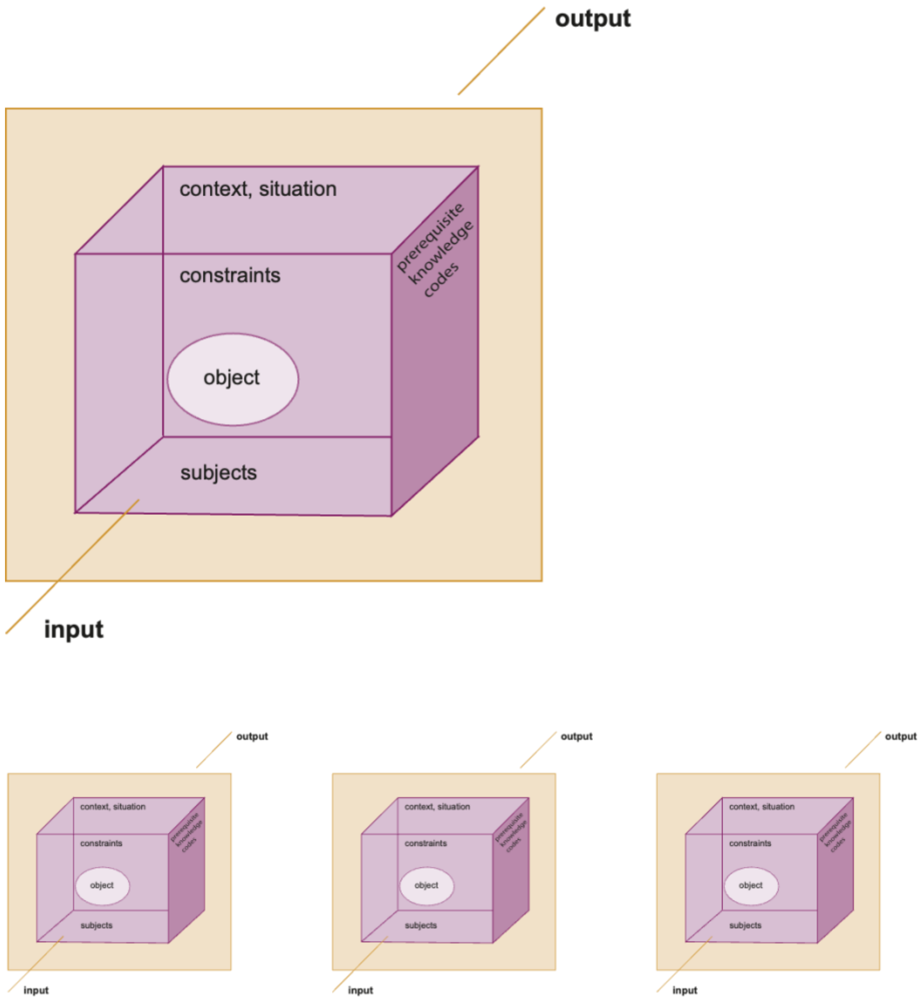

Figure 13 Single topology and an array based on that same situation

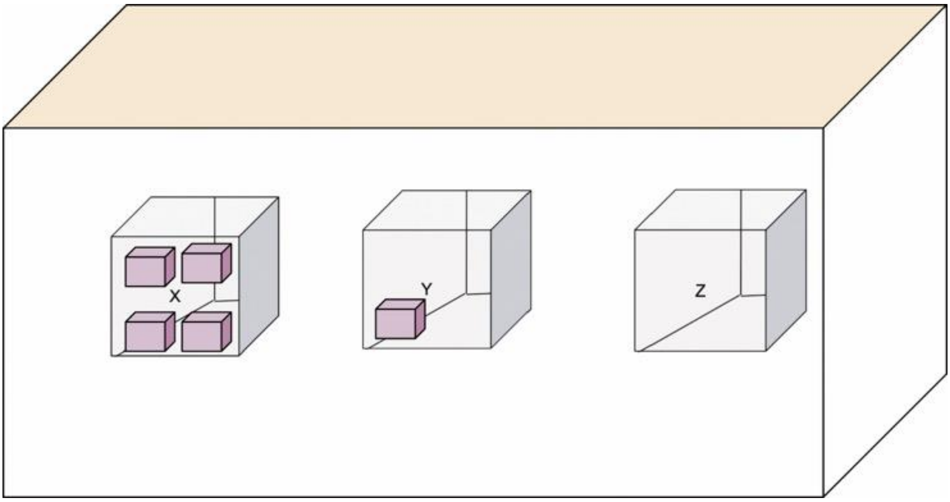

Figure 14 Comparison of different topologies (A, B, C, D) situations: the innovation space topology

An innovation space can be conceptualized as a modal cube consisting of various elements represented by different situational contexts, such as SMEs, projects, or other organizational units. This space functions as a form of a "truth table," providing a structured framework for reasoning about the relationships and interactions within and across these elements. The space and the set of elements within it are modeled using epistemic modal logic, as the set is assumed to contain possible worlds or states of knowledge. This allows for capturing uncertainty, possibility, and necessity within the environment. The focus of the model is on the extensions of knowledge and their semantic representations. It aims to understand how knowledge behaves when it is actively used or applied across different elements in the set—whether in decision-making, problem-solving, or innovation processes.

The space's topology is defined by two main axes:

Vertical axis (ontologies): Representing shared, explicit knowledge structures.

Horizontal axis (dispositions): Representing tendencies, attitudes, or dispositions of actors or systems. Integration occurs, or can only occur, between these different axes, explaining how changes or updates in ontologies (vertical) and dispositions (horizontal) influence one another.

A key challenge in the research is to explain how the integration of knowledge extensions vertically (across ontologies) and horizontally (across dispositions) affects broader categories such as entire ontologies and specific dispositions or specializations. Such integration relies on understanding epistemic advancements, namely, "what is this functionality?" The reasoning about how multiple extensions multiply across different elements helps in reducing the complexity of these multiplications by defining their unique roles within each element. The behavior of knowledge in our model is also influenced by the system's goals, leading to what is essentially a paradox of extensional knowledge: extensional knowledge carries a second qualifier—its extensions in terms of (attributions or descriptions)—which are the set of all possible instances or interpretations. These semantic and conceptual explorations act as multipliers in a semantic sense, necessary for sense-making and understanding. We found that barriers in these semantic representations tend to be weak in the UAS-SME environments we researched, leading to more colloquial or less precise operators. Agents operating in different situations may be tempted to use these semantics in justifications, often oversimplifying the complex nature of knowledge and its functions.

Conversion capabilities of agents in ill-structured or uncoded environments.
Our preliminary research finds tension between the conceptual development of distinct functionalities of knowledge needed to address epistemic constraints that result from uncertainty. This complicates forecasting on necessary requirements in functionalities.

As Nirenburg & Raskin state, "It is not the presumed (inaccurately) non-ambiguity of the one as well-established ambiguity of the other, but rather in the constructed and overtly defined nature of ontological concepts and labels on which no human background can operate unintentionally to introduce ambiguity as opposed to pervasive uncontrolled and uncontrollable ambiguity in natural language." (Nirenburg & Raskin, 2001).

Making designs for functionalities or objects
Modeling concepts and relating them to functionalities requires definitions of goal states and the necessary new capabilities of agents, and a process model for constant conversion between pragmatics and formal codifications for transferring, translating and transforming knowledge in different stages. Using a process model for knowledge management builds on the SECI (model see Figure 15) for conversion from tacit-to-explicit knowledge.

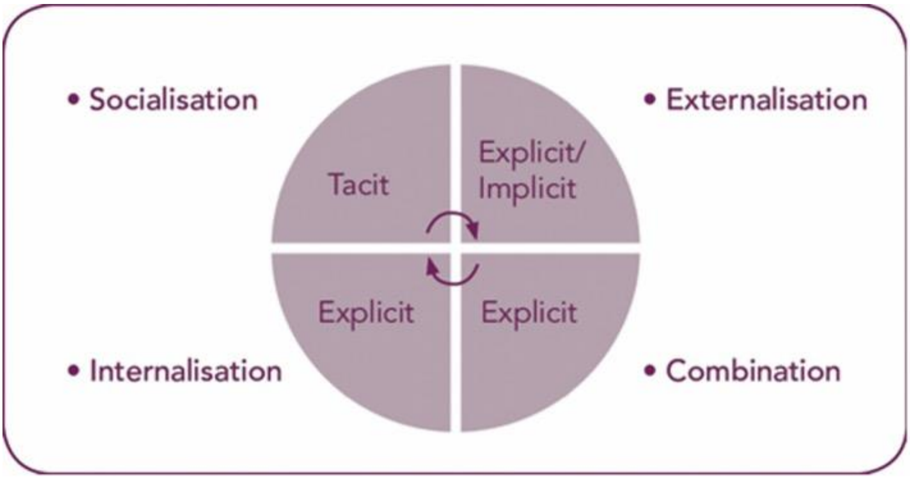

Figure 15. The Socialization, Externalization, Combination and Internalization of knowledge: source Nonaka & Takeuchi 1995

Absorption maturity and object design in different worlds

Describing the characteristics of a goal state and dependencies can allow students to recommend knowledge-management tools or objects to facilitate knowledge integration through absorption processes. The figure below represents various potential knowledge barriers faced by SMEs.

Determination of positions by dimension:	Boundaries spanning directions				Possible Instruments
	R1. Type of boundary need Analysis and Dismantling Syntactic (SY) Semantic (SE) Pragmatic (PR)	R2. Direction and Scope: DBO principles Representation, Transformation, Mobilization Legitimization	R3. Knowledge Absorption Identification (I), Assimilation (A) Valorisation (V)	R4. Functionality Transfer (TF) Translate (TL) Transform (TM)	
C1.1 Organizational Characteristics					
C1.2 Contextual characteristics					
C1.3 Boundary spanning capacities	Low High	R T M L	I A V	TF TL TM	
C1.4 Connectedness					
C1.5 Legitimacy of knowledge					
C1.6 Design driven					

Figure 16 Representation of knowledge boundaries and modification requirements

Based on the initial stages of our research, we developed a simplified Canvas model to systematically represent the results obtained from interviews and surveys. This model was constructed against the backdrop of essential instruments required for knowledge absorption by SMEs and the necessary human-resource management (HRM) tools. This approach facilitates a structured approach and analysis of how SMEs utilized these instruments to enhance their absorptive capacity and operational effectiveness

2.2.4 Conversion as a possibility to constitute foreknowledge

The SECI conversion model (Nonaka & Takeuchi, 1995) is still used to model the process of converting tacit-to-explicit knowledge. Recent studies question how AI can obtain external knowledge for organizations, especially when it comes to integrating tacit knowledge (Cockburn & Sterns, 2019; Furman & Teodoridis, 2019). Extracting relevant information to reduce epistemic uncertainty and engineering functionalities also requires the conversion of ontological or conceptual knowledge to semantics in knowledge domains and translation to pragmatic and natural languages.

Knowledge generation and exploitation in collaboration is influenced by the dynamic conversion capability of actors and agents. This capability requires a dynamic interplay or transfer of different codified modalities of knowledge through interaction (Asheim, 2007). However, as we have seen in Chapter 1,Ttis operational approach, aimed at a higher knowledge conversion, has not yet been successful.

According to the literature, a high level of conversion capability is when actors and agents effectively identify and convert different types of knowledge codifications. This capability increases:

a. When a system has experience with agents that span boundaries, it is understood that capability increases (Haas, 2015);
b. When a system contains codified knowledge (Jashapara, 2004). Also, the production, sharing and absorption of new knowledge is formalized and aimed at storing explicit knowledge (Etzkowitz, et al., 2013);
c. When identification is based on different legitimations of knowledge. Legitimation is the difference between the presence of intensions and extensions in representations of knowledge (Carnap, 1937). This idea of intensions and extension is the basis for semantic externalism (Putnam, 1975) and has been developed into the model of conversion to situations in which the agent uses descriptions of knowledge (Rattan, 2006). We assume that a lack of these descriptions leads to different contextual understandings needed for semantic interoperability (Valente & Marchetti, 2005).

Modification by knowledge management

Knowledge management facilitates the exploitation of new ideas and concepts into explicit knowledge or procedures aimed at collaborative learning, creating a shared understanding of these concepts for a common purpose and action (Roux et al., 2006; Jennings, 2005). It plays a crucial role in supporting and facilitating knowledge, thereby enhancing absorption capacity (Zahra & George, 2002; Connelly & Kelloway, 2001). This perspective emphasizes a dynamic process that actively contributes to organizational learning and innovation. When effective, knowledge management shifts between developing tacit and explicit knowledge to build a systematic, continuous knowledge creation, sharing, and revision. This approach aligns with the concept of absorptive capacity (Cohen & Levinthal,1990), which recognizes the value of applying new external information. Therefore, developing capacity in knowledge absorption through effective knowledge management of both tacit and explicit knowledge is key to sustainable epistemic advancement.

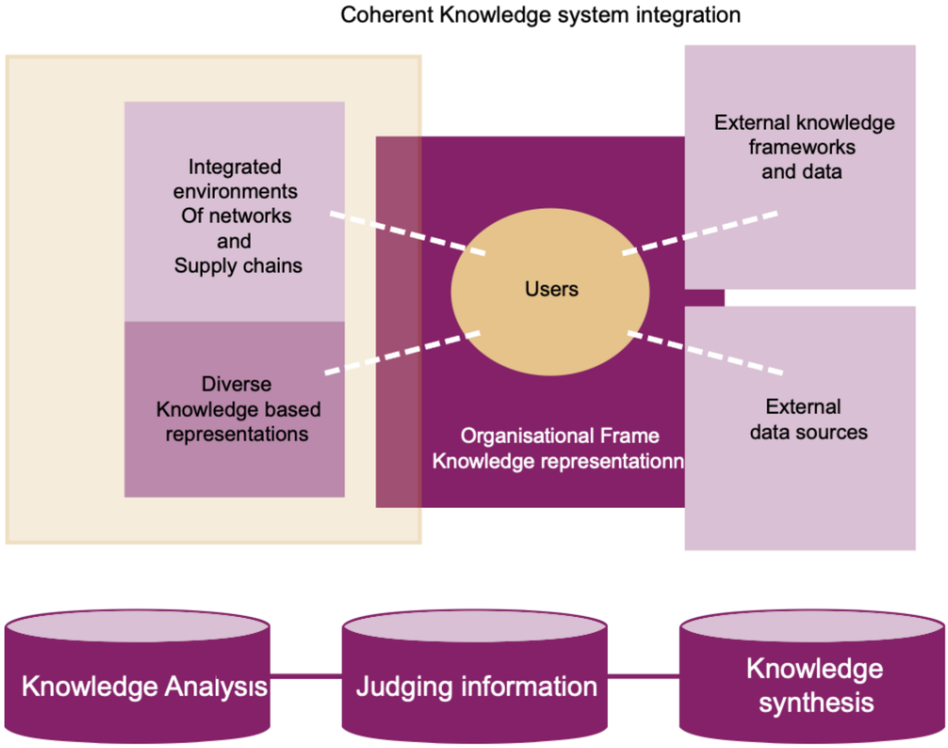

Figure 17 Representation of situational knowledge and multi-agent environments

Using levels of maturity, knowledge management makes it possible to create both conceptual ideas and practical procedures for different situational or individual capabilities such as knowledge synthesis in the individual user environments of smaller SMEs. We can distinguish discrete semantics based on synthesis rather than integration. There are currently no (matrix) interfaces for boundary analysis for smaller SMEs with different levels of absorption sequences — identify, transfer and transform (SMEs) and sense, seize and reconfigure (human agent) — to develop and finally use objects and technological functionalities in different phases of the relationship between UASs and SMEs.

This kind of support mechanism is based on the reflexivity advantage of users' prior knowledge: revisions on exploitation becomes less time-intensive with a tailor-made design of dynamic capabilities (Scheneckenberg, et al., 2015; Haas, 2015; Fallon-Byrne & Harney, 2017). Design-driven situations comprise semantic dimensions based on innovative product ontologies (Battistella, et al., 2012). Furthermore, these design principles facilitate co-creation of knowledge (Dell'Era, et al., 2010).

Here the use of discrete modals is more effective when based on the specifics of the knowledge domain. In order to model this, we developed a conceptual formula[1] as well as quadrants that analyze the different (codified) spaces. Conversion of tacit knowledge captures knowledge on personal levels while conversion of explicit knowledge in ontologies of organizational knowledge creates organizational interoperability.

2.2.5 Sets as epistemic instruments

We use elements of set theory (Kripke, 1963) which inspires us to use dynamic epistemic logic, comparable with different dynamic scenarios. The abstraction enables us to analyze more deeply how different extensions affect the semantics that influence the governing principles of spaces. For instance, we can formulate propositions for diverse SMEs at various levels. When we observe the capabilities of agents, we can differentiate between monotonic and non-monotonic reasoning to understand their behavior in developing experience-based schemas.

Although studies have been conducted on how different agents change their beliefs to make necessary epistemic advancements (Kuhn, et al., 2000), the literature pays little attention to this on the UAS-SME level, in contrast to academic science (Bartolotti, 2020; Battistella, et al., 2012; Bendixen & Rule, 2004; Bendixen, 2016).

We need knowledge-management instruments to develop and design objects in terms of ideas, facts, phenomena and artifacts necessary for the translation to functionalities or capabilities. The management of specific knowledge representation, and the context dynamics and differentiation of capabilities of the agents involved determine the feasibility of identification, transfer and requirements to transform objects in the specific systems (Barney, 1991; Teece, et al., 1997; Bischof dos Santos, et al., 2016; Garcia-Valdecasas, 2015)

[1] An innovation space has epistemic functionality (e)f when the design of the space creates necessary conditions for the conversion and absorption of knowledge to different systems that create access to different worlds: IS = (e)f(CC)*(AC)

2.2.6 Governance choices for sets

Governance concerns power relations in the modes of creating, structuring and coordinating knowledge. This definition concerns the institutional choices (Vadrot, 2011) for levels and types of knowledge (Pearce & Raman, 2014), language and language formats (Williamson & Hogan, 2020)

Education organizes the epistemic system as a learning process, questioning the legitimacy of knowledge in different phases. Organizations are small epistemic social systems that use different sources to justify a variety of procedures, and patterns or interpersonal influences that affect the epistemic outcome, its legitimacy and possible belief revisions (Robertson, 2009). In our literature review, we analyzed governance possibilities in the existing curriculum to develop a model suitable to enhance the capacity to absorb knowledge through experimental spaces.

We assumed that making justified and coherent statements depends on the proven credibility of a specific context, cluster, or set of subject matter experts (in SMEs) involved. This has epistemic functionality. In our study we developed possible aims necessary for distinct governance.

The governance of relationships between UAS and SMEs is essential for effective absorption of knowledge

Knowledge governance primarily focuses on structuring knowledge, dissemination, and integration. Epistemic governance is centered on developing new knowledge, particularly aimed at decision-making for evidence-based technological advancements. Network governance emphasizes the dissemination of tools and can be compared to policy transfer governance. Finally, social epistemology governance focuses on social systems and could be relevant for formulating communities in our research.

What	Type of governing
Organization of dissemination (Dolowitz & Marsh, 2000)	Administrative
New modes of representation (Goldman, 2011)	Social construction
Design of social systems for promoting knowledge (Alasuutari & Quadir, 2016)	Construction of epistemes based on norms
Transformations of epistemic governance (Normand, 2016)	Actions and relations to shape knowledge
Paradigmatic structures of knowledge production (Carayannis & Campbell, 2021)	Governing of these structures
Goals of subsystems in education (Safavi & Håkanson, 2018)	Knowledge governance

Table 1. Governance of UAS-SME relations

Epistemic Innovation Policy and the analysis

Based on knowledge-in-use and Mode 3 approach to higher education (Carayannis & Campbell, 2021), we studied the paradigmatic structure of the context: a higher education institution or system explores ways of integrating principles of knowledge production and knowledge application, not only promoting diversity and heterogeneity, but also creating creative and innovative organizational contexts for research, teaching and innovation. Therefore, Mode 1, Mode 2, and Mode 3 qualify as examples of "knowledge paradigms" in higher education. We also include ideas on the currently emerging Mode 4.

Space requirements and topology

The epistemic space should have predictability in output in terms of relations between the sets of epistemic contexts, agents and objects involved, the semantics of functionalities and the consequences in terms of present and future knowledge, and human resources management.

At first this is a conceptualization since we know that an outcome requires constant evaluation of the sets (which is also a purpose), but it can be expanded by using more probabilistic predictions based on statistics.

Table 2 shows epistemic governance for applied knowledge in innovation spaces using the concept of modal consciousness, based on a comparative analysis of challenge-based learning experiences; adapted from Malmqvist, Kohn Radberg, & Lundqvist, 2015.

	Actual		**Target Aim**
A: Traditional	B: Problem-based	C: Challenge-based	D: Advanced professional space
Engineering Science	Engineering	Engineering & Business	Engineering knowledge
R&D context	Product context	Social Context	Human capital in relation to technology
Analysis	Designing	Problem formulating & designing	Problem stated with support of governance and relevant stakeholders
Individual	Integrative	Team & individual	Multidisciplinary teams
Objective	Team	Value-driven	Epistemic-change driven
	Customer needs		

Present	**Weak**	**Not present**	**Distinct**

Table 2. Epistemic governance of applied knowledge

2.2.7 Inferences of coherent sets

The study was conducted against the backdrop of the emerging technologies of Industry 4.0, where we observe a significant increase in information dissemination, an integration also leading to epistemic uncertainty.

Epistemic uncertainty, we argue, leads to a misalignment between semantic, pragmatic and colloquial representations of information. Semantic representations enable us to convert information into what we call an epistemic functionality: a distinct (semantic) and discrete (linguistic) representation of knowledge that allows agents in a particular context or system to communicate with other systems.

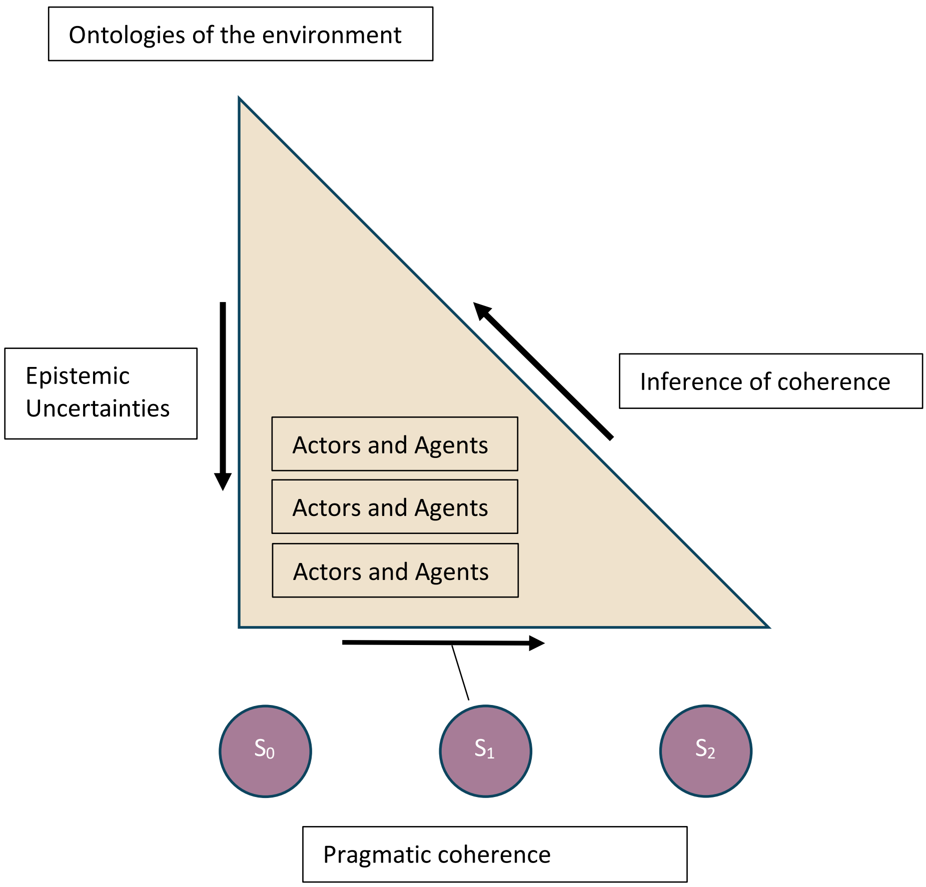

Figure 18 Representation of an epistemic space

Given the highly differentiated characteristics of SMEs and their potential capacity to absorb knowledge, specific modifications are required to enable human agents to continuously connect new information to their specific pragmatic knowledge without contradiction or ambiguity in semantic representation. We call these primarily technological epistemic functionalities responding to the uncertainties of Industry 4.0

Due to the highly fragmented nature of the absorption of knowledge, there are no distinct archetypical SMEs. This hinders the development and codification of uniform objects, thus necessitating modeling based on SME typology and or taxonomies.

The new role of the student as a kind of observer using different inquiry instruments provides an insufficiently nuanced and indistinct picture of knowledge systems. As a result, UASs have adopted a participatory approach, based on iterations that demand a different role than in the research fields of Industry 4.0. Again, given the highly differentiated characteristics of SMEs and their potential for absorbing knowledge, distinct modifications to that knowledge are required to enable human agents to adapt their routines. Inferences on these modifications require non- contradictory disambiguation in semantic representations.

Due to the complexity of knowledge absorption processes, the lack of distinct SMEs as a priori models makes developing and codifying the uniformity of objects as epistemic stances difficult to assess. Also, different modifications, in the form of different objects developed and tested by UASs, must be stored and used in the knowledge repositories of both UASs and SMEs, enabling them to further develop codified knowledge of the integration process in their own systems.

Inference of coherent pragmatic contexts

By gaining experience in diverse contexts and learning in experimental spaces (epistemic or modal spaces), we can share knowledge about the absorption of knowledge. This concept aligns with recent discussions in pragmatics and epistemology, particularly on the role of context in drawing inferences about knowledge acquisition. By focusing on the interplay between context, belief systems, and the absorption of knowledge, this approach provides a framework for understanding how knowledge is acquired and shared in complex, collaborative environments. These mechanisms challenge the topology of the space. It requires epistemic governance to direct them to constitute an epistemic functionality of that space.

Coherent reasoning
An epistemic space requires sets of SMEs in terms of the situations in which agents face uncertainty. We aimed to study which objects contribute to convert concepts of possible future states to new dynamic functionalities for the agents involved.

Modal logic helps students to analyze the knowledge-based system, the agents and their capabilities. It can be used to analyze the effect of the distribution of knowledge in the organization in various modalities:

- Epistemic modality to describe agents' beliefs and capabilities and discern potential gaps in their knowledge;
- Deontic modality to inform students about the ethical questions agents face;
- Alethic modality to reason on the dynamic capabilities needed to meet contingencies, necessities and possibilities. This also enables reasoning on various strategies that may help the organization improve flexibility;
- Temporal modality to analyze how time constraints affect development of learning to integrate new routines, especially when collaboration with other SMEs occurs, such as in networks.

Modally structured reasoning
In short, by using these modalities to make formal project statements, such as a proposition for the particular context, the UAS actor defines distinct goals for the experiments. In general, the use of modal logic contributes to structuring knowledge that may be necessary in certain situations but is affected by what the agents already know. Understanding, in terms of reasoning on knowledge, can be crucial for adoption and effectiveness.

Epistemic governance aims to develop distinct spaces to address different uncertainties on different levels. It is concerned with explicating reasoning on knowledge, reflective learning as a result of knowledge creation, and its potential application to realize epistemic advancement. In that sense, these preconceptions may allow students to learn how to make claims in their inquiries based on normative frameworks (Lorenzen, 1987).

Learning on the epistemic states
Epistemic uncertainty is a lack of knowledge that can be brought back to the agents' epistemic state and the specific phenomena (Hüllemeier & Waegeman, 2021). Learning in experimental environments takes place in terms of reasoning on epistemic uncertainty in the (series of) situations or contexts involved. Understanding take place by making mental representations of the situation, based on the composition of semantics. In other words, if an agent draws one specific inference for instances of that kind, it can draw any specific inferences for that kind (Chang, 2019).

Therefore, to conceptualize coherent reasoning in students, we apply a modal logic in various situations (S) as a way of finding a response strategy (R) to integrate the new semantic codes that enable agents to respond with new dynamic capabilities. We argue that this understanding helps to construct the weak or ill-structured routines, situations, and events—what we conceptually term habituals, based on the habitus of Bourdieu (Bourdieu, 1996). Habituals are characteristic actions that have gained more attention (Anon., 2024)

Designing objects to meet that uncertainty, context and or situation are ways of creating scenarios that serve as possibilities. Deep possibilities represent things that might be prior to what one knows, and strict possibilities are related to what agents know (Chalmers, 2011). Knowing what agents are capable of can explain what is preferable or plausible, but may be difficult to realize (see Appendix: Dimensions of possibilities).

Engineering semantics in knowledge engineering
Different systems use different logic to express functionalities in knowledge-production modes and corresponding knowledge legitimation. Not understanding these differences hinders the absorption of knowledge, exchange and consequently epistemic advancement. Different epistemic systems require varying levels of distinct information, such as conceptualizations, regarding the functionality to be utilized and the knowledge to be applied. For example, data that provide information can differ in terms of their semantics. The differences between A and B express the differences in logic and corresponding truth functions in different states, with different beliefs and different stages of learners and or agents.

Using modal consciousness enables an understanding of contrasting knowledge claims and consequently the constitution of knowledge functionalities. Especially high contrast in knowledge modes affects distinct functionalities. This affects engineering of knowledge in, for example, skill descriptions, curricula and or knowledge bases.

2.2.8 The conscious agent integrates functionalities of knowledge

The absorption of new critical knowledge is increasingly influenced by the ability of human agents to continuously reduce the epistemic uncertainty surrounding potential new knowledge. This involves both identifying relevant external information and translating and articulating this information into existing routines.

A conscious agent is distinct from the experienced agent and professional agent. An experienced agent is guided within a knowledge system, while a professional agent is capable of converting implicit knowledge and sharing it with other agents (Hoorn, 2021). A conscious agent is aware of the importance of epistemic progress and can consciously and independently decide on the potential effect of adding value to functionality. This agent becomes increasingly able to influence the environment by incorporating external information in its routines, habituals, events and situations. The system operates independently within the boundaries of a knowledge system.

The concept of modal consciousness enables us to analyze how UASs students can help increase the absorption capacity of specific clusters of SMEs and the barriers in various local contexts or situations. This lets us model the integration of knowledge and introduce different levels of agents, objects, and knowledge systems. Using epistemological models can serve as epistemic tools (Boon, 2019). Small SMEs especially benefit from this. Functionality is thus aligned with the capability and capacity of agents and the knowledge system.

Experienced agent	**Professional agent**	**Aware/conscious agent**
Guided by the development of experience	Operates independently within the boundaries of a knowledge system	Integrates knowledge from external sources with existing functionalities of knowledge
	Monotonic: no revision of functionalities	Non-monotonic attitude: revises beliefs
Unaware of future states	Relies on necessities in future states	Aware of contingent future states
Habitual Routine Situation Event		

Table 3. Distinctions between types of agents

By modeling these systems, we can analyze which factors, such as beliefs and the way a future state and its effect are presented, influence rejection or refusal of beliefs. Economic risks or epistemic effects, for example, can play a role by modifying necessary new routines of agents (Zhixiong & Yuanjian, 2010; Klassen, et al., 2023). Important for the absorption of new knowledge is the development of a type of auto epistemic logic where an agent can reason on the absence of knowledge (Boghossian, 2006) as a primitive constituent (Hoffman, 2008; Bartolotti, 2020).

Constituents of habituals for distinct knowledge

SME (future) agents face an increasing demand to decide on the legitimacy and authority of external information and the effect of integrating it with existing functionalities and processes (Jonassen, 1997; Sansone, 2016; Bendixen, 2016). Informal language or personal colloquialisms have a greater degree of intensional logic in that they add personal information and experience or the lack thereof (Carnap, 1937; Chalmers, 2011; Gärdenfors, 2017).

Especially distinct smaller routines (habituals) can play a significant role in smaller SMEs, as they are difficult to translate to formal semantic representations that can be scaled up. Recently, more attention has been paid to researching habitual actions or events for which there are insufficient distinct modalities and translations (Anon., 2024). This means that new information, which is often conceptual, also lacks examples that can be added (Maton, 2020)

Based on our preliminary research, we have distinguished differences between the boundaries and barriers that influence the absorption of knowledge. Our findings show that SMEs with knowledge barriers are more inclined to shield knowledge, which also requires cultural changes. Knowledge boundaries primarily aim to prevent conceptual separation, which can influence how knowledge is identified and distributed within an organization.

Experiments and space topology

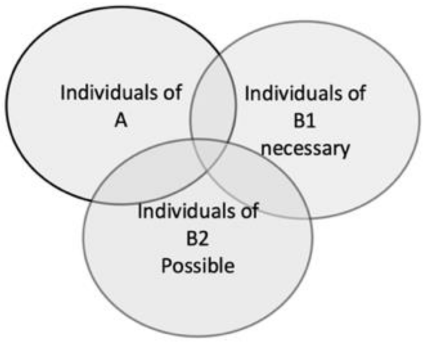

Figure 19 Experimental space

Successfully influencing specific local knowledge systems through UASs requires making coherent selections based on governance support to enhance the (epistemic) status of models of local SMEs. Using the challenge-based learning model (Malmqvist, et al., 2015), we can study governance of key mechanisms in innovation space. We focus on knowledge that is constantly evolving requirements to optimize operations (Dula, et al., 2024).

Distinct experiments

Successful and effective absorption of external information by SMEs and their agents requires the ability to manage uncertainty about that information and the associated risks. This is why this chapter analyzes how the necessary dynamic capability (Mazzacuto, 2018) and capacity of SMEs can be influenced by applied research between UASs and SMEs, enabling future agents to continuously integrate and use emerging technologies. Our preliminary research shows that developing coherent reasoning can influence this ability. Key mechanisms for experiments include applying epistemic modal logic to analyze and model compatibility and capacity.

Functionalities in constantly changing worlds

Conscious agents are capable of integrating new critical knowledge, which enhances their individual and collective response in their practices. Integrating knowledge requires agents to have the necessary capability to constantly explicate the revisions that successfully add value in their pragmatic context. This study aims to model the UAS and SMEs agents' adaptation processes, individual systems and epistemic functionalities that enable collaborative (modal) reasoning on these requirements.

This involves reasoning on the concepts of revisionary objects needed for future states, the necessary translations and modifications for knowledge exchange on the agents' supporting system to maintain goal states in relation to environmental dynamics.

Similar epistemic contexts provide the opportunity to understand the complexity of changing epistemic practices and objects (Knorr Cetina, 2001). By developing the properties of sets of contexts, based on sets of epistemic systems, we differentiate levels in learning spaces based on the maturity of the agents and systems involved. By repeating and combining these aspects we aim to define coherence in the development of prior knowledge that can be updated and revised by agents and or systems. This is a type of two-dimensional semantics: combining the pragmatics and intensions of all possible worlds (Chalmers, 2010; Chalmers, 2011).

Conceptualizing pragmatic coherence

Knowledge integration in experimental environments (innovation spaces between UASs and SMEs) is effective when necessary epistemic advancement is realized using objects (e.g., scenarios, processes, products) that are semantically codified so that the various agents involve can identify the objects and grant access to the necessary networked environments.

These objects are considered epistemically functional if they help agents identify and integrate information into their existing capabilities, which is essential for reducing uncertainty in technology-related problem-solving areas. These objects act as learning mechanisms for translating explicit discrete linguistic representations (expressions, codes, signs) of revisions to skills or knowledge. These mechanisms can be systematically organized in the SMEs and UASs knowledge bases. They provide information on the epistemic functions that give access to other semantic worlds. We call this the absorption capacity between UASs and SMEs.

On a more substantive level it means that the UAS organizes activities or experiments to develop dynamic capabilities (Mazzacuto, 2017) that enable students and agents to collaborate on modeling the absorption capacity of clusters of SMEs. This involves innovation spaces that have epistemic functionality when the topology of the space creates world conditions that collect knowledge on the capabilities of agent and students in different environments. Access is affected by levels of modal consciousness for coherent reasoning on necessary capabilities. We express these reasons in necessary codes exchange between these systems.

Our study aims to develop models of spaces in which SMEs and UASs collaborate to overcome gaps in the dynamic capabilities of human agents resulting from new technologies. We aim to develop knowledge on the functionality gaps through meta-knowledge, contributing to a broader understanding of the absorption of knowledge and the revision processes and mechanisms by which SMEs agents collaborate. When considered as manageable contextual learning environments, innovation spaces address epistemic doubt and uncertainty.

However, there is no topological design for these spaces to govern, constrain and address these questions. Such a design involves non-linear learning with possible different stages and or tiers for the agents and students involved. Analyzing various types of potential spaces can yield a taxonomy that clarifies the knowledge functionalities of agents engaged in meta-reasoning about their necessary knowledge requirements and personalized modifications.

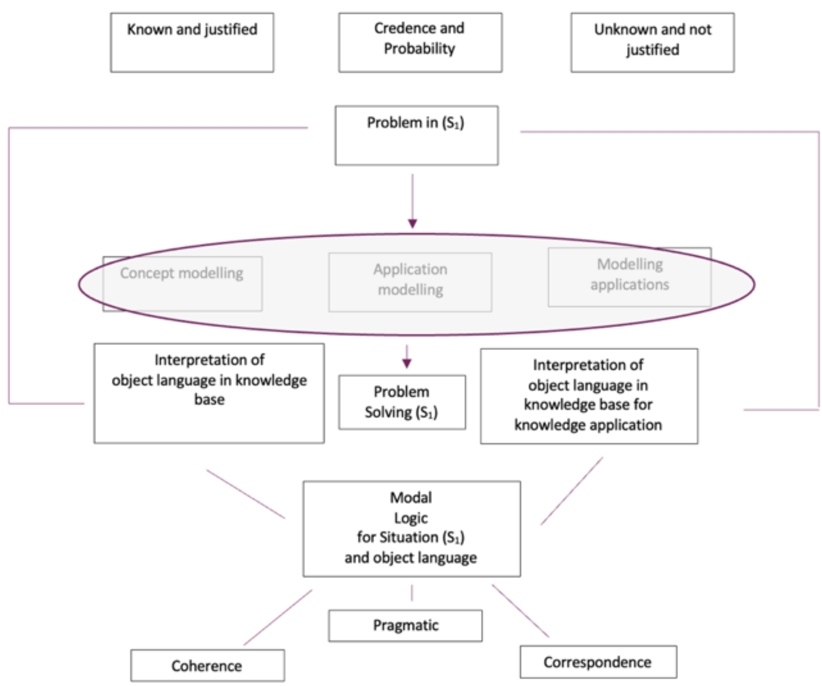

Figure 20 Representation of horizontal and vertical absorption of knowledge

Learning that the evidence is incoherent can be evidentially relevant, based on the information theory (Poston, 2022). We conceptualize coherent reasoning between different situations (S) as a way of finding a response strategy (R). Agents must reason about revisions to existing functionalities or objects proposed in designs.

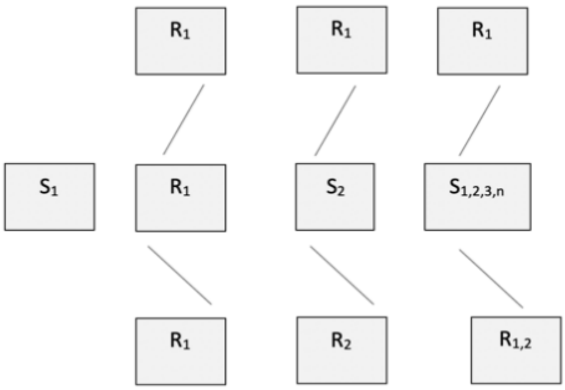

Figure 21 Arrays of Situations and Responses

Coherent reasoning is closely related to logical reasoning that affects beliefs when these beliefs cohere with a wider range system of beliefs. It relates coherentism to referentiality and comes in contrast to self-reference. Based on Poston, (Poston, 2022) we assume that a wider range of incoherencies in events also requires techniques or an attitude toward the evidence presented. This sub-study shows that refining the effect of beliefs of agents in the field may contribute to the possible necessary changes. It requires reflection on one's own inquiry approaches.

2.2.9 Summary of critical gaps in the literature and research perspective

Human agents are crucial intermediaries for the absorption of knowledge. However, these agents are ineffective in knowledge transfer since they rely on the same resources that create structural holes in information transfer (Burt, 2004; Kalish & Robbins, 2008; Soda, 2009). The participation of key actors and agents to span institutional boundaries may be affected by ambiguous roles (Jacoby, 2001; Hislop, 2005) and different routines for acquiring, sharing, or exploring new knowledge (Chu, 2014). Boundary spanners are individuals who link the institution to its environment (Brown & Duguid, 1998; Haas, 2015). The roles and skills of boundary spanners can create convergence in ideas and concepts, or functions through the use of objects. There has been ample research in terms of roles in in general, such as connectors, librarians, framers, judges, prototypes, metric monitor, story tellers, scouts (Fichter & Beucker, 2012; Tidd & Bessant, 2013).

Boundary roles are researched in relation to information identification acquisition and transfer (Meerkerk & Edelenbos, 2014; Kleijn, 2012; Fallon-Byrne & Harney, 2017) it is not clear how reformulating and recombining related information affects epistemic beliefs. Boundary objects can effectively influence the transfer and absorption of new knowledge (Roux, et al., 2006; Zahra & George, 2002; Szulanski, 2000). Boundary objects are physical objects, processes or practices, or texts that can be used in multiple knowledge systems or social worlds (Star, 1989; Carlile, 2002). There is little literature on boundary objects as epistemic stances. Agents learn from experimenting, which gives the opportunity to share new meanings and values (Hakkarainen, 2009) and also link communities through collaborating on common tasks (Star, 2010; Carlile, 2002; Fox, 2011) because of their iterative potential (Abraham, et al., 2015; Engeström, 2001; Lee, et al., 2014). However, for these objects little is known about the time and risks involved for SMEs. While a syntactic knowledge boundary can be uncovered by differences in the transfer of information, a semantic knowledge boundary affects conceptual and ontological descriptions. A difference in new capability reveals a pragmatic boundary (Fox, 2011; Rosenkranz, et al., 2014; Pöyry-Lassila, et al., 2013).

Our study found gaps in how habituals, routines, situations and events affect the necessary, possible and contingent goal states to determine new functionalities of knowledge. The uncertainty of a clear goal state requires reasoning through experimenting and simulations to create knowledge on the varying dispositions of organizing habituals, routines, situations and events that conscious agents create.

As a result, future technological and semantical representations of functions are speculative. We assume that if a function is not distinct, it is not a function. Yet if it is distinct, it is so only in its consequences or effectiveness. This creates risks for SMEs when it comes to the absorption of new dispositions into their processes.

Absorption capacity and increase organizational maturity and the modal space
Lately there has been much discussion on using logic in applied epistemology (Battersby & Bailin, 2018). Understanding possible worlds can help to provide answers to how to adjust knowledge objects (such as datasets or policies) to increase absorption maturity. Based on the previous we explore how temporary ambiguity of knowledge in a present epistemic state requires adaptation of objects to represent a future present state.

In modal semantics this would mean[2] the possibility that a knowledge is possible in a given situation based on a contingent argument. Therefore, we studied how specific designs of objects can act as speculative realism to reason on semantics, using constant evaluation.

This requires highly conceptualized semantics that we can use in our SMEs model and that can act to develop prior knowledge in terms of its potential to translate to different pragmatics for the SMEs involved. Innovation policies utilize this approach to define strategies for dynamic capabilities (Aas & Breunig, 2024) and relates to research on the speculative design of objects (Dunne & Raby, 2013).

2.2.10 Presumptions and consequences for the methodology

Following our preliminary research, we defined the direction of our analysis. We presumed that integrating necessary knowledge to define its functionalities aimed at reducing uncertainty is affected by the ability of human agents and their consciousness of the constitution and construction of knowledge.

When consciousness is absent in agents, the constitution and development of functional revisions of knowledge affect the dynamic range of functionalities in the time and space required to address continuous uncertainty in the face of emerging technologies.

Beyond recognition
We place our research in the context of emerging technologies to which human agents react. We use the dynamic epistemology framework to explain how reasoning based on modal logic helps to constitute the additional necessary functionalities of knowledge. We argue that this constitution is a capability to add, complete or revise existing functionalities that are no longer necessary. The first condition (a) is that

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[2] $\Diamond P \land \Diamond \neg P$ followed by $\Diamond P \land \Diamond \neg P$, or $\Diamond(\Diamond P \land \Diamond \neg P) \land \Diamond \neg(\Diamond P \land \Diamond \neg P)$

agents in SMEs are willing and can potentially have access to external sources. The second condition (b) is that they have the capability to constitute beyond personal beliefs.

We assume that the tension between (a) and (b) are affected by different logical readings of agents, such as time (temporality) and space (contexts) in which the ability and willingness of agents take place. Using our conceptual framework, we studied how these conditions create tensions in the identification of knowledge needs and consequently epistemic transfer and transformation costs. In other words what could agents gain from these learning experiences?

Based on our findings, we argue that fulfillment of these conditions affects the constitution of the functionality of knowledge. We argue that the framework of epistemic modal semantics and possible world semantics can contribute to the distinction of functions of representation and functionality in different worlds. Since knowledge in possible world semantics is independent of contextualities and capabilities this requires adaptations in the design of objects to constitute functionalities in different contexts. Therefore, we developed several sets in which agents gain access under epistemic governance. The sets are differentiated in terms of agents' capabilities, epistemic states and domains.

2.3 Conclusions: agent-learners' consciousness of capabilities

Increasing information affects the epistemic certainty of that information. To effectively transform this information into knowledge that can be used in different contexts requires methods that can combine that information and its epistemic functionality in specific contexts. Developing differentiated SMEs models that act as epistemic tools and instantiations supports agents in continuously adapting to necessary new information in present and future routines. The mechanism of coherent learning by individual agents relates to multi-agent knowledge systems and environments. Absorption of knowledge is affected by uncertainty of new information and consequently its transformation to functionalities of knowledge. Reducing uncertainty to mitigate risk comes with economic and epistemic costs for SMEs. Revisions and maintenance of new functionalities and routines can improve responses to the constant changes that attempt to add value. In order for SMEs to use earlier developed knowledge (a priori) by UASs requires strong, that is justified, knowledge that can be transferred and used but most of all maintained in terms of revisions by agents.

This requires complex designs based on inferences of successful coherent designs in practice as well as additional theories on the capabilities, agents and SMEs involved.

Our theoretical framework shows that epistemic models of SMEs can serve as an instrument to provide insight into various barriers that disable the necessary absorption of knowledge by SMEs and its agents. By experimenting with different models, such as scenarios or simulations, and different objects for the various models, we can monitor gradations in complexity and feasibility of the design. A conscious agent is the highest level (tier) at which an agent reasons and explicates the revisions of capabilities for a design. Students include revisions and the way agents share the explications in their design.

Abstracting the characteristics of SMEs' epistemic model representations of present and goal states, and the associated discrete functionalities to bridge these states, is a function of an innovation space.

Identifiability

By researching successful designs of capabilities, relevant agents and environments, we aim to define distinctly identifiable and justified social ontologies. Such ontologies can be further developed and transformed to the requirements of agents and communities of practice of UASs and their domains and disciplines. This enables reasoning on the effects of new paradigms and conceptualizes the related representations of knowledge.

Adaptive knowledge-management principles

Currently, there is a significant focus on developing modalities that center on habits. This type of routine-temporality can explain an important boundary for reflexive reasoning of agents and students in their short-term, iterative relationships. This temporality also exerts significant pressure on the development and sustainability of epistemic objects during various conversions between different languages, especially since students often are less experienced than SMEs agents.

Being an observer/participant can be complex when reasoning about one's own role and knowledge and the effect of objects and agents. Reasoning with a formal language can resolve the effects of colloquialisms as semantic barriers. This inquiry addresses the necessary elements to facilitate the transition of students from objective observers to participatory researchers in diverse knowledge systems. The shift in the role of human agents from the object to subject of research in SMEs impacts the analysis of the current state of affairs and potential future epistemological states. This transformation has implications for managing various levels of learning, both for the students and human agents involved.

The concept of modal consciousness emphasizes the awareness of different absorption capabilities resulting from agents and their knowledge system. The shift toward participatory research aligns with the interpretivist paradigm in qualitative research, which emphasizes understanding and interpreting different subjective perspectives from specific contexts. This approach stands in stark contrast to the positivist paradigm commonly associated with quantitative research, which presupposes an objective reality subject to independent study. The changing role of human agents reflects a move toward a social constructionist epistemology, which posits that reality is actively shaped by individuals rather than existing independently. We show that this perspective acknowledges multiple realities and dimensions and emphasizes the importance of understanding different contexts. Managing these different levels of learning in this new paradigm requires a recognition of the complex interplay between individual perspectives, social interactions, and the existing knowledge base.

This epistemological shift has profound implications for both research methodology and the development of professional knowledge. It requires researchers and students to cultivate a heightened awareness of their own epistemological assumptions and how these shape their approach to knowledge creation and interpretation.

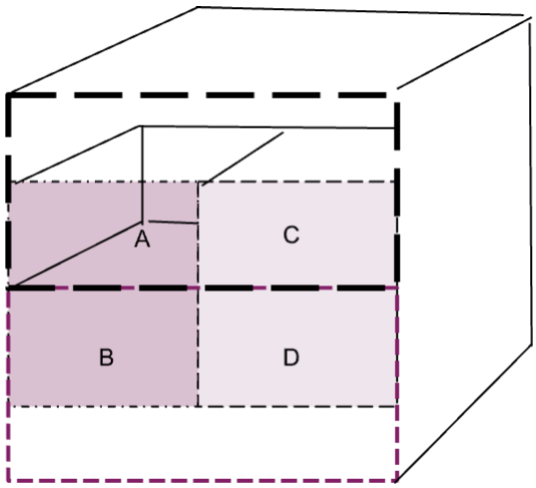


Figure 22 Distinct worlds

Governance over these experiments and the design of an innovation space require epistemic governance aimed at new paradigmatic structures and their effects on the development of applied knowledge. The space explores ways to reduce ambiguity and uncertainty, thereby improving the identification of information as well as access to the authorities of that information. Governance also concerns proliferation between and within communities and knowledge domains. Existing curricula can use cases from practice, thereby also improving the relationships between technology and applications in existing education. This approach not only contributes to the theoretical understanding of the absorption of knowledge in SMEs but also offers practical implications for policymakers and practitioners in fostering innovation ecosystems. Learning through experimenting with objects of applied science can generate valuable epistemic insights necessary for knowledge integration and synthesis among various actors. These experimental processes often reveal unexpected complexities and nuances, challenging existing assumptions and fostering a deeper understanding of absorption processes. Innovation spaces facilitate this type of learning by providing environments with non-linear knowledge-production modes. These modes are characterized by their direct connection to knowledge application, breaking away from traditional linear models of knowledge creation and dissemination.

2.3.1 The conceptual framework

Our theoretical framework shows that the absorption of knowledge between UASs and SMEs requires an epistemological approach. Uncertainty of an epistemic nature influences the absorption of knowledge.

We need models of the phenomena to gather information on how UASs and SMEs share their interest in developing functional knowledge for capabilities. Using modal logic as a framework enables experimenting with different functionalities. The epistemic space is a learning space to collect information on the needs of knowledge, characteristics of ill-structured knowledge environments and the design of an application of objects. It aims to reduce differences in epistemic and metaphysical dimensions by analyzing the effect of beliefs of students and agents and their integrations capabilities.

This research aims to model:

- Knowledge of dynamic environments in present and future knowledge representations in terms of goals or strategies based on environmental dynamics.
- Conditions to create modal awareness and consciousness among students and agents in the field. This concerns moving back and forth between epistemics and pragmatics based on agents' experiences, routines and capabilities.
- Designs of objects that enable adaptation, revision or the extension of the capabilities of agents and students in terms of describing necessary representations of knowledge, and strategies or actions.
- The capability of students and agents to reason on barriers blocking access to information systems.
- Conditions that support and facilitate moves between epistemological and practical dimensions (Chalmers, 2011).

Conditions

The semantic engineering of functionalities requires goals (epistemic governance) in terms of levels of students and agents and their relations. These are governing principles and statements that affect the terms and conditions of the knowledge exchange process and feasibility of revisions to the dynamic capabilities of students and agents on different levels. This concerns analyses of how (novice) learners are able to distinguish between different types of environments. It also relates to the domain knowledge of learners and the way it can be transferred to another context with different agents and beliefs.

Absence of strong knowledge codifications or other types of knowledge descriptions affect the complexity of the problem-solving environment. Absence of codification requires other knowledge modifications and complicate determining the structure of knowledge in a specific context, situation or event.

High differentiation in pragmatic environments in reality and research

SME-Production Mode (1-4) and Quadrant position (A-D)	**Knowledge Modification**		**Epistemic Representation and responsiveness to uncertainty**		**UAS-SME Integration of knowledge absorption in industry 4.0 and beyond**
	Engineering Science	R&D context	Analysis	Agent(s)	Knowledge absorption process Access - Identification - transfer and transformation systemic (integration and/or assimilation; individual)
Mode 1 (B)	Traditional in terms of craftmanship, incremental innovation, discipline specific	Aims to improve standardization in disciplines within the context of the organization low volatility and **low epistemic uncertainty**	Based on responses by individual in tasks analyzed through effective and efficient output. Subjective reflective	Requires supervised learning based on task, where exploration creates uncertainty rather than reduces it Low responsive-ness	SMEs: Boundary spanning, **informal** rather than formal style of research with application focused research UAS: curriculum driven. Learning to be aware of context in relation to knowledge domain. Activity style based on innocence student and less epistemic doubts

SME-Production Mode (1-4) and Quadrant position (A-D)	**Knowledge Modification**		**Epistemic Representation and responsiveness to uncertainty**		**UAS-SME Integration of knowledge absorption in industry 4.0 and beyond**
	Engineering Science	R&D context	Analysis	Agent(s)	Knowledge absorption process Access- Identification – transfer and transformation systemic (integration and/or assimilation; individual)
Mode 1-2 (C-D)	Knowledge takes place in the context of its application through quality control	Participation in communities of practice is limited	Problem formulation affected by output and customer relations: **systematic reflective basic**	Agents use knowledge base that relates to different disciplines and domains	SMEs: more networked both formal and informal can contribute to knowledge boundaries as a result of embedded knowledge practices and social norms creating semantic closure or structural holes. UASs require shifts to problem and challenge-based approaches in research and advancing in modality awareness
Mode 2-3 (D-B-C)	Co-specialization with/from mutual learning and adaptation	Networks, communities of practice	Supportive Knowledge management (Tier 2-3) Knowledge diversity as goal	Experimentin g in real time High responsive-ness	Under epistemic uncertain this requires shifts and steps in knowledge absorption directed at skills, interfaces for knowledge exchange, data labs and adaptive reconstructions of future states. Uncertainty can be reduced by combination of epistemic and aleatoric modal for probabilistic representation (what if) in relation to practices in SME

SME-Production Mode (1-4) and Quadrant position (A-D)	**Knowledge Modification**		**Epistemic Representation and responsiveness to uncertainty**		**UAS-SME Integration of knowledge absorption in industry 4.0 and beyond**
	Engineering Science	R&D context	Analysis	Agent(s)	Knowledge absorption process Access- Identification – transfer and transformation systemic (integration and or assimilation (individual)
Mode 3-4 (A-C)	High integration of different knowledge forms and domains	Diverse knowledge eco systems. Specifically, outside existing knowledge boundaries. Acceptance of high epistemic uncertainty	Non-linear and adaptive Paradigms shifts and system revisions Diversity of Modals	Conscious Agency development. Contingent scenarios use.	Collaboration is based on contingency knowledge management base and - interface between partner relations in which students and employees act together

Table 4: Analysis of UAS-SME relations. This table is a representation of knowledge absorption under epistemic uncertainty based on different production modes and drives for exploration and consequently different topologies of spaces.

2.3.2 Implications for research design

Consequently, our analysis of UAS-SME relations entails critical conditions for continuous absorption of knowledge and directs the topology of innovation spaces for knowledge sharing on absorption instruments and the necessary dynamic capabilities.

The aim of this study is to explore how UASs can contribute to enhancing the absorptive capacity of SMEs with regard to the continuous acquisition of critical knowledge. SMEs are of significant economic and societal importance, given their substantial contributions to employment, innovation, and regional development. UASs supporting the strengthening of SMEs' absorptive capacity facilitates knowledge transfer between education and professional practice and contributes to the structural integration of new insights into business operations. Effective relationship and practice-oriented research makes UASs intermediaries in enhancing the innovation potential in the SME sector.

The first objective of this study is to analyze how, and with which underlying motives, various forms of interaction and relationships between UASs and SMEs are developed and structured. Identifying and addressing epistemic uncertainty presents a particular challenge, as such uncertainty manifests in multiple gradations and often remains implicit. This necessitates the collection of specific, context-dependent data and the generation of practice-oriented insights, thereby enabling a more accurate assessment of which strategies are effective in evaluating the impact of new technologies on practical knowledge. It is also crucial to examine the adaptive capacity of various knowledge structures in different SMEs, and their human agents, in order to understand the extent to which they are able to respond effectively to these changes. Based on the aforementioned arguments, our first research question is:

How can UASs and SMEs co-develop the absorption of knowledge strategies to enhance their mutual capacity for identifying, transferring, and applying knowledge under epistemic uncertainty?

The second objective is to model different types of SMEs, representing specific groups, based on diverse student levels and their corresponding knowledge domains. Here we examine the extent to which students can identify knowledge needs of enterprises, and their awareness of the various factors influencing the absorption of knowledge.

Particular attention is paid to students' attitudes to the continual augmentation of their knowledge and their willingness to adapt existing beliefs. We identify the capacity to adjust to new insights and actively integrate relevant knowledge as crucial prerequisites for effective absorption of knowledge in the dynamic context of SMEs.

Furthermore, this study explores the various dualisms in knowledge dimensions between UASs and SMEs, with particular attention for the diverse gradations of tacit knowledge as opposed to formal, explicit knowledge expressions. The analysis focuses on how these variations in knowledge forms influence the processes of identification, transfer, and transformation of knowledge within UASs. Specifically, the study examines the extent to which a high degree of tacit knowledge affects the willingness and capacity of SMEs and their agents to absorb new knowledge, and to what degree this requires additional efforts in knowledge conversion by students and lecturers.

Here, human capital agendas and instruments play a crucial role in shaping the interaction between new technologies and the existing capacity to develop dynamic capabilities for the absorption of knowledge. The extent of this capacity can be operationalized through the configuration and maturity level of HRM and knowledge-management systems in organizations, as well as the degree to which students, through their attitudes and competencies, can positively influence these dynamic capabilities.

In this study, we focus on organizations that are confronted by environmental changes resulting from the introduction of new technologies. We analyze various forms of collaboration, including public-private sector (PPS) partnerships, Living labs, Field labs, and inter-institutional alliances between UASs working on joint research and innovation projects. Finally, we integrate the research findings with the aim of distinguishing between different types of SMEs based on their absorptive capacity, thereby providing more nuanced insights into how these enterprises approach the absorption of knowledge in diverse contexts of collaboration and innovation.

These theoretical perspectives on epistemic functionality, knowledge modalities, and absorptive dynamics form the conceptual foundation for the empirical study. In the next section, we explain how these ideas informed our research design, case selection, and analytical strategy. This study investigates how UASs can enhance the absorptive capacity of SMEs for sustained acquisition of critical knowledge. The research takes a multidimensional approach by:

- Examining the structuring and motives of diverse forms of UAS-SME interaction;
- Modeling types of SMEs based on student profiles and knowledge domains, with a focus on students' ability to identify knowledge needs and factors influencing the absorption of knowledge;
- Analyzing dualisms in UAS knowledge dimensions, particularly the interplay between tacit and explicit knowledge on the processes of knowledge identification, transfer, and transformation;

- Assessing the moderating role of HRM and knowledge-management system maturity, as well as student attitudes and competencies, in shaping dynamic absorptive capacities;
- Exploring various collaborative forms (e.g., PPS partnerships, Living labs, Field labs, and inter-university projects);
- Integrating findings to differentiate SME types according to their absorptive capacity.

The study explores the critical role of UASs as knowledge intermediaries in the innovation ecosystem, particularly through practice-oriented research and the facilitation of sustainable SME collaboration. It aims to demonstrates that variations in SME context, collaborative format, and internal capabilities such as systems and human capital significantly shape the absorption of knowledge processes. Furthermore, the study explores how student engagement, attitudes and skills can serve as catalysts for organizational learning and adaptation, especially in dynamic technological environments. Operationalizing absorptive capacity through HRM and knowledge-management maturity aims to explore inter-organizational differences for collaborative interventions through enhanced SME the absorption of knowledge.

CHAPTER 3

Research Design

Chapter 3. Research Design

This chapter on the mixed-methods research design is laid out in the following sections:

3.1 Introduction

The previous chapters showed how emergent technologies cause epistemic uncertainty and affect the optimal use of such technologies due to SMEs' limited absorption capacities.

Our framework suggests that identification, transfer and transformation processes are affected by differences in the epistemic uncertainties of organizations and human agents. Especially epistemic uncertainty requires future representations of knowledge in terms of dynamic capabilities that are often conceptual rather than pragmatic. This type of inquiry requires an awareness of the effect of modal logic to determine how the absorption of knowledge behaves under epistemic uncertainty. Dispositions of various processes also need inquiry to explore the capabilities of human agents to learn from the logic that consequently determines the type of responses to these processes.

The first aim is to study how our framework holds in reality. Most important is to explore how to model the different environments, epistemic tools and agents involved that can act as learning spaces for the exchange of information and for sharing strategies and practices in the absorption of knowledge.
A conscious agent is capable of taking steps (epistemic stances) with different methods or objects to assimilate new information in knowledge systems (Patton, 2019). This requires learning to reason on these environments in order to develop effective change-strategies for the absorption capacity of SMEs and human agents. This reasoning involves understanding various consequences of the choices made in epistemic and practical dimensions.

Our research design includes the following aspects:

a. we distinguish environments with a certain degree of epistemic doubt that contribute to the capability of learners to develop epistemic tools, objects or methods (Bendixen, 2016);
b. learning environments can be governed on several levels to make distinctions in learners' capabilities (Bartolotti, 2020) in relation to what is necessary and possible in different environments. For example, how do these different epistemic concepts relate to teaching, learning, and other associated philosophical concepts such as morality and even economics at RUAS business school? Little is known about the integration of epistemological concepts in the curriculum (Carter & Kotzee, 2015; Watson, 2016);
c. we identify effective knowledge modification and engineering tools for different environments;

d. models provide information (data) on continuous instantiations in SMEs regarding the agents, properties of objects and characteristics of environments, so that we can draw inferences on coherent practices;
e. based on these models we constantly revise future knowledge representations, in terms of strategies based on possible and plausible foreknowledge creation and constitution. These models can act as new schemas in levels of learning for human agents. These agents being capable of learning through these models is aimed at integrating new information in multi-agent environments.

The empirical focus is to research how UASs create and govern the conditions necessary to facilitate experimental collaborative moves by students and human agents between different theoretical, epistemological, and practical environments. We aim to reduce uncertainty and develop tools for agents that affect their (potential) capacity to absorb knowledge.

Research aim and strategy

Research aim	Exploratory
Research approach	Abductive: define plausible explanations
Research questions	How can UASs and SMEs co-develop the absorption of knowledge strategies to enhance their mutual capacity for identifying, transferring, and applying knowledge under epistemic uncertainty? 1. How can UASs and SMEs share knowledge about tools and instruments for continual advancements in dynamic capabilities under epistemic uncertainty? 2. What differences among SMEs affect the dynamics of the absorption of knowledge and how does this in turn affect the ability of UASs and SMEs to develop strategies together? 3. What is the effect of pragmatic and semantic boundaries of co-development and knowledge exchange processes between UASs and SMEs? 4. What design of an innovation environment or innovation space contributes to effective and efficient mutual absorption of knowledge by UASs and SMEs?
Objectives	Modeling support mechanism for dynamic absorption of knowledge Dissemination effective human-resource and knowledge-management strategies based on epistemic governance models
Research strategy	MMR sequences
Data samples	Quantitative and qualitative data collection, merging data and theories in each sequence to build on the epistemic model SMEs, Field labs, Living lab, PPSs, Consortium, CEOs/owners, (HR) managers, lecturers, experts, employees and students
Research Instrument(s)	Semi-structured interviews, Focus groups, Surveys, Secondary Data

Table 5. Research aim

Our goal is to model different spaces to effect, model and understand absorption capacity processes under epistemic uncertainties between the different UASs and SMEs systems. We conceptualize four types of modal spaces for different levels of uncertainty, absorption capabilities and levels of collaborative inquiry among students and SMEs agents.

We further aim to distinguish the potential for absorption capacity that prepares SMEs for identification, transfer, transformation and ultimately the maintenance of knowledge under constant epistemic uncertainty. This distinguishes numerous types of governance goals. In addition, we explore these spaces to better understand what instruments can be developed under epistemic uncertainty to enhance the epistemic capabilities of agents and students in terms of knowledge modification and engineering.

3.2 Research design

We used a mixed-methods research design (Tashakkori & Teddlie, 1998; Creswell, et al., 2003; Harrison, 2013) with multiple phases integrating both quantitative and qualitative data to provide a comprehensive understanding of the phenomena that affect the absorption of knowledge.

In our understanding this paradigm is suitable for the type of problem we study. It is a type of post-positivism that allows the researcher to both interact and observe. MMR also allows us to include more elements of the constructivist paradigm, based on the idea that students interact with the real world and that affects the way they adapt or modify knowledge. Observing interactions in the field also has consequences for the choice of MMR and we took care to be aware of how this affected the research. UAS students are novice learners compared to SME agents. Especially when students try to influence their real world, the designs they construct for applications of knowledge depend on the interactions in a certain real-world environment. Our MMR is sequential and exploratory rather than explanatory. It is positioned as a contrast rather than in opposition to an objectivistic paradigm, since it involves elements that depend on whether the research design helps researchers find what they want to know (Feilzer, 2010).

MMR allows us to use both quantitative (descriptive analysis) and qualitative data to create a more complete picture of events and situations (Brewer & Hunter, 2006). Based on our framework the explanatory element tries to find if an SME of a certain size and age, and distinct routines finds it harder to respond to technological changes than, for example, a SME of the same size but with other knowledge distributions. If this is so, it explains the SME's vulnerability and urgency to develop more ways to identify future capabilities of human agents. These are part of the new learning paradigms for both SMEs and UASs.

Parallel MMR over a longer period of time enables us to triangulate data, compare findings, and identify areas of convergence or divergence between the quantitative and qualitative results.

Research questions, constructs, measures and design logic

Based on our theoretical framework we formulated design properties for an innovation space that enables co-development of absorption strategies according to the development of objects by students on different maturity levels:

1. Knowledge sharing and integration in an innovation space is effective and efficient when necessary epistemic advancement is realized and justified knowledge is transferred and transformed based on awareness of epistemic modalities
2. An innovation space has epistemic functionality **(e)f** when its design creates the necessary supporting conditions for converting tacit to formal knowledge languages that are absorbed and integrated in different systems: **IS = (e)f(CC)*(AC)**
3. An innovation space addresses contrasting knowledge claims that require modal cognition. It is a representation of actual experience that can be used to apply knowledge
4. Inferences can be made on the use of effective functions of objects students use in SMEs. Therefore, we need to research the properties of objects that enable effective epistemic stances in that space.

We conceptualize an innovation space with effective epistemic functionality, when its design is epistemically governed on different levels and contexts for knowledge integration using objects with distinct semantics that create access in different worlds.

Consequently: how can we find certain sets of knowledge representations that are accessible to UASs at different levels of learners and agents and that can be extended over the range of comparable representations in a set?

3.3 Case selection

Case selection is based on the themes found in use at Rotterdam UAS (RUAS; circular economy, digitalization, social economy). Different spaces were selected in such a way to enable comparison. This concerns the criterium of incommensurability. If the epistemic systems differ too much the outcomes are unreliable (Scherer & Steinmann, 1999). So, all cases reflect the idea of RUAS taking part in challenges that relate to transitions. In theory, agents in these spaces are confronted with knowledge boundaries due to lacking various levels of prior knowledge. The different environmental properties, goals and statements influence their behavior in terms of epistemic capability.

Human capital

The choice of case is based on the need for developing long-term programs to meet the future, government-determined challenges which play important roles for UASs and SMEs (European Commission, 2019).

We also want to study the impact of involvement with other parties that are influential in developing vocational education and the human capital agendas related to programs in top sectors (agri & food, chemistry, creative industry, energy, life sciences & health, high-tech systems & materials, water & maritime industry, horticulture & starting materials and logistics)

The choices for paradigmatic structures and analysis are based on:

a. New organizational manifestations (lab environments), including cases that are not strongly related to particular SMEs since collaboration in interdisciplinary projects often involves students. Also, we need information on how to organize these simulations based on real -world environments.
b. The relation of higher education to trans sectoral organizations (e.g., TNO, Top sector, Municipalities, TKI Dinalog, etc.)
c. Research diffusion in society in relation to governance and education on modal and epistemic cognition.
d. Non-linearity of knowledge production, meaning that it takes place at the moment rather than produce first and then apply (Design lab).

Participation and data collection

According to policy documents and the gray literature, complex environments face disruptive changes without having the needed knowledge on hand. In short: we need spaces that evoke epistemic doubt for students, where they learn to reason on knowledge acquisition and explication. This requires purposive sampling to select environments that meet the specific criteria (Yin, 2003).

The cases are selected in such a way that the results of dissimilar cases not only contribute to the theoretical build up but can also be generalized, in contrast to more homogenous cases. In all cases, the advantage was that the research goal was compliant with the methodology: most SMEs differ in demographics and knowledge-production modes.

This means that each case covers a part of the problem so that outcomes and information can be related (Thomas, 2011). Data collection and analysis are described for each case in relation to the specific theoretical proposition of this phase.

To safeguard extern validity, the description of contextual factors is important (Yin, 2003) We also include cases that fail because of disengagement. These cases are categorized and used to enhance the theoretical concept of engagement (Abassi, et al., 2015).

According to Kuhn, "[S]tructures, practices, and worlds [are] what preserve the breadth of scientific knowledge; intense practice at the horizons of individual worlds is what increases its depth" (Kuhn & Weinstock, 2000). One objective is to describe the epistemic modal logic for applied knowledge in innovation spaces and develop metrics for the properties of objects rather than for the objects themselves (engineering). When successful, this is part of a conceptual claim. Pragmatic coherence can be described as based on the epistemic context or situation. Using the characteristics of the sets involved we can indicate progression of coherence between different sets. Inferences are measurements of progressiveness. This is what Chang calls "coherence between measurements inferences across measurements contexts" (Chang, 2019).

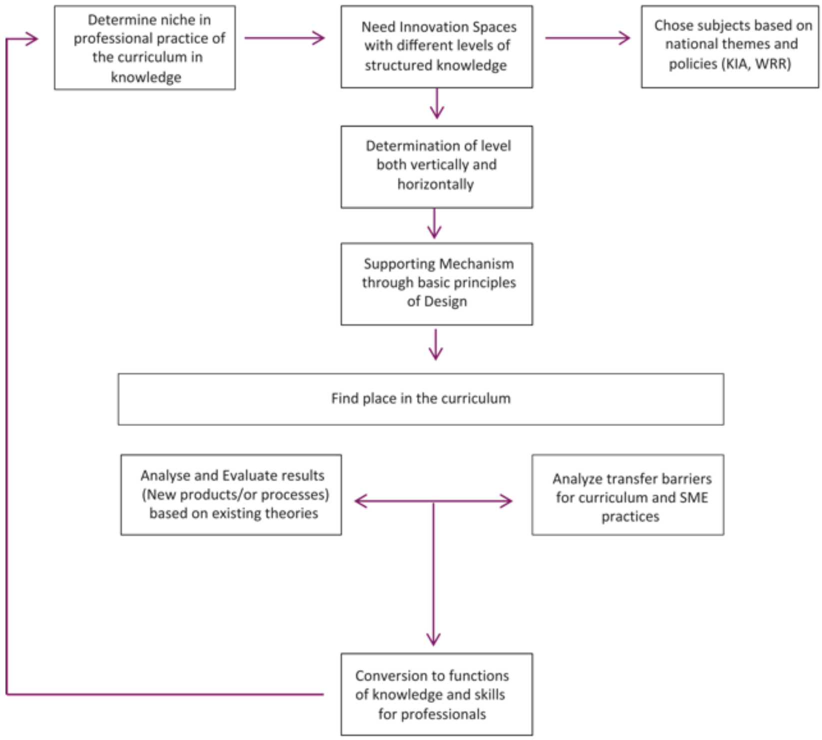


Figure 23 Decision steps to determine cases

3.3.1 Epistemological paradigm, mixed research methods, data collection

We used an epistemological paradigm for two reasons. First, a paradigm can generally tell something about the study, the researcher's ideas and consequently their approach. Our epistemological paradigm studies how students know what agents know and need to know. Secondly, we want to analyze how this students' knowledge affects the constitution of knowledge by human agents and the system involved. To address this problem, the research and design tasks for UASs students take place in a limited time frame of interaction with SMEs.

The study also requires a pragmatic design approach for two reasons. First, a quantitative approach does not (fully) explain epistemic uncertainty. Also, the study analyses what capacities and knowledge are needed in highly differentiated environments. Secondly, our aim is to understand which mechanisms in general contribute in these pragmatic contexts to the absorption of knowledge, also considering current research on pragmatisms.

Pragmatism is “the philosophical position that what works in particular situations is what is important and justifies or ‘valid’” (Johnson & Christensen, 2014) Here the attention outcome of the research and the significance of the research question are important. This also relates to the complex position of novice learners. Therefore, we conceptualized these situations as epistemic instruments that enable students to learn to make inferences of coherent pragmatic practices or schemas. We conceptualize this as consciousness based on schemata, described as arrays. As a result, the MMR design involves a mix of qualitative and quantitative methods in different sequences, since most projects take place at fixed moments in the curricula. By collecting data concurrently over a number of sequences and combining and merging these data, we build on explanations from multiple cases in different phases to develop a more complete understanding of the research problems rather than limiting the research to either qualitative or quantitative methods (Creswell & Plano Clark, 2007; Creswell, et al., 2003). In each phase we use the data to finish our epistemic model.

Overview of data collection stages		
Project duration	**5+years**	**5 stages, 7 phases**
Stages	5	Theoretical approaches, research stages for sub-studies, and analysis stages to conceptualize a UAS -SMES innovation space
Phases	7	Some stages consisted of multiple phases due to the MMR design and the semester planning at UASs. These conflicting schedules arise because academic calendars at UASs are typically organized into semesters or teaching blocks that do not always align neatly with the research design timeline.
Total projects	13+1 extended Case Study	N= 59 (12/19/18/10) 2 projects of 15 failed due to unforeseen circumstances (covid restrictions)
SMEs (99)	Data from: A: (17), A2: (9), B: Sharing (9) C: (17), C2B: (9),D: (12)D2: (8) D3: (18) D2 (survey n264) was used to map and compare differences between SMEs in potential AC	
Interviews	33	Interviews with representatives of selected SMEs, lecturers and students in various phases of the project.
Interview analysis	64	Reviewed by researcher: researching the ability of students to make conversions tacit- explicit and explicit - pragmatic based on developed concepts and suggested interventions.

Overview of data collection stages		
Project duration	**5+years**	**5 stages, 7 phases**
Surveys	4	Several types of surveys were held in different phases. Evaluation (e.g., Sobek/ used to assess students' perceptions) exploration in preparation of focus groups, diagnostic, descriptive. A 5-point Likert scale was used in descriptive and diagnostic surveys.
Experiments	2	a) Design lab experimented on prototyping and using propositions in their environments. b) Parsing used to compare principled mechanisms in conversion and knowledge distribution
AI use	1	In sharing case we first labeled the different codes from interviews in 17 SMES all on subject of innovation by HRM students (open codes). We used Atlas.ti code manager to compare codes with SME characteristics. The codes were categorized by density (abstractions) and gravity pragmatic significance to gain insights from textual data.
Expert meetings	2	
Focus groups /organizations	3	
Focus groups	9	Students. N=31
		Open, unstructured and non-participatory observations took place, as well as participatory in the Design case. This is a way of evaluating the capability of agents (to take stances against epistemic elements).
Design lab (5)		
Inspiration sessions	10	Preliminary stage, over a period of 6 months with a set of SMES (17) in preparation of solution labs
Other: webinars/ conferences	Webinars (3), seminars (3) and international conferences (4)	
Papers	5	
Consortium/PPP participations	2	
SMEs actively involved		Leadership (4) Learning culture (18) HRM B (19) MRDH (12; Sharing (15*)

Table 6. Overview of data collection stages

Merging data requires variables measured in parallel in order to complement different data to a reliable conclusion (Cohen, et al., 2018). We choose a design that is explanatory and sequential to find both a reliable, more extensive interpretation of cases (Yin, 2003). This means that each case covers a part of the problem (Thomas, 2011). MMR designs are also used when the aim is to understand transformative change or when the researcher has a relationship with the community and needs to retain objectivity to avoid potential bias (Romm, 2015).

3.3.2 Sequential design and its stages

This study uses various methods on different types of data to enable us to gain both an in-depth understanding of the processes involved, and to make more valid inferences about possible interventions based on an epistemic model for different sets of SMEs than can be done with only a single method (Tashakkori & Teddlie, 1998). This helps to explain complex problems (Poth & Munce, 2020). After each phase, triangulation takes place with new literature research.

Differences in contextualized and decontextualized environments offer opportunities to assess the engineering of solutions in differentiated environments. These are monitored as potential key elements of possible spaces for knowledge exchange so we can develop protocols for governing on the context-levels and challenges involved. Different epistemic goals of actors involved may shed light on their attitudes and capabilities to integrate new functionalities (Brew, et al., 2018). The joint cases are part of an ethnographic approach to define a set for governing innovation spaces between UASs and SMEs to enhance absorption capacity. By developing methods and tools UASs can actively influence the capacity to absorb knowledge according to potential capabilities and capacities.

The MMR in time:

Sequence	Timeline builds to a conclusion supporting various data collection methods	Data analysis and synthesis
Assumptions	Evaluated for every stage	Reflect on analysis and synthetize assumptions
Questions	Direct the study to maintain goals as abductions may affect direction of research	Answer sub-questions to answer the main research question
Framework	Explores rather than explains or validates measurements to answer the question	Fill in the gaps in literature and main theoretical framework
Stage	Quantitative & qualitative approaches monitored for desired evaluation tools	Cross-case analysis: weigh the projects in terms of relevance
MMR	Abductive using inductive and deductive approaches that relate to epistemic uncertainties and knowledge integration theories. Aims to develop consciousness of distinct uncertainties	Reflect on the methodology and steps taken
Cons	Time and organization pressure of collection, analysis and integration of data in sequential phases. Explore new paradigm on knowledge creation requires this approach to learn from it	Conclusions based on the results
Generalizations	Inference of coherent practices can be used to do probabilistic research on characteristics key to SMEs and what dynamic capabilities are required to respond to technological changes	Relevance of the work and future research

Table 7. The MMR sequence

3.3.3 Exploratory character in sequential design

Each stage explores a key element of the research question on the absorption of knowledge. We use qualitative and quantitative data to find patterns that can lead to further exploration and ultimately help to make predictions on the types of SMEs, agents and students involved. Our conceptual framework and the elements that affect the absorption of knowledge in our UAS-SME case are applied in the following ways:

The opening stages analyze possible frameworks to approach the absorption of knowledge by both SMEs and UAS in relation to regional changes. We also look closely at the Triple Helix configuration— since RUAS aims to develop this model separately from communities of practice— and its different effects on UAS-SME relations.

We study how we can distinguish between different SME systems in relation to their knowledge needs and new capability requirements for absorption capacity. We aim to find patterns or interpersonal influences of students, lecturers and SMEs that affect the legitimacy of outcomes (Goldman, 2011). We also study how to develop coherence in organizational-knowledge practices, knowledge representations and strategies to respond to technological changes that can be placed under paradigm shifts that are other than more common needs for knowledge. In other words, a disruption of routines. We aim to understand on an explanatory level the mechanisms both SMEs and UASs employ in different ways to create strategies, scenarios as well as other methods to gain access to objects or capabilities that help to solve the gaps in their existing knowledge base.

This has been a long-term project with various stages. Although we had to plan and go back and forth to collect data, we kept a diary in each stage to focus on separate elements of the study. In stage I we narrowed the scientific claim, its objective and the hypotheses. We first explore governing principles based on environmental dynamics. In stage II we focus on systems to capture epistemic taxonomies that explain different responses to uncertainty. In stage III we look at agents' conversion capabilities. For example, we focus on the capability of agents and novice learners and their domain knowledge. In stage IV we analyze the effect of differing environments and relations on our modal space to explain integration of new information.

Stage V is concerned with a cross-case analysis of the stages to determine the epistemic functionality of the environments against the background of our framework of a modal space. On an epistemological dimension this explains both the effects and practical translations for dynamic capabilities that are either necessary, (im)possible or contingent. This epistemic functionality can further develop statements for research, agents, systems, and objects that lead to changes in the absorption of knowledge between UASs and SMEs.

3.4 General limitations of MMR

The pros and cons of MMR are well documented in the literature. As expected, data merging requires enormous planning and consideration. Because of the time it took, as well as the calendar planning of the UASs' curriculum, we not only had to plan data merging between phases, but also triangulation and data collection preparation for the following phases. Also, we took on extra cases to collect data since our findings had to exclude chance factors.

Methodological considerations

The limitations of our theoretical framework include a possibly normative scope or findings resulting from value-based methods (Davison, et al., 2006). This relates to the fact that knowledge absorption is a theoretical construct with many different layers.

Another possible limitation may be observational bias. To avoid these limitations, we interviewed experts on epistemology, knowledge-management and innovation spaces. The choice of expert may also be in contrast to serendipitous findings or intuition-driven research. The researcher as a stranger cannot be truly involved. This can create objectivity but as a result may lack deeper understanding (Simmel, 1950). The methodology also relates to our goals. The first is to research concepts and methods for learning and development in general, and specifically those that support students in vocational institutes. We are inspired by the trialogical approach (Tiwari, 2015) to learning through interactions. Based on Lundberg's framework (Lundberg, 2013) we conceptualize the environment as a supporting mechanism for learning new ideas, as well as an embedded space where epistemic changes are strongly affected by the type of environment and practices. The individual student acquires knowledge through participation in practices based on the developments of shared objects (Leydesdorff & Ivanova, 2016). This approach is strongly related to ideas labs for development and ideation (Bergvall-Kåreborn, et al., 2015).

Researching the feasibility of these spaces may require conditions on the effect of change in institutes and organizations based on a path decency that may cause countereffects, such as inertia or resistance to great changes suggested in different policies (Kuipers, et al., 2018). It also relates to research methods into the differences in agents and students, more traditional approaches to learning, and the socioeconomical effect of regional change dynamics on labor in general but specifically in personal lives.

Working with an experimental solution lab involved enormous administrative preparation that revealed differences in the styles of organizing physical spaces, conceptual ideas, and instruction material for experimental phases (Gijsbertse, et al., 2020). In addition, our findings reveal that surveys often lead to differing interpretations among respondents or had a low response rate. Interviews indicated that concepts like "innovation readiness" or "ownership of work" are often interpreted differently.

A dispersed pattern also appeared in the results of larger surveys with fewer questions, as well as with questionnaires dealing with small themes. This made it hard to use questionnaires to demonstrate the differences between larger and smaller companies on content-related topics. Sometimes employees need to work less often on computers or do not have a fixed workspace. Therefore, questionnaires were used to visualize path dependency and changing routines, relationships with educational institutions, and experiences with projects (boundary spanning) in SMEs.

Another aim of the questionnaires is to provide support as they give quick insight into the maturity level of HRM and/or knowledge management. Because they also provide comparative information on environments when creating sets, we can also study to what extent students use data from a questionnaire to support design characteristics.

But above all, the aim of the study is to find out which research methods can contribute to a deep understanding of how of human agents in specific knowledge contexts can be better enabled to access other worlds and networks. Finally, a more refined insight into contexts and epistemic barriers must be developed from the different taxonomies of SME sets in order to be able to use both predictive and explanatory analyses.

3.5 Data collection

The RUAS curriculum describes students as changemaker who are being prepared for complex contexts, learning to work in spaces together with industry partners to develop new knowledge (Bormans Commission, 2023). We selected spaces in which RUAS collaborates with students, lecturers and research centers. Since all spaces were meant for this purpose, but had different governance and themes, we chose to study the projects RUAS actively selected from their program. UAS research centers are advised to collaborate more with SMEs to promote innovation and increase absorption capacity. Dealing with complex problems in types of collaboration can help to prepare students for increasingly fluid professions (WRR, 2013; ATW, 2014; Rathenau Instituut, 2016; ATWI, 2018).

SME participation

The aim is to indicate as precisely as possible how different characteristics can be brought together to make the findings generalizable. This requires repetition of occurrences or characteristics in comparable settings. SMEs often have limited time and resources available to participate in research. To determine what epistemic uncertainty entails and which instruments were available for this purpose, few examples matched what we were looking for in specific environments. In that case, the focus is more on understanding phenomena than on validating findings (Johnson & Duberley, 2000). This involves developing theories about the contribution of epistemic models and tools for modifying knowledge at a practical level (where no prior knowledge exists).

Regional environments

Regional and local influences and disruptions exert a significant impact on innovation, opportunities, and the requisite dynamic capabilities associated with these processes (Bogers, et al., 2012; MRDH, 2022). Therefore, we specifically looked for companies that already operate or are expected to participate in these networks or ecologies. Given the region, transport, trade and logistics in a broad sense, play an important role.

Data collection is based on the theoretical framework of epistemic modal logic that facilitates modal reasoning in dynamic multi-agent environments. We collected data on how epistemic boundaries between UASs and SMEs affect the absorption of knowledge processes between the two entities. Overcoming these barriers requires students or agents to move consciously between epistemic and contextual dimensions of knowledge.

3.5.1 Data collection stages

A preliminary field study researches configurations of spaces in theory and in practice. It unveils the critical needs of different types of SMEs and semantic communities (Gearheard & Shirley, 2007).Therefore, the aim of our field study is to explore which phases, agreements and expectations of different actors and agents affect collaboration and integration of knowledge.

The first type of space builds on an experimental solution space, which in turn is based on an innovation-seeking paradigm to make risk assessments (Posthuma, et al., 2019). Our analyses show when such a space is a suitable and under what conditions. SMEs tend to add value and mitigate risks in operations, meaning that a solution space requires a strong solution focused framework that builds on the evidence found in risk mitigation.

3.5.2 Time-intensive data collection

The data collection method is influenced by the research design. First, the exploratory nature provides many insights that bring the causes of the absorption of knowledge into increasingly sharper focus. Each phase of the design requires evaluation which we wrote up in articles published in professional journals. However, this form of research is time-intensive, due to fieldwork and continuous evaluation and change between data collection methods. Indeed, fieldwork observations require a lot of time, but simultaneously bring about many logical explanations and supporting information.

Besides that, given the linear programming in education, tight schedules, and curriculum requirements, it also takes much time to find companies and/or assignments for subsequent phases that are logically connected to the outcome of a previous phase. One choice in this regard is, for example, conducting focus groups so that both groups of students and companies can be compared with each other, and we can address the effect of group dynamics and the method of conducting research.

Analytical spaces and learning capacities

Learning from innovation in conceptual spaces can be analyzed from diverse perspectives, such as stakeholders' experiences in collaborative learning processes including dialogue alignment, consensus building, interactive ideation, iterative co-development, and commercialization (Cantu, et al., 2015). Learning outcomes can be assessed by the acceptance of new concepts or the degree of knowledge internalization, as well as the perceived benefits by agents (Schauer, 2014; Connelly & Kelloway, 2001; Dedehayir & Seppänen, 2015). Our study focuses on the properties of situational spaces that optimize effective and efficient learning to support situational reasoning under epistemic uncertainty. Also, it explores the epistemic objects or artifacts as epistemic stances to show how differences can support transitions between knowledge states. We conceptualize the topology of these spaces in terms of self-reference and transitivity, focusing on boundary conditions that influence solution designs.

3.5.3 Ethnomethodological vs. ethnographical approaches

Applied science, often contrasted with theoretical science, builds context-dependent knowledge. By characterizing problem situations, we aim to develop taxonomies that underpin methods to understand modalities in innovation spaces. This study adopts ethnomethodology (Maynard & Clayman, 1991) to analyze organizational practices, complemented by ethnographical methods to capture cultural and behavioral variations among agents and students in specific problem settings. This dual approach facilitates distinctions across ontological, contextual, and situational levels. Detailed observation of events, environments, actors, and stakeholders permits a nuanced epistemological inquiry, enabling the construction of conceptual taxonomies that map agent experiences across diverse epistemic environments.

Research scope

Our empirical analysis contrasts various project types—ranging from Triple Helix constructs, solution labs, and PPS collaborations to Consortium projects, Living labs, and Field labs—alongside traditional minor programs at Rotterdam UAS (RUAS). We examine differences in governance, outcomes, effects, and collaborative learning dynamics across these cases.

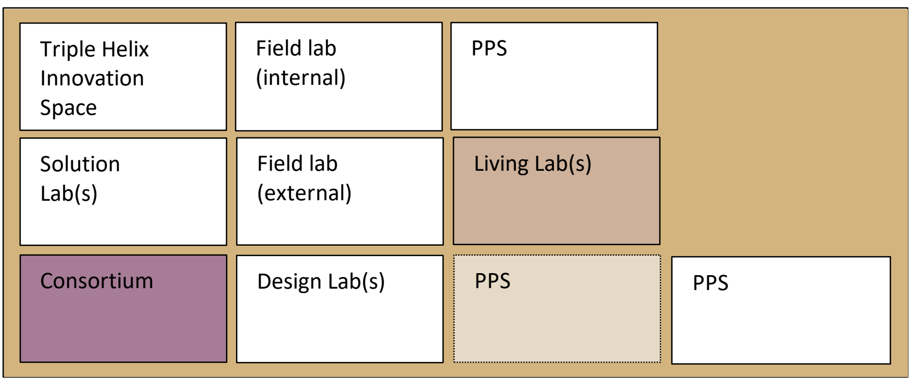


Figure 24 The different cases as epistemic spaces in the research

The cases involve the following themes: Food factory, Future Regional Labor and Unemployment, the Volatility of SMEs, Sharing knowledge experiment, The sustainable workforce, Living lab airport skills, Living Lab energy, Public-Private Partnership in skills developments, Public-Private Partnership in developing a learning community, Sharing logistics/human resources, Social care+, leadership, learning culture.

Explicit distinctions between UAS-SME collaborations and research universities-large firm partnerships are essential for contextualizing this study's focus on applied, practice-oriented knowledge dynamics. UAS-SME systems emphasize rapid, student-mediated diffusion tailored to resource-constrained firms, unlike the theory-driven, long-term R&D pipelines in research university-large firm models. Highlighting these differences sharpens theoretical precision, validates case selection, and enhances generalizability for similar applied settings.

The effect of different methods

Living labs and Field labs lie in between real-world experimentation and co-creation. Both have a very high potential in knowledge creation through combining phases for iteratively integrating explicit knowledge in practical contexts, testing ideas with SMEs, students, and researchers. This can uncover new solutions. Diffusion is potentially very high because knowledge can immediately be applied and shared among participants (e.g., in digital airport projects or logistics pilots). The contextual setting makes tacit-to-explicit conversion in SMEs, which often lack internal R&D resources.

Consortia and strategic alliances (including public-private partnerships and centers of expertise) are also highly effective, especially for sustained transfer. They potentially provide structured multi-stakeholder collaboration. Creation is higher through formalized processes across organizations, while diffusion is also very high via formal channels such as reports, networks, and policy briefs. Longer terms (more than a year) ensure integration, making them ideal for regional challenges (e.g., sustainability or digitalization in Triple Helix models). They outperform more ad hoc approaches in scalability.

Additional methods such as in-depth interviews or focus groups have high potential for externalization or socialization unless further synthesized. Additional evaluation through surveys enables diffusion based on broader patterns as a result of validation. As boundary spanners, students can develop new perspectives via reports. Theoretical modeling is relatively medium to low overall, mainly because it remains too conceptual.

Overall, labs and consortia are often more effective in UAS-SME contexts because they can bridge academic theory with SME practice, based on iterative co-creation and natural diffusion.The application focus potentially affects knowledge integration in terms of reducing inertia. Moving on from constraints is especially crucial for resource-constrained (smaller) SMEs.

Differences in knowledge transfer UAS-SME vs. research universities-large firms

Based on the above (emphasizing practical methods like Living labs, Field Labs, and consortia for iterative co-creation, tacit-to-explicit conversion, and natural diffusion in UAS-SME contexts), there are clear structural and functional differences in knowledge transfer and adoption between UASs and SMEs versus research universities and large firms.

Key differences in knowledge transfer in UASs and SMEs

Transfer is highly practical, applied, and regional. Our research shows that the focus is on demand-driven, practice-oriented research, making it potentially accessible and approachable for SMEs especially when they lack internal research resources. The methods used enable real-world co-creation as well as immediate application, tacit-to-explicit conversion and diffusion among stakeholders. Longer-term collaboration aimed at groups or sets of SME can reduce inertia (negative introspection in terms of modal logic) through iterative work. Transfer is more informal and has high regional impact albeit on a limited scale.

Research universities and large firms

Transfer is more formal, theoretical, and scaled. Research universities emphasize fundamental research, leading to codified outputs. Large firms, with strong internal R&D, absorb knowledge via contractual agreements and or spin-offs industry co-patents. Transfer channels large-scale consortia, or government-funded programs, often more global than regional.

Key differences in knowledge transfer and adoption

Adoption is potentially faster and more direct due to contextual, iterative methods (e.g., labs for practical testing). SMEs can quickly integrate particular knowledge especially to address resource constraints. Students potentially act as carriers and diffusers of knowledge. However, effectiveness depends on problem type (tactical/regional challenges) and prior disciplinary experience for iteration.

Aspect	UAS + SMEs	Research Universities Large Firms
Focus	Applied, practical, regional	Basic/theoretical, global
Primary Methods	Living labs, student projects, regional consortia	Patents/licensing, large R&D contracts, spin-offs
Transfer Speed/Style	Fast, hands-on, iterative co-creation	Formal, codified, contractual
Adoption Effectiveness	High for immediate application; reduces inertia	High for scaled innovation; builds capabilities
Best For	Resource-constrained, tactical problems	Complex, strategic, high-investment R&D
Challenges	Limited scale/broad diffusion	Misalignment with practical needs; slower uptake

Table 8. Key differences between UAS and Research Universities in transfer and adoption of knowledge

Different methods used by field labs, living lab or solution experiments

In the analyzed UAS-SME innovation spaces, field labs stand out as more technology-focused environments for long-term research, based on testing and implementation of technical solutions, for example. In our case this is shown by risk assessments for electric towing vehicles and the effect of digitization of airport facilities. However, this often involves extended periods of validation exploration and experience. On the plus side it enables UAS students and lecturers to work with research universities.

Living labs sometimes include a greater variety of stakeholders, including those not from companies such as local residents (neighborhood residents in our cases), non-profit organizations, and small enterprises alongside industry. Knowledge transfer is less aimed at creation or diffusion in formal organizational knowledge systems (e.g., as codified procedures, databases, or strategic frameworks), Instead, it focuses on immediate, intuitive adaptations that must also fit existing non-formal practices.

In our research on UAS-SME innovation spaces, solution labs (or solution experiments) proved to be primarily aimed at collaborative learning through intensive interaction between students, lecturers, and practitioners, rather than solely delivering immediate technical or pragmatic solutions. The cases consistently showed that when the exploratory and learning-oriented nature of these labs was clearly communicated upfront, participants adopted a more open atmosphere of experimentation and mutual discovery. This reduced pressure to find direct, ready-to-implement solutions and instead fostered richer epistemic exchanges, allowing for deeper reflection on underlying tensions and alternative trajectories, even within pragmatically constrained SME contexts.

The comparative table is essential for enhancing the transparency and replicability of multi-case research, as it condenses the complex involvement data (SMEs, students, teachers) into a single, scannable overview.

This enables cross-case comparisons of scale and methodological approaches, which might otherwise remain hidden in narrative descriptions. Beyond clarity, the table serves as a foundational reference for future research to replicate or extend this knowledge transfer framework, and need benchmark metrics (e.g., the optimal student SME ratios for transfer success) that can inform scalable interventions in applied settings.

Type	**Case(s)**	**SMEs**	**Students**	**Super-visors**	**Topic**	**Method**
Preliminary	A2	7 Public Private/ 2 SMEs	researcher		Gaps in SME - UAs research	Interviews Focus groups Survey
Consortium*		9*	27	8	Logistics	Interviews Student Object Interviews
Solution Lab experiments	C1	17	84+	6	Social innovation	Surveys Interviews Student Objects Evaluations
	D1	264/12	Researcher		Volatility for environmental dynamics	Survey (n264) Interviews (12)
	D2		Researcher		Learning Communities for skills and knowledge exchange	Interviews Focus groups

Type	Case(s)	SMEs	Students	Super-visors	Topic	Method
Strategic Alliance	D3	18	75+	4	Knowledge alliances	Survey Focus groups Student Object evaluations
Preliminary	(F) Y1, Y2	1	23	3	Triple Helix	survey(s) Focus groups
Solution Labs	(F) Y6.1, Y6.2	9		3	Labor markets Changes Schiedam	Interviews Student Object evaluations
Field lab External	(F) Y4, Y5	1	15	3	Digital Airport	Propositions Observations Student Object
Living Lab	(F) Y7, Y8	6	18		Local Area and Businesses Developments	Observations Student Object
Field lab internal	(F) Y8, Y9		21	4	Digitalization and skills	Interviews Student Object Surveys Focus groups Observations
Field lab internal	(F)	Airport	12	4	Digitalization and skills	Propositions Interviews Student Objects Student Object
	X1	1	4	Researc her	Knowledge Management	In-depth Case, SME) evaluations of methods and Impact
Innovation Pool	Z1	6			Integration HRM and Logistics	In-depth Case SMEs UAS-SME Learning Cultures

Table 9. Comparison between types of innovation spaces and methods for analysis

3.5.4 Design lab development for UAS-SME collaboration

We set up a solution lab for our study, based on the experiences and expectations uncovered in the preliminary stages. It was one of the first Design labs at RUAS established as a preparatory design course. We experimented on two cases with a mix of different groups of students and compared the results to analyze the effects of design courses on knowledge boundaries. This experiment involves analyzing specific design capabilities from relatively novice or innocent learners to make representations of situational knowledge needs.

On this experimental level we studied which (modal) space enables students and agents who need to reflect on understanding different dimensions of knowledge, and how actors and agents can benefit from experimenting with information and knowledge acquisition.

The experiments involved design elements of the Triple Helix case (Y6), a Field lab case, a Living lab case (Y8b1 Y8b2, Y8c) and the Sharing Consortium case. Based on case type, we analyzed the propositions made, iteration activities, general experiences with design, and domain knowledge. All the projects are guidelines that teach students to develop skills in design, meta cognition and general research.

3.5.5 Participation of students

All students were either at the end of their third year or at the beginning of their fourth year. All came from a mixture of disciplines, almost all from RUAS, but in some cases from other UASs. An estimated 400 hours of observations were conducted. Sometimes a case involved different projects on a specific theme. Most cases involved 1–3 projects with an average of 12 students participating in each case, apart from the Sharing logistics and Preliminary cases, which were a large project also involved an experiment.

The time span of these projects was more than three years since most take place once a year in minor programs. In addition, several projects had to be canceled and replaced because of the Covid-19 epidemic. In the overall project, data were collected to analyze epistemic capabilities needed to create epistemic change.

To determine the true effectiveness of the relationship between a type of challenge and its output we compared different types of challenges with the UASs’ strategic plans in general and specifically with the RUAS knowledge centers’ schedules. Again, we use comparative analysis of challenge-based learning experiences (Malmqvist, et al., 2015) for comparison.

3.6 Qualitative and quantitative collection methods in the explanatory sequences

The total research project took more than five years to answer the research questions. Quantitative and qualitative data were collected, analyzed and merged in each phase. Meanwhile the researcher attended academic meetings and conferences, domestic and abroad, to find answers and meet with other researchers, students and professionals in the field, which is an inspiring, often overlooked and valuable tool for learning in applied education. These encounters uncovered significant details on exchange, sharing, integration, transfer, assimilation in the refined process of fabricating knowledge. They especially confirmed the important contribution of epistemologies to how we can know what we need to know.

The identities of the actors involved in this study have been anonymized entirely. The decision to anonymize was made to ensure that organizations could be confident the subject would not be interpreted normatively, avoiding judgments related to good or bad measures or attitudes of organizations or employees. It is important to recognize that absorptive capacity is influenced by a multitude of factors and should not be evaluated through a normative lens of right or wrong. Rather, it functions as a complex capability contingent on contextual determinants. See Appendix B for generalized descriptions of these SMEs, based on the research.

A1. Data survey: RNE/preliminary research/scenarios characteristics

N=17	Company Name	Number of Employees	Sector	Company Age	Function interviewee
A.1	Mercury	>250 (600)	Maritime Industry (offshore)	55	Manager
	Solutionlab				Employee
A.2	Mercury				Human Resources Manager
	Mercury				Employee
	Mercury				Technology Director

N=17	Company Name	Number of Employees	Sector	Company Age	Function interviewee
A.5	Venus	51-150	Marine and Energy	90	Assistance to the Director
	Venus				Human Resources Manager
	Venus				Human Resources Manager
A.6	Uranus	>250 (400)	Maritime Energy Offshore	13*	Expert Engineer
	Uranus				Human Resources Manager
A.7	Saturn	51-150	Maritime Industry	108	CEO
	Saturn				Resources Manager
	Saturn				commissioning coordinator/ secretary OR
A.8	Jupiter	>250 (500)	Maritime Ship repair	26	HR Adviser
A.9	Jupiter				HSE Supervisor
A.10	Pluto	>250 (6000)	Maritime Transport	107	Technical writer
	Pluto				Training & development manager

Table 10. Case A1 data survey

*Survey and meeting participants
**Is a merged company (2011)

A2. Data interviews: phase 1

	Company Name	Sector	Interviewee	Topic
A2.1	Varuna	Research and Development organization	A2.1	Lab Cultures of SMEs and learning
A2.2	Ixion	Regional industry association	A2.2/ A2.2.1	Addressing Gaps in research between SMEs and UASs for student involvement
A2.3	Oumuamua	Healthcare and medical Research	A2.3	Addressing Gaps in research between SMEs and UASs for student involvement
A2.4	2I/Borisov	food manufacturing sector	A2.4	Addressing Gaps in research between SMEs and UASs for student involvement
2.5	Ganymede	Public sector	A2.5, A2.6. A2.7	Triple Helix Culture
A2.8	Hyperion	Higher Education and Research	A2.8	Path dependencies and Dynamic Capabilities
A2.9	Rhea	Public sector	A2.9	Governance
A2.10	Selene	Education and training sector, specializing in maritime transport, logistics, shipping, and port-related education	A2.10	Requirements for new education due to environmental and technological changes
A2.11	Vesta & Pallas	Public sector	A2.11. A2.12	Governance, Solutionlab in Municipalities and collaborative research by researcher for the Roadmap Next Education

Table 11. Data interviews: preliminary phase

Step 1. Data came from interviews with experts on the topic of innovation spaces, education and companies. Meetings were held with the municipality on governance of the project. Representatives from companies, the university, local residents and RUAS were grouped in one meeting. Data were also collected from employees of local companies in shipping and transport, including six focus sessions on changes in human capital. After these sessions, we sent a questionnaire of 61 items to attendees and other companies. In total this involved 20 companies concerned with regional changes in the effect of technology on human capital. The results of the questionnaire were discussed in a separate meeting with stakeholders from the companies and the municipality. The result of this session was evaluated by an external expert.

Step 2. Data came from a moderated group session with stakeholders from the municipality, two ICT representatives from UASs, and MRDH.

Step 3. Data came from four sessions with three different municipalities. Fieldnotes were taken all three steps.

B1. Data Interviews: phase 2/Sharing logistics case → C1 case

	Company Name	Number of Employees	Sector	Company Age	Employee	Function
B.1	Ceres	1392	Trade and Transport	93	B1.1	Director
B.2	Haumea	>250	Trade & Transport	105	B1.2	Engineer
B.2	Makemake			107	B1.3	HR Manager
B.3	Eris	>250		115	B1.4	Campus recruiter
B.4	Gonggong	>250 (500)	Trade & Transport	26	B1.5*	Campus recruiter
B.5	Orcus	>250	Trade & Transport	26	B1.6	Consultant Logistics
B.5	Orcus				B1.7	Student
B.6	Sedna	>250	Trade & Transport	105	B1.8	Student
B.7	RUAS	+/- 4000	Education	37	B1.9	Lecturer
					B1.10	Lecturer
					B1.11	Lecturer
					B1.12	Lecturer
					B1.13	Lecturer

Table 12. Case B data interviews: phase 2/ Sharing logistics → C

*Specifically involved in the Talent Innovation Community

C1. Data survey: SME characteristics in the HRM Business (1)

	Company Name	Number of Employees	Sector	Education	Company Age	Function
C.1	Salacia	51-150	Trade & Transport	VET*	99	Recruiter
C.2	TrES-4b	51-150	Trade & Transport	VET	98	HR employee
C.3	WASP-76b	51-150	Trade & Transport	VET	36	HRM Manager
C.4	TOI-6894 b	51-150	Trade & Transport	VET	58	HR Manager
C.5	HD 209458 b	51-150	Trade & Transport	VET	145	Owner
C.6	Kepler-10b	51-150	Trade & Transport	VET	96	HR Manager
C.7	Proxima Centauri b	1-50	ICT	UAS	20	Finance Manager
C.8	KELT-9b	1-50	Trade & Transport	VET	10	
C.9	55 Cancri e	200-250	Trade & Transport	VET	75	Sustainable Developments engineer
C.10	GJ 1214 b	1-50	Trade & Transport	VET	10	HR officer
C.11	Tyche	>250	Food Production	VET – UAS - University		
C.12	Theia	1-50	Trade & Transport	VET	10	Sales & Marketing Manager
C.13	Nemesis	51-150	Trade & Transport	VET	56	Supervisor
C.14	Planet Nine	1-50	Trade & Transport	VET	44	QHSSE Manager**
C.15	Oberon	200-250	Trade & Transport	VET	49	CEO
C.16	Titan	300-350	Trade & Transport	VET	77	Manager Transport
C.17	Kepler-22b	51-150	Healthcare	VET		Health and safety coordinator

Table 13. Case C data Survey: SME characteristics in the HRM Business

*MBO
**Quality, Health, Safety, Environment

SME characteristics in the HRM Business (2)
In total 42 further interviews, based on the input of the survey, were conducted with employees with the help of students and analyzed for our research. All other interviews were done by the researcher.

C2. Data from interview participants
CEO (4), CFO (1), Charterer (2), IT specialist (2), ICT employee (1), HR officer (4), HR adviser (1), HR employee (1), Project Manager (1), Policy Maker (1), Order picker (3), Supervisor (1), Lorry Driver (7), Tram / Bus driver (6), Crane Driver (1), Operational Planner (2), Manager Order picking (1), Manager Warehouse (2), Manager Logistics (1)

C2b. Data from HRM (Business codes) comparison with Logistics (engineering) codes
This phase involved gathering data from student transcripts and conducting interviews to explore participants' decision-making processes. Capturing deeply embedded tacit knowledge necessitates tailored data collection. The theoretical framework and preliminary data collection phase suggest that well-defined tasks typically incorporate the specifications of required knowledge and/or procedural actions. The absence of such specifications increases the probability of tacit knowledge components, requiring supplementary methods such as observation or job shadowing. When explicit procedural documentation or descriptions are absent, students must generate such descriptions themselves. These codes must then be compared with existing theoretical frameworks to define the problem-solving area. Also, further analysis must take place to be sure these codes can be added to standardized knowledge sets to compare SMEs. Specific contextual conditions (e.g., lack of HRM practices) require students to use these explicit codes and describe specific modifications to actions to solve the problem (knowledge management).

This research methodology is complex and time-consuming due to the profound impact of contextual factors and organizational characteristics on internal knowledge dissemination processes. Understanding the organizational habitus necessitates a thorough investigation of these specific variables, including employee attributes and environmental conditions.

The collection of this data provides insights into students' capacity to move back and forth between different domains of epistemological and professional practices. This analysis also shows how particularly temporal limitations imposed by the organization of a curriculum (standardization of time) affects the research. Therefore, we conducted interviews to study the students’ methodological considerations that were either consciously made or recognized during this process.

The first questionnaire sent to companies focused on key characteristics of knowledge explication. The results for each company were shared with the students. Subsequently, the researcher developed a schema with potential codes and themes for each company. These codes were then compared with codes extracted by students from the interview transcripts. As an experiment, Atlas.ti was used to explore whether other choices could emerge from the transcripts. These three groups were compared with each other.

The process of code conversion (part of the SECI model) can also be analyzed through the lens of student-employee interactions (Farnese, et al., 2019). For instance, this approach can show whether interaction with students rather than codification generates deeper insights into specific challenges in a particular situation. This may constitute a form of knowledge exchange; however, it would necessitate an alternative method of documentation to capture these dynamics effectively.

Company Name	Number of Employees	Sector	Company Age	Function
C.2.1 Zythera Prime	51-150	Trade & Transport	12	Student-operational manager
C.2.2 Veltrax IV	200>	Trade & Transport	-	HR employee
C.2.3 Orinex Alpha	51-150	Trade & Transport	117	HRM Manager
C.2.4 Kyronis Major	51-150	Trade & Transport	74	HR Manager
C.2.5 Eryndor Beta	150-250	Trade & Transport	121	Owner
C.2.6 Quorath Expanse	250>	Trade & Transport	75	HR Manager
C.2.7 Pyralis Nine	250>	ICT	17	Finance Manager
C.2.8 Xandora Prime	500>	Trade & Transport	5	
C.2.9 Verlina VII		Trade & Transport	80	Sustainable Developments engineer

Table 14 C2b HRM Data

C4. Evaluation survey: Sobek study data.

Lastly, we conducted a survey of students (n=84) to evaluate how confident they felt about the results of their research. Due to the complexity of the environments and time pressure, we expected high differentiation-based knowledge boundaries. Based on the ill-structuredness of knowledge and uncodified information, knowledge engineering is supported by high levels of conceptual modeling. More open-ended problems involve structured steps derived from intermediate representations (Sobek, 2004; Sobek & Jain, 2004). In the early stages we included the Sobek survey results to explore why graduating students chose a particular SME.

D.1 Data survey and interviews: phase 2/ Volatility

Applying the results of the Sharing case (B1) we developed a survey to find smaller companies that face different problems in their modal shifts and dynamic capabilities as a result of digitalization. In this stage we found that digital scans do not suit all organizations because of their different configurations, business models and dynamic capabilities.

Little research has been done on the relationship between the knowledge boundaries of individuals and organizations and the capacities and capabilities to absorb knowledge on different levels. These differences can be categorized in maturity tiers. Highly mature systems are aware of these processes and use them effectively, meaning that the tiers articulate the demand for knowledge needed at the right level of absorption capability and capacity.

We used our findings from the previous stage to find key knowledge barriers (syntactic, semantic and pragmatic; Carlisle,2004) and different stages of absorption, identification, transfer and transformation of critical knowledge between UASs and SMEs. We needed to know how innovation can be seen as a distributed process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and non-pecuniary mechanisms in line with the organization’s business model” (Chesbrough & Bogers, 2014).

Using a smart scan reduces the risk of incurring costs for exploration and exploitation exchange (innovation efficiency). First, the scan identifies knowledge needs, whereupon we can determine what an organization needs to absorb new knowledge and the type of knowledge the organizations need for innovation. The scan allows us to determine the available knowledge on a specific subject or process (knowledge stock) as well as the available system of knowledge management, learning experiences and dynamic capabilities in terms of human resources (knowledge flows). By identifying the knowledge boundaries, we can lay out the instruments for exceeding specific boundaries in order to successfully transfer and transform knowledge so that it can be exploited. With the help of the theory, we can add the specific cultural elements of the organization to ensure scan rigor. Besides organizational characteristics (Dan, et al., 2021), it helps to look at the behavior of employees. An HR distributive approach allows us to create a path for effective, differentiated absorption activities based on the SME's maturity level.

D.1 Data from in-depth Interviews (volatility & disruptions)

Since a lot of learning takes place through incremental innovation process steps such as learning by doing or imitation (Lundval, 1988) we needed information how these steps are taken in SMEs with little help from formal HR and knowledge-management (KM) processes and with the speed of uncertainties in mind. We sent a survey to 3066 SMEs of which a total of 264 companies returned completed questionnaires. We posed a limited number of questions since SMEs have hardly any time to fill out a questionnaire. We then conducted in-depth interviews with 12 SMEs selected from the survey. The interviews were semi-structured and applied the same themes and theoretical framework used in previous phases. The themes involved specific changes in the SME environment and how they affected the routines, knowledge and skills of employees. The interviews also included questions on the capacities to work with students in and relation with (specific) knowledge domains and disciplines.

	Company Name	Number of Employees	Sector	Company Age	Function
D1.1	Euphrosyne	200-250	Food Industry	28	HSE Manager
D1.2	Cybele	1-50	Recycling and logistics	18	Quality Control Manager
D1.3	Hermione	48	Recycling waste plastics	74	Manager/ HR Manager
D1.4	Davida	6	Trade& Transport	14	Owner
D1.5	Eunomia	51-100	Marine Electronics	55	Manager/ HR manager
D1.6	Gliese 581g	35	Energy	48	
D1.7	Camilla	80	Retail	101	Manager
D1.8	WASP-49b	12	Trade & Transport	37	
D1.9	Tau Ceti		Trade & Transport	88	Manager /HR
D1.10	Hektor	51-100	Steel Wholesale	57	Manager
D1.11	Vulcan	5	PCB Recycling	40	Quality manager
D1.12	Europa	11-50	Education		Consultant Business models

Table 15. Data from in-depth interviews (volatility & disruptions)

D.2 Data Interviews: Characteristics of SME environments/In-depth interviews/future skills/social ontologies/Learning communities/UASs and SMEs

	Company Name	Number of Employees	Sector	Company Age	Interviewee
D2.1	Tatooine	>250 (620)	Trade & Transport	106	HRM Manager
D2.2	Naboo	>250 (2300)	Supply Chain Engineering	140	Business Analyst Employee
D2.3	Coruscant	1-50	Logistics	32	Employee Manager
D2.4	LV-426	51-150	Consultancy	3	HR
D2.5	Altair IV	51-150	Logistics	48	Planner
D2.6	Altair IV				Logistics Supervisor
D2.7	Altair IV				Senior Manager Logistics
D2.8	Pandora	>250 5000		101	Operations Manager
D2.9	Arrakis	200-500	logistics	12	General Manager
D2.10	Arda	+/-2000	logistics	105	Recruitment
D2.11	Windesheim University Applied Sciences	+/-2800	UAS	38	Lecturer Logistics Management:
D2.12	Windesheim University Applied Sciences		UAS		Lecturer Lectorate Supply Chain

Table 16. Data Interviews from case D2

D 2.1 PPS Transfer; Research on transfer skills; TNO, 21CC education, Olympia, RUAS and The Hague University of Applied Science

D3. Data Survey: Characteristics of SME environments/SMEs learning culture/focus groups

The survey was sent to 18 SMEs (n = 312)

	Company Name	Number of Employees	Sector	Education	Company Age	Response		
						n	r	rate
D3.1	Euphoria	51-150	Business Services	UAS-University	38	50	13	26
D3.2	Entea	1-50	Industry	VET	80	35	20	57
D3.3	Super-Ego	1-50	It		5	21	10	48
D3.4	Thanagar	51-150	Healthcare	UAS-University	14	150	16	11
D3.5	Xorr	>250	ICT	UAS-University	57	99	38	5
D3.6	Klyntar	51-150	Maritime/ offshore	VET	58	70	15	21
D3.7	Magrathea	51-150	Construction Industry	VET- UAS-University	106	200	33	17
D3.8	Caprica	1-50	Agriculture	VET-UAS-University	22	35	10	29
D3.9	Mogo	151-250	Construction Industry	VET-UAS	20	150	11	7
D3.10	Krypton	1-50	Industry	VET-UAS-University	47	60	24	40
D3.11	Rann	51-150	Healthcare	VET- UAS-University	>25	75	31	41
D3.12	New Genesis	1-50	Industry	VET-UAS	22	30	13	43
D3.13	Tamaran	1-50	Trade & Transport	VET-UAS-University	20	130	12	9
D3.14	Korugar	1-50	Retail	UAS-University	96	31	13	42
D3.15	Illa	51-150	Trade & Transport	VET	114	80	17	21
D3.16	Worlorn	51-150	Trade & Transport	VET	54	43	24	56
D3.17	Oa	51-150	ICT	51-150	25			
D3.18	Gallifrey	200	Food industry	2	-	1	-	-

Table 17. Case D data survey: Characteristics of the environments

* Sometimes employees filled out different branches

**VET (in this dataset a mixture of LBO-MBO as a result of the size of this group)

***Agriculture and Agriculture industry: the latter refers to products or processes.

E. Data collection from Y-X-Z cases

Based on the experiences in the preliminary research we selected diverse spaces and the relation with critical junctures in the routines of students and organizations. We involved the ethnographic element since we had observed the effect of lock-in and lock-out solutions. As time progressed, participants often chose suboptimal solutions as a result of complexity and or conflicts with exiting routines (Nooteboom, et al., 2005; Crespi & Scellato, 2014). The aim was to analyze whether the space properties generated dynamics that evoked epistemic capability. If we want to determine how the justification of knowledge is influenced by the capacity of agents, we cannot rely only on formal descriptions. The conversion capability that ultimately influences epistemic capability in terms in adapting beliefs may be influenced by novelty and knowledge boundaries.

The basis of each space is a problem situation, which we term call a case. In all cases, the researcher was present in the office to observe the behavior as well as the setting. In all cases, the researcher took part in meetings with students. A course was developed in the Design lab and Living lab cases. It gave students extra training in the basics of design research and thinking and was meant to evaluate the difference between spaces and problem context.

All students came from a mixture of disciplines, almost all from RUAS. Observations took an estimated 400 hours (300+ hours of data). Sometimes a case involved several projects on a specific theme. Most cases had 1–3 projects, with an average of 12 students involved in each case. The exception was the HRM-Logistics case, a large project that also involved an experiment (see stage III). Project duration was approximately 8–12 weeks, depending on the agreements with stakeholders. of observation.

All projects took place in the Rotterdam area. The time span was more than three years since most projects tool place once a year in minors' programs. In addition, several projects had to be canceled and replaced because of the Covid-19 epidemic.

Data came primarily from observations and the final products of the projects. Other sources were poster sessions, meetings, presentations, interviews and documents. In the overall project, we collected data to analyze epistemic functionality in relation to their capability to create needed epistemic change. We also looked at functionalities of agents and their capabilities to create knowledge on different dimensions in order to exchange knowledge.

Overview of data collected from Y-X-Z cases

Type of Case	Number of groups & codes	Theme(s)/Titles
Triple Helix-Solution Labs	Y01, Y02	An experimental design for next education in three solution labs
Solution Lab experiment	Y2a Y2b	New Skills for digital crimes (a) Sustainable employability (b)
Solution Lab experiment	Y8d	Health care
PPS 1	Developments of a common skills language and skills matching methods (results not included in manuscript)	
PPS2	B Y3 /Y4	Sharing Logistics HRM Interviews Survey
Living Lab	Y4&Y5,Y6	Electrification and emergencies (E-GPU's) New skills in the digital airport
Living Lab	Y8 a,b, c	Entrepreneurs in the local area lag behind when it comes to digital business. The City of Rotterdam wants a green and healthy city. The neighborhood courtyard garden
Field lab I&II	Y 9a-g	SMES for new generations SMES in the digital age
Strategic partnership of RUAS with UAS 2	E(z)	How to create learning cultures in SMEs
Extended Case Knowledge Management	X1	Research using Framework Knowledge Management resulting in transformation and use of application
focus groups Future Skills	Z1	3 sessions with Logistics SMEs on changes in logistics

Table 18. Cases based on projects in the second stage

Focus groups on evolution

We also interviewed focus groups of students.

Focus groups	
Field lab I & II	Both individual and group interviews. N=2x6 students
Learning Culture	N=3x6 students
ICT Labs	On skills and expertise in digitalization in education
SME Schiedam	On changing labor markets and skills

Table 19. Two focus groups for evolutions

3.7 Data analysis through sequential exploration (MMR)

Based on the conceptual model of spaces that facilitate absorption of knowledge we constituted mechanisms that we see as necessary in the relation between UASs and SMEs, following Carayannis & Campbell's necessity for Mode 3 for higher education (Carayannis & Campbell, 2021). This implies that learning comes through making knowledge and its applications explicit from different levels of incomplete information.

To determine the effectiveness of the relationship between type of challenge and its output in absorption of knowledge we compared challenge types with strategy plans for UASs in general and specifically with the research agendas of knowledge centers involved in the study.

Data analysis through the sequential exploratory (rather than explanatory) MMR approach took place by connecting the insights from each project phase or case to a new phase or case. We used both quantitative and qualitative data in each phase to complete our research. This type of design passes sequential information on to a subsequent phase. The qualitative and quantitative results are analyzed and documented in papers.

In each study phase, we used descriptive analysis to help understand the key components of different environments in terms of the human agents or students and SMEs or organizations involved. The effects of these different conditions help to explain the epistemic governing requirements to simulate these environments.

The MMR sequence also adds information to our semantic analyses in terms of propositions for design types that support conversions from highly embedded knowledge environments.

Each phase built further on the model based on our theoretical framework. The final model explores how agents and systems can make various moves to reduce uncertainty by integrating of knowledge. The quadrants used in each sequence are modal spaces that represent what particular modifications of knowledge these environments require to be effective. In the last phase of the sequence, we placed the analyzed data in a final quadrant to reason on our findings and formulate conclusions.

Thus, our research focuses on the effects of uncertainty in the behavior of human agents, of their environment and type of routines on their perception of changes that affect the integration of critical new information. These routines, the personal histories of agents, have legality of their own (Bourdieu, 2004) and thus affect changes to what comes after and what is unknown.

The cases aim to explain conditions that allow change to be aware of change, for example, the effects of environmental changes on their contextualities or events and the desired responses in terms of a conscious choice to reject existing beliefs. Our theoretical framework shows how these differences can be explained in terms of naïve behavior (Kuhn, et al., 2000), or innocent behavior (Bartolotti, 2020). We do this because epistemological changes increase our understanding of the changes that affect knowledge domains and disciplines (Maton, 2013; Henwood & Marent, 2019; Hüllemeier & Waegeman, 2021) and that requires changes in how we prepare future human agents for these changes.

3.7.1 The analytical strategy

This section outlines the data analytical strategy. The approach is abductive, aiming to achieve a more comprehensive understanding of the complexity of the absorption of knowledge under epistemic uncertainty. After analyzing the quantitative and qualitative findings at each stage, we synthesized the data in a conceptual quadrant for the following reasons:

- This allows us to find differences between projects, SMEs, and societal challenges, while keeping the characteristics of the student group consistent. The goal is to develop a model that contributes to inferring coherent practices.
- Our conceptual analytical framework describes types of SMES (archetypical) that can be used for the governance of spaces to share knowledge under epistemic uncertainty.
- The quadrant is based on possible world theory and the dualistic dimension of SMEs and UASs.

3.7.2 Explaining the data analysis model

Inquiry allows access to different worlds to explore the effects of epistemic modalities and temporal logic on functionalities of knowledge, the absorption of knowledge and sharing of strategies between UASs and SMEs under epistemic uncertainty. For instance, habituals, routines, situations and events that form processes and organizational beliefs affect the possibilities for human agents to acquire new information or create knowledge.

Stronger interactions in terms of the output of microprocesses entail more discrete actions. These processes are crucial in supporting the output of macroprocesses. The actions allow lesser reflexivity on follow-up actions increasing uncertainty. Learning by practicing with new extensions of tasks is limited. The temporal logic is closely connected with the type of process, time to respond and reflect, and the absorption of knowledge.

In general, changes require awareness of knowledge modalities and environmental knowledge to make consciousness changes in processing knowledge alterations in response to changes in the environment through absorption of new critical knowledge. These changes are not spontaneous.

Different types of epistemic systems affect both the role of inquiry and sharing of absorption strategies under epistemic uncertainty. We were able to describe four categories for different levels and types of semantic and pragmatic inquiry and possible inferences to other situations. These inferences contain strategies to realize integration of knowledge (organizational level) or reconfiguration of dynamic capabilities (human agent levels).

In general, the analysis emphasizes the dualism of justification of knowledge. A more pragmatic knowledge legitimation may require further credence to convince agents, other than formal empirical legitimations. We see that in SMEs with strong ties with clients, experts or colleagues to mitigate risks. So, the environments of inquiry and justification require UASs to have a distinct role in relation to other agents and in their knowledge environments.

The inquiry time depends on previous experience (schemas). Finally, the organization and inquiry of habituals, routines, situations and events reveal possible levels of strategy sharing (knowledge codification, role of formalized HRM and knowledge management, its maturity levels) and the possibility of transfer between UASs and SMEs.

In addition to the quadrant analyzing the effects of epistemic uncertainties on the absorption of knowledge between UASs and SMEs (see below), we also visualized the barriers between UASs and SMEs based on each case. The type of visualization is based on the type of disposition in SMEs that explain or even predict agent behavior. We placed the habituals (Bourdieu, 1990) as routines that have the strongest reinforcements and predictability based on the highly repetitive task environments of a system. A system and its agents act on the type of triggering situations (Vanderbeeken & Weber, 2002). When a particular task has fewer reinforcements for behavior, it requires more descriptive and externalized reinforcements. Longer periods of reinforcements create reflexivity and automation in tasks. This explains the description in natural languages and use of tacit knowledge.

A types: Necessary for all worlds Uncertainty decreases from (multi-model) of modalities. Strongly formalized axioms analyze the behavior of knowledge.	D types: Aimed at as many worlds as possible Uncertainty is based on the epistemic states of groups related to understanding the external dynamics of different worlds.
Processes and reasoning are expressed in formal semantics allowing easier exchange and sharing. It allows adaptation of beliefs through reasoning on sequences, emphasizing the necessary conditions and relationships, from using sources outside the organizational context. It emphasizes the roles experts have in spanning epistemic dimensions with distant relation to specific practices or processes. Temporal logic relates to a mixture of classical and modal logic (linear and non-linear).	Processes and reasoning require ongoing development expressed in various languages (e.g., artificial, modal and or natural) to capture essential characteristics of (human) agents in multiple contexts of networks, ecologies and projects. It emphasizes the necessity of knowledge integration based on effective use. Temporal logic highly relates to situations events.
B types: Inference, only possible in one world Uncertainty comes from high temporal logic and less from formalized expressions of task for reflectivity.	C types: possible in some worlds and not possible in other Uncertainty: state of the game, based on understanding external dynamics of different worlds.
Processes and reasoning are expressed mainly in natural languages and through microprocesses and actions, with dominance of existing beliefs emphasizing the necessary conditions and relationships within the organizational context that comprise fewer human agents, emphasizing each other's practical knowledge, situatedness, and resource availability. Highly aimed at mitigating organizational risks. Temporal logic highly relates to microprocess and/or situations.	Processes are expressed in both natural and formal languages based on social ontologies. Articulate the essential characteristics and relationships in the organizational context, highlighting the universal presence of common interests (rather than ontology), knowledge as tangible, tacit, and situated, and the significance of such factors as engagement, trust, practices, and objects in organizational dynamics. Temporal logic highly relates to communities and various members involved across time.

Table 20 Analysis quadrant based on our conceptual framework

In this table the archetypical epistemic types are meant to continuously adapt the models of epistemic representations to make distinct statements on the relationship between epistemic uncertainty and the absorption of knowledge. The types inside the quadrant can overlap. The individual descriptions aim to relate to the types to reason on differences.

3.8 Data coding and analyzing strategy

Our qualitative data analysis integrates open, axial, and selective coding, consistent with the grounded theory methodology. This multi-stage approach enables both a systematic and flexible exploration and interpretation of complex qualitative data. The analysis began with open coding, evident from the wide range of questions in the initial survey administered during stage 1, allowing us to identify diverse concepts emerging from participants' responses. In subsequent stages, constraints related to limited SME availability necessitated the collection of more focused data, often reducing the volume of surveys and interviews. During these stages, discrete concepts were further refined and labeled with codes. The axial coding phase, conducted primarily in the later stages, involved organizing and connecting the initial codes to elucidate the distinct effects of different modalities in relation to temporal logic. Through an iteratively moving back and forth across the data, we systematically validated our assertions on how epistemic uncertainties impact the absorption of knowledge in SMEs.

We adopted a structured, iterative coding strategy informed by both thematic and process-oriented qualitative analysis in the MMR. First, we developed an initial coding framework aligned with our four sub-questions. For sub-question 1, we identified and coded data segments reflecting mechanisms of how knowledge sharing and continuous learning dynamics between UASs and SMEs takes place, with particular attention to how actors integrate diverse knowledge types under conditions of epistemic uncertainty.

For sub-question 2, we assigned codes to capture variations in SME characteristics, such as sector, size, and organizational culture, processes and routines and how these differences represent possible modalities of knowledge that affect the absorption of knowledge and the collaborative formulation of strategies with UASs.

In addressing sub-question 3, our coding focused on identifying pragmatic and semantic boundaries, types of agents, and contextual factors that mediate knowledge exchange and co-development processes. Here, we specifically looked for instances of conscious epistemic negotiation by human agents operating in varied semantic and pragmatic contexts. Finally, for sub-question 4, we conducted axial coding to integrate emerging themes from the previous stages, focusing on models and prominent factors contributing to the design of innovation spaces that facilitate effective, efficient absorption of knowledge between UASs and SMEs.

Throughout the process, we employed constant comparison across cases and iteratively refined our codes to ensure reflective alignment with both the data and evolving analytical insights. This strategy enabled us to systematically map the interplay between organizational context, epistemic challenges, agentive reasoning, and the spatial and structural dimensions of the absorption of knowledge and innovation.

It is important to note that our research focuses on SMEs, which often have limited experience in completing survey questionnaires. Our findings indicate that practical barriers such as lack of time and insufficient access to computers significantly affect the willingness and ability of SME representatives to participate in surveys. Furthermore, we observe considerable variation in how questionnaires are completed. This can be attributed to factors such as the density of information in the questions, time constraints, social desirability (participants providing answers they perceive as most acceptable), and the manner in which information is presented.

We found this in all cases. However, in order to reduce epistemic uncertainty, the collection of more extensive data is essential. In this context, we aim to model the various SMEs according to their distinct needs and capacities. These models can, in return, contribute to a deeper understanding and further development of integration and absorption processes, particularly as these involve students from diverse backgrounds.

STAGE 1	**CONCEPTS**	**SUPPORTING LITERATURE**
ORGANIZATIONAL & CONTEXTUAL CHARACTERISTICS	Innovation culture	Prefontaine, 2013; Hafkesbrink & Schroll, 2011; Toivonen & Friederici, 2015; Pratt, 2014.
	Barriers	Connelly & Kelloway, 2001; O'Reilly & Tushman, 2007; Howells, 2001; Gurteen, 1999; Riege, 2005;
	Sticky context	Cantu, Corsaro & Tunisini, 2015.
	Attitudes/ beliefs/teams/ leadership	Isakesen & Karlsen, 2012; Wensveen, 2012; Hsiu-Fen & Gwo-Guang, 2006; Connelly & Kelloway, 2001.

STAGE 2	CONCEPTS	SUPPORTING LITERATURE
BOUNDARY-SPANNING CAPACITIES	Type of Knowledgebase Tacit / Explicit Community type	Polanyi, 1967; Nonaka, Konno, 1998; Nooteboom & W.P.M. Van Haverbeke, 2005; Jørgensen, 2018; Jonkergouw, 2015; Ponzi, 2002; Biesta, 2015; Endres, M, Endres, S; Chowdhury, S; & Alam, I, 2007; Garcia-Perez, A; Mitra, A, 2007; Hartmann, R. S. (2008)
	Same sub-system /values/ Past experiences /path dependency Autonomy, roles	Haas, 2015; Helbig, 2013; Sommer, 2015; Moodysson, 2007; Papachroni, Heracleous & Paroutis, 2015.
	Type of role in exploring and sharing knowledge	Shuen & Sieber, 2009

STAGE 3	CONCEPTS	SUPPORTING LITERATURE
CONNECTEDNESS **KNOWLEDGE CONVERSION**	Network/helix Connection building Micro dynamics Mixed actor	Meerkerk & Edelenbos, 2014; Pinto, H., 2014., Faria, 2010; Stange, Leeuwen & Tatenhove, 2016; McKenna, 2006; Molina-Azorin, 2014; Fichter & Beucker, 2012; Tidd & Bessant, 2013; Tushman M. L., 1977. Nonaka, I. & von Krogh, G. 2009; Etzkowitz, H, & Ranga, 2013; Schoffelen & Huybrechts, 2013; Fiske, 1991; Moore, M., & Westley, F., 2011.
	Connectivity skills	Puusa, 2010.

STAGE 4	CONCEPTS	SUPPORTING LITERATURE
LEGITIMACY OF KNOWLEDGE	Rules, hierarchy, conformity with rules, justifiability, shared beliefs, network	Beetham, 1991; Isakesen & Karlsen, 2012; Fiske, 1991; Jacoby, 2001; Hislop, 2005; Song, Bij & Weggeman, 2006.
	Knowledge boundaries crossing/dialogue Social proximity	Cummings, 2003; Schauer, 2014; Dedehayir & Seppänen, 2015; Carroll & al, 2003.

STAGE 5	CONCEPTS	SUPPORTING LITERATURE
DESIGN-DRIVEN DYNAMIC CAPABILITIES	New product meanings, values, enablers, Structural holes	Tushman M.L., 1977; Puusa A. A., 2010.
	Skill Assessment Support	Francq, P., 2011
	Social Proximity Same set of values Community type Past experiences Defined Roles	Barrioluengo, Uyarra, & Kitagawa, 2016; Dedehayir & Seppänen, 2015.

Table 21. Stages of interpretative phenomenological analyses

Coding themes analysis

The following themes and sub-themes were collected to address bidirectional and bidimensional knowledge barriers for the absorption of knowledge

Exploratory/epistemic	Subordinate themes	Codes based on sub-themes
Modal consciousness and conscious moves between epistemic and practical dimensions to affect the absorption of knowledge between UASs and SMEs	Size, age, sector, processes as intermediate variables that explain differentiated embeddedness of knowledge. Ability and goal to compare the value of practices and theoretical approaches with various subsequent inquiries	Physical absence, projections for what is, and causal relations: e.g., students observe a learning culture
Dynamic capabilities Sensing and seizing new information to identify, transfer and transform it	**Dynamic:** strategic adaptation, involvement in networks, skill development	Design is a process of iterations that also create more doubt
	Ordinary: operational efficiency, time constraints in the organizational system	
Disruption/ Uncertainty: Known or unknown	Necessary knowledge on knowledge of agents and systems. Responses to requirements in skills. Learning in SMEs based on time requirements	Notions of disruption (e.g., digital transitions) are abstract leading to guesses in the design and engineering of knowledge
	Labor markets, skills, task changes, routines	
Epistemic governance aimed to span boundaries (epistemic, practical)	Statements on projects, evaluation and explicit goal for stakeholder dissemination. Students' choice of organization. SMEs' motivation to participate. Strategies, policy for informal exchange activities, courses, meetings	Students' perceptions of research/ inquiry does not match the context
HRM/KM accommodation or support in actions	Awareness of relation between knowledge, its domains and practical processes in the real world	Knowledge perceptions of SMEs
	Relation between HRM and KMM management	

Exploratory/epistemic	Subordinate themes	Codes based on sub-themes
Absorption - dynamic capability division	Understanding formal and informal languages. Making designs in different languages, maintenance requirements	Inquiry based on what students know
	Embeddedness of knowledge affects capabilities, especially in transfer and transformation	
Distinct relationship participation & collaboration	Distinct relation of curriculum and skill requirements for students and agents: Projects, standard curriculum, partners or consortia as third partners	Ideas of how (domain) knowledge can be produced/perceived in other (arbitrary) situations, e.g., attitudes to unstructured knowledge environments
Disposition of knowledge	Epistemic doubts and behavior characteristics in the inquiry process to create collaborative interest or need	Epistemic doubt is affected by type of SME, knowledge domains and type of inquiry
Conversions/translations	Research (goals) capability for internal exchange of information either in UAS research centers or by key SME agents. Willingness to change ideas	Objects and designs are directed by expected RUAS requirement
Temporality	Possibilities of the above within UASs/SMEs timeframe	Perceptions of how experiences contribute to existing knowledge
Dispositional context and sociomaterial environment	Dynamic spaces that affect ideas on changes in SMEs. Using objects for dynamic capabilities between UASs and SMEs. Ability of students and agents to reconfigure or rearrange their routines	Dissemination of results to actors & stakeholders for personal integration and curriculum

Table 22. Description of data themes collected for analysis

Knowledge on applied epistemology

While integrating the data and codes found in the subordinate themes, we found patterns in the cases used for our research. The findings of the meta codes relate to a deeper understanding of applied epistemology, necessary for UAS-SME relations (see also Chapters 4 and 6).

Meta code	Description	Representative subcodes
Temporal logic and relation to modalities of knowledge	Focuses on how time structure, duration, rhythms and orientation affect knowledge exchange, learning, and use.	Timescale • Dualisms in temporal orientation (past, present, future reflection) • Sufficient time for both students and agents to exchange information and learn from the effect of new knowledge - all timelines are standard in projects and research • Time of conversion from tacit-to-explicit to formal representations by students creates differences in understanding - time to make expressions from formal skills and knowledge representations for (future) learning behavior of agents • Pressure from knowledge-in-use in routines and microprocesses challenges adaptations (synchronicity vs a synchronicity) - temporal rhythms (routines, project cycles) • Contingencies and legitimation of knowledge differences between UASs and SMEs (disruption/uncertainty, known/unknown futures) - recursive logic reflection: reinterpret past to imagined future

Meta code	Description	Representative subcodes
Epistemic modalities of knowledge	Modality by which knowledge is apprehended, constructed, justified, and made sense of.	• Dualism on modalities that affects legitimation/application of knowing (propositional, practical, embodied, conceptual) - taking different epistemic stances on applications that respond to uncertainty, - the embodied knowledge dimension involves intuitive understanding gained through continuous interaction with the environment—for example, recognizing patterns or early signs of bottlenecks that may not yet appear in the data but emerge from tacit insights. • Epistemic governance: on levels of sets for coherent practice in epistemic and engineering advancements - inferences needed for UASs to build on • High differentiation: in semantic and pragmatic boundaries between agents and students - specifically, boundaries between how knowledge is valued and validated, shared and legitimated - especially in routines, traditions, discourses and curricula • Epistemic: The creation of value in responses to constant epistemic uncertainties and its effect on contingent strategies for learning - practical translation and conversion between languages and knowledge domains • Diachronic evolution: UAS evaluation are strongly influenced by curricula and affects changeability vs real-time adaptations

Table 23. Dualism in systems and modalities

3.9 Software used for qualitative data analysis

All interviews were held with representatives of selected companies, lecturers and students selected in different phases of a project. Based on the information from previous stages we developed a detailed understanding of the different phases of knowledge exchange, especially the relation between human agents and routines in particular environments. Most interviewees were selected from the actual survey respondents because we found that smaller SMEs usually had little time for either surveys or interviews.

Most interviews were recorded. Sometimes this was not allowed, and sometimes interviews were part to meetings. We used Atlas.ti to analyze the transcripts. We filmed some focus groups as well, since it is difficult to understand different speakers only from recordings.

We used Atlas.ti to analyze the substantial volume of codes. This program also used AI functionalities in one case (see C.3) to identify similarities at various levels of 'density' and 'gravity'. Additionally, we analyzed the extent to which the codes assigned by students exhibited an intensional character. This analysis of higher-level meta codes for thematic analysis revealed that new knowledge in students resulted from a wide distribution of intensional coding, suggesting that here students were confronted by doubt and uncertainty when acquiring new knowledge. This finding was most evident in the student research into the effects of digital transformation and the Living lab case. Furthermore, the interviews indicated that a high degree of conceptualization by students is often difficult to translate into concrete (practical) solutions in companies.

The datasets were supplemented with interview data. Other questionnaires, initially processed in Excel, were subsequently also imported into JASP (a free and open-source software application designed for statistical analysis for further analysis). This program offers the advantage of facilitating the straightforward importation of Excel files for extended statistical analysis.

The process of open coding was also implemented, especially since many SMEs make limited use of formal instruments for both internal and external knowledge internalization. Open coding provided the necessary flexibility to derive relevant insights and to identify emerging themes and concepts. The individual steps the researcher followed in each phase of the coding process included: fully transcribing interviews based on recordings and or filming (in cases of focus groups to determine which respondent made comments) and maintaining field notes in a research diary, which also entailed the possibility of immersion. For example, through direct observations in the organization, either during or after the interviews.

During and after each phase, field notes and research diaries were cross-referenced with relevant literature. This facilitated the segmentation of data, which provided the foundation for further analysis in subsequent phases. While this approach has a significant advantage of generating new insights, it is also time-intensive and requires continuous reflection on the various data sources. In the final phase, all data were analyzed and synthesized, enabling the identification of patterns and the development of substantiated conclusions and recommendations.

Data analysis code book

A research diary and a codebook were used during the data collection and analysis processes. In the different stages data and codes from both surveys and interviews were organized in separate cases that represented conceptual categories. The exploratory themes created a high number of new codes that also affected three separate processes in the absorption of knowledge and its effect on integrating (system absorption) and assimilation (human agents' absorption).

The codes needed to address the type of relation between UASs and SMEs since we aimed to describe effective processes for knowledge modification that are based on coherent processes in SMEs. For example, most theories on the absorption of knowledge lack explanations of how the absorption of knowledge is affected by epistemic uncertainty as a result of inquiry in itself. We found that when smaller SMEs made inquiries, these were often informal and based on (temporal) constraints that limited making new organizational-knowledge representations (subordinate). This affected how these systems and agents and their types of processes could be made continuously volatile or adaptive, rather than produce a one-off solution to epistemic uncertainties. Students often find one-offs successful in terms of proof for their research.

The three phases of absorption of knowledge often require a follow-up phase after eventual transformation: maintenance and support capacities or ways to create effect in terms of skills adaptation, risk assessments or, in general, higher maturity through evaluation of new peripheral knowledge. Exploring this among students addressing epistemic uncertainty we found that increased epistemic doubts affect legitimation by SMEs.

We also found that a support mechanism is often present if the knowledge is not peripheral but belongs to the core domain of knowledge. However, higher uncertainty changes the direction of new knowledge and its distribution and consequently its semantics for expressing and reasoning on these constraints.

This example shows that although our framework suited our challenges, it required deeper understanding of how to deal with high differentiation levels of SMEs and their processes and agents and environments.

3.10. Conclusions: different relations with different realities

Our theoretical framework tells us that paradigm shifts require tools that enable us to understand new realities as a result of epistemic uncertainty. It requires knowledge of future knowledge requirements and SMEs to support this. Therefore, we need information that helps to reduce the ambiguity between real-life knowledge and epistemological manifestations.

This, we argue, requires consciousness in moves between the different epistemological and practical dimensions that create flows of information to each of these dimensions. This is the conceptual level of the absorption of knowledge. The absorption of knowledge requires activities, both individual as well as organizational that create forecasting or probabilistic knowledge as well as reflexive knowledge based on the activities of human agents in different networked environments working with different types of (human) agents.

So, our questions are concerned with how these dimensions reflect each other's true identity through activities for learners. It concerns questioning how RUAS and SMEs develop different types of inquiries, instruments and/or tools that support information exchange in each dimension.

To do so we need to develop epistemic and pragmatic knowledge that can express changes in existing descriptions and categorizations of knowledge, its domains, disciplines, grammar and semantics and finally its functionality. These descriptions contain knowledge barriers in both dimensions that affect not only new constitution of knowledge, but also new meanings for human agents.

Using our theoretical framework and MMR sequential analysis we conceptualized an innovation space with epistemic and practical dimensions where different methods are used to determine knowledge needs as a response to epistemic and practical uncertainties. By comparing cases we identified sets that could help to understand sets of various environments that have differentiated capabilities and routines that require constant changes.

This chapter has outlined the methodological approach used to address this complex issue, which necessitated an in-depth exploration of the dynamic capabilities of human agents in different contexts, situations or events, or habitual states. This particularly concerns knowledge on how human agents (both students and employees) and systems move either unaware or consciously between the two dimensions to exchange information or knowledge in order to revise, adapt or create capabilities to respond to epistemic constraints they encounter.

Summary

UASs and SME each have a share in exchanging information that reduces their epistemic and practical uncertainties about skills and capabilities to make them responsive to emerging technologies. Sets may have varying epistemological dimensions that require a specific refinement or necessary inquiry. Solutions may come from uncontrolled trial and error which may be effective but not efficient. Therefore, epistemic governance are helpful in selecting projects, agents and students, based on different knowledge claims that can act as scenarios or simulations. To define these scenarios, we need constant refinements of statements based on developing knowledge activities, domains, disciplines, and objects derived from the information exchange.

Chapter 3 outlined complex processes of the absorption of knowledge between UASs and SMEs. We found various themes to describe our findings. We carefully selected themes in each phase and refined or rejected them in following phases that eventually resulted in a group of themes and sub-themes that remained consistent for all phases involving participants. We use our analytical model to describe our findings in the next chapter.

CHAPTER 4

Research findings

Chapter 4. Research findings

This chapter describes our research findings. It continues as follows:

4.1 Introduction

4.2 Visual representation

4.2.1 Visual representations of the cases

4.2.2 Case A (Triple Helix)

4.2.3 Case B (Sharing logistics)

4.2.4 Case C (Sharing human resources)

4.2.5 Comparative analysis of Case B and Case C

4.2.6 Case D1 (Volatility)

4.2.7 Case D2 (Future skills)

4.2.8 Case E (Learning culture and responses)

4.2.9 Case F (Conceptual environments; Y0-Y9)

4.3 Main conclusions

4.1 Introduction

The MMR approach was primarily chosen to enable comparative analysis between different groups of students and the various projects they participated in. RUAS (Rotterdam UAS) has established dedicated timeframes in its educational programs for specific research projects aligned with emerging societal themes. In these projects, students collaborate with companies on research into a given thematic area. Following analysis, we integrated the qualitative and quantitative data to present our findings. Data integration provides a more comprehensive and holistic view of the various boundaries that influence the absorption of knowledge. It allows us to identify patterns and relationships that might not be apparent when analyzing qualitative or quantitative data in isolation. Finally, merging data after sequential analyses allows us to add progressively deeper insights, reinforcing the exploratory nature of the research. This approach also gives us the opportunity to investigate inconsistencies or similarities between different data sets.

Company size appears to be a limitation for many businesses choosing to participate in research. However, interviews with smaller SMEs reveal that this is not always the primary explanation for their decision not to collaborate with RUAS. Our study aims to uncover the primary objectives of the absorption of knowledge: whether that be assimilating new information into existing frameworks, preparing the system for future initiatives, developing potential absorption capacity through assimilation processes, or addressing urgent capability constraints that require immediate resolution. This approach allows us to describe distinctions in the absorption of knowledge that show how SMEs develop new knowledge to improve their overall capabilities, adapt to changing environments, and solve urgent operational challenges.

4.2 Visual representation

We used visual representations to present the findings for the following reasons:

- Visual representations provide a powerful tool for communicating complex ideas to diverse audiences, including other researchers, stakeholders, or practitioners in the field (Miles & Huberman, 1994).
- We aim to preserve the integrity of our assertion: this makes it possible to verify and reflect on whether the use of concepts has been consistently reasoned across different contexts and cases. Not knowing what particular knowledge is needed to respond to uncertainties hinders the process of absorbing knowledge.
- Tensions, in this context, refer to the dynamic and often conflicting forces that shape how knowledge functions are constituted, enacted, and transformed in practice under uncertain conditions. By examining these tensions, we can illuminate distinct constituents of knowledge functionalities and their operational implications. These tensions reveal critical points where existing capabilities, cognitive and epistemic understandings, and organizational structures interact and under time constraints create conflicting understanding resulting in uncertainties that influence decision-making and adaptation processes in small and medium-sized enterprises and learning agents and students involved. To structure this analysis, we identify and investigate multiple forms of tensions manifested in empirical cases:

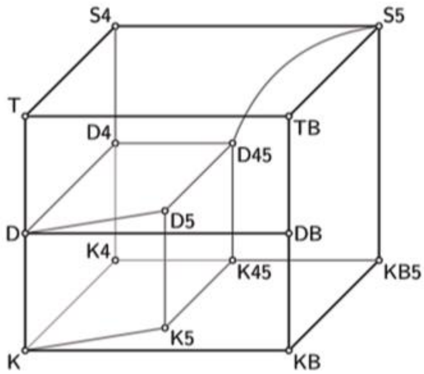
The basis for the analysis is the epistemic modal logic represented by the modal cube, in which the conversion of information into formal and informal knowledge and the associated expressions (labels of information) can be analyzed as knowledge. These properties correspond to key axioms in the modal cube: reflexivity, factivity, transitivity and symmetry (for conversion to knowledge)

Tensions

In real-world epistemic analysis, agents like students or professionals may interpret knowledge imperfectly, straining the ideal frame conditions (e.g., assuming symmetry when evidence is asymmetric).

Awareness

Different “shapes” of the modal cube correspond to which of the axioms about knowing are adopted and or how many systems an agent or an organization includes. The cube shows how the different types of logics, and how each is responsible for different knowledge properties and its effects.



Epistemic logics in a modal cube shows what is assumed about knowledge. In our research we analyze how human agents are affected by their use of (in)formal logic and/or awareness of this logic, for example the use of reflexive instruments. This awareness turns it into a hypercube where the agent is looking at different worlds and or situations.

This figure shows the ideal modal cube and how this shape changes based on dominant logic.

Figure 25. Example of a hypercube, based on Leme, R., Olarte, C., Pimentel, E., Coniglio, M. E. in The Modal Cube Revisited: Semantics without Worlds (Technical Report) arXiv:2505.12824

Epistemic assumption about knowing	Modal system and position in/near cube
Knowledge is factive	Moves from K to T: reflexive frame
Agent knows that they know (positive introspection)	Reflexive + transitive
Agent knows that they don't know (negative introspection)	Adds 5, giving S5-like systems (equivalence frames)

Table 24 Example how knowing affects labels (conversion) of) information

Different positions and shapes of the modal cube when compared to real life practices

Vertical axis: Density and gravity/ Heaviness of beliefs

This axis tracks show gravity of information beliefs pull downward making ideas harder to maintain. Bottom (high gravity): Weak systems with low density where factivity is affected by doubt. Factivity distinguishes strict knowledge from weaker doxastic states (e.g., beliefs based on information from others than formal evolution and reflective systems).

Top necessary knowledge (S5) where all knowledge is certain and self-aware continuously updated and compared to other situations, but this is impossible in real life.

Bottom strong beliefs are formed through everyday doubts and facts, straining assumptions on what is true in terms of formal knowledge. Tensions appear as a result of constant (temporal) realism.

Horizontal axis: Free ideas vs. strict rules/ Rhizomatic vs. constrained expertise
Left: free-flowing ideas, like a web or lattice of labels that are punt on different situations. Knowledge as a result spreads in different directions without fixed paths (in contrast to constraints) think brainstorming or informal or colloquial knowledge. Danger of rigid endings since ideas branch endlessly.

Right end (strict expert rules or protocols): Narrow, semantic and or syntactic barriers based on expertise enforces limits. This situation is deal for great for professionals but creates isolation in terms of new ideas. This a regime of constraints on the far end.

Tension Cube Element	**Corresponding Aggregate Dimension**	**Meaning of Visual Deformation/Arrow**	**Empirical Grounding**
Horizontal stretch (width of cube)	1. Situational Embeddedness & Relational Complexity	Wider = more pulling forces from context, relationships, and constraints → knowledge stays embedded in daily operations	High code counts in 1.1–1.3 → cube becomes flat and wide (most cases)
Vertical stretch (height of cube)	2. Movement Across Levels of Abstraction	Taller = stronger upward movement from concrete to conceptual/strategic	High code counts in 2.1–2.3 → cube becomes tall (successful/ambitious cases)
Green arrow (usually horizontal/right-ward)	3. Observed Pragmatic Trajectory	Direction and strength of what actually happened (data-driven path)	Dominant codes in 3.1–3.3 → thick arrow along the base (pragmatic outcome)
Red arrow usually upward/diagonal)	4. Desired/Normative Integration Trajectory	Direction participants explicitly wish for but rarely reach	Codes in 4.1–4.3 often counterfactual ("if only…", "we need…") → weak/dotted arrow pointing toward unrealized potential

Table 25. Different positions and shapes of the cube

To move from a modal cube to one with horizontal "situational embeddedness" and vertical "movement to levels of abstraction" tied to interview codes, map epistemic properties (like T, 4, 5 axioms) onto qualitative data from interviews, treating the cube as a dynamic framework for analyzing knowledge in context.

Horizontal axis: Situational embeddedness

For example: the horizontal axis capture how deeply knowledge is rooted in specific contexts (left: highly embedded, concrete situations) versus detached generality (right: abstract, decontextualized).

Interview codes like "team dynamics" or "daily routines" anchor left-side vertices (weak systems like K/KD), showing doxastic states tied to local rumors or biases.

Codes like "general principles" push right toward S5-like ideals, but tensions arise when practitioners over-abstract, straining symmetry (for example in routines)

Vertical axis: Abstraction levels from interviews

Bottom (concrete codes): Specific quotes (e.g., "Client called upset") this shows weak frames (high "gravity," non-factive beliefs).

Top (abstract codes): Themes (e.g., "trust erosion") → S5 equivalence, but real interviews reveal downward pull from doubts.

├ 1. Horizontal Stretch: Situational Embeddedness & Relational Complexity

(Wider cube = higher complexity and richer connectivity; pulls toward operational detail)

├1.1 Deeply interwoven with daily operations and resource constraints

├1.2 Multiple interdependent actors and regional/personal relationships

└1.3 Institutional/compliance barriers and slow sector dynamics

├2. Vertical Stretch: Movement Across Levels of Abstraction

(Taller cube = stronger shift from concrete-operational to strategic-conceptual layers)

├2.1 From immediate problem-solving to reusable methods/principles

├2.2 From local fixes to structural/strategic reorientation │

└2.3 Explicit creation or development of new (theoretical) knowledge

├3. Green Arrow: Observed Pragmatic Trajectories

(Green arrow = dominant observed path based on the inquiry. Concrete phenomena re-constructions to modalities.

├ 3.1 Cost-driven, risk-reducing, and flexibility-oriented outcomes

├ 3.2 Operational urgency as primary focus

└ 3.3 Student/extra hands role in immediate problem resolution (vs role in long term problems)

└ 4. Red Arrow: Desired/Normative Integration Trajectory

(Red arrow = direction participants may value but is difficult to achieve since fuller integration also requires higher abstraction)

├4.1 Need for cultural shift (e.g., away from competitor thinking, toward collaboration)

├ 4.2 Call for neutral platforms, better information dissemination, and knowledge sharing

└ 4.3 Frustration over opportunities for learning and innovation

Table 26. Code tree of dimensions cross case

```
├Vertical Axis: Heaviness of Beliefs (Density/Gravity)
│  ├ Bottom (High Gravity: Weak Systems K/KD)
│  │  ├ Pragmatic Doxastic States
│  │  │  ├ Everyday Doubts → Non-Factive Beliefs
│  │  │  ├ Temporal Realism → Constant Strain on Truth
│  │  │  └── Information from Others in networks → Informal Evolution
│  │  └── Low Density Knowledge
│  │     └── Strained Factivity (a claim to know: such as crane operator in Case A)
│  └── Top (Low Gravity: Ideal Systems S4/S5)
│     ├── Necessary Knowledge
│     │  ├Certain & Self-Aware (Full Introspection)
│     │  ├ Continuously Updated
│     │  └── Comparative Across Situations
│     └── Unrealistic in Practice (Impossibility)
│
└── Horizontal: Knowledge Flow Structure
   ├Left(Rhizomatic: Free-Flowing Ideas)
   │  ├ Web/Lattice Structure
   │  │  ├ Branching Without Fixed Paths
   │  │  ├ Brainstorming/Informal Knowledge
   │  │  └── Colloquial Labels → Situational Spread
   │  └── Danger: Endless Branching (No Rigid Endings)
   └── Right (Constrained: Strict Expertise)
      ├Narrow Semantic/Syntactic Barriers
      ├ Expert Protocols & Rules
      ├ Professional Isolation
      └── Constraint Regime (Limits New Ideas)
```

Table 27. Aggregate axes

4.2.1 Visual representations of the cases

To support our results of our research we created visualizations in order to a) avoid high levels of abstraction, b) adhere to the themes to identify patterns, and c) be able to find deviations. The figures mainly represent how the integration of epistemological and pragmatic dimensions affect the absorption of knowledge.

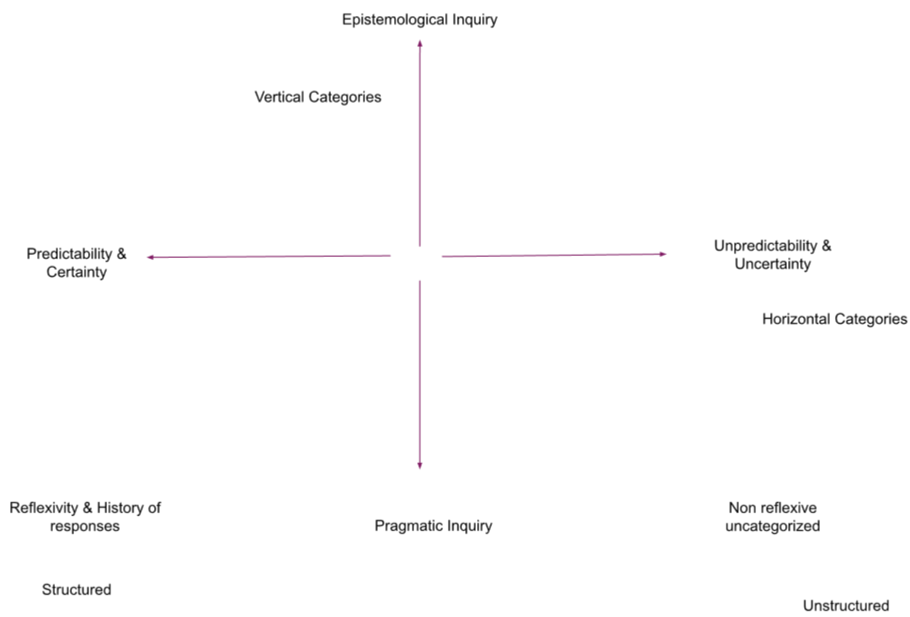


Figure 26 Visualization of tensions basic figure without tension arrows.

The modal logic cube framework relates to absorptive capacity between two systems by providing a structured way to visualize and analyze how knowledge is shared, transferred, and integrated across organizational boundaries. This enables understanding of the effectiveness and dynamics of knowledge exchange and integration essential to absorptive capacity, which is the ability of UASs and SMEs to identify, transfer and transform into functional knowledge apply knowledge gained from another. The semantic plane adds a topological dimension to this model by representing knowledge elements as points within a topology derived from the modal cube. In topological semantics of modal logic, the modal operator □ (necessity) corresponds to taking the interior of a set, while ◇ (possibility) corresponds to the closure. By placing the semantic plane within the modal cube topology, the cube not only represents the logical connections but also models the continuity, and boundaries of knowledge elements in the innovation space. A horizontally stretched modal cube indicates an emphasis or extension in the dimensions represented along the horizontal axis of the cube.

Horizontally stretching the cube signifies: an expansion of detail in the knowledge or situational relationships which may be dispositions, transfer properties, or other interaction factors. This can represent heightened complexity or richer connectivity in how knowledge or modal properties are related in that dimension compared to the others. A vertical stretch of the modal cube implies an expansion or emphasis associated with different levels of abstraction, structured conceptual layers, or hierarchical organization within the system being modeled. In modal logic the vertical dimension allows moving between different levels of abstraction.

The orange arrows (in figures 26 - 32) symbolize the direction in which the outcome moved (inquiry to the construction of a phenomenon), while the purple arrows (in the next figures), based on the framework, indicate which direction would contribute to the integration of different dimensions. For example, the extent to which reference is made to the creation and development of new knowledge, the indicated need for it, and so on. We did not use red or green as colors since there is no right or wrong here.

4.2.2 Case A (Triple Helix)

Case description: The case took place in Schiedam, where old traditions are giving way to new activities, including changes to a knowledge-intensive manufacturing industry that involve knowledge exchange and increasing innovative capacity.

Much is being done to the physical infrastructure of the area to improve accessibility, but less is happening on knowledge exchange and access to create networks to promote innovative capacity. The aim of cooperating with educational institutions, especially RUAS, is to help develop a new labor market by researching solutions for the organizations involved. Seven medium- to-large SMEs worked on a transition path together with RUAS.

Uncertainty, dispositional context and sociomaterial environment: The environment of the SMEs involved is highly dynamic and uncertain. Digitalization will have a great impact, but companies are unsure how this will affect knowledge in terms of developing new skills. The actors involved think more cooperation with other companies and education is needed. Regional cooperation on new scenarios for the sector is seen as most beneficial to their organization. A service scenario is both undesirable and likely. This requires other kinds of knowledge and skills. Employee policies (human resources) is seen as the most important aspect, along with labor-market policy limitations in the organization to enable collaboration with other companies/organizations (within and outside the maritime sector). HRM themes seen as important are task analysis, organizational development, learning through upskilling and retraining. A flexible, scalable workforce is especially important, in addition to region. The latter may indicate the relationship with labor-market policies.

Accommodation and support: All SMEs have HRM support and the capacity to support exploration. HRM themes seen as important are talent, training, task analysis, organizational development. Lifelong learning becomes important especially through upskilling and retraining; too little is still being done on this. Collaboration is seen as important, especially in knowledge development, skills and product development. Cooperation on training takes place less with public schools and business is seen as leading in this.

Distinct Relationship: RUAS was relatively unknown to SMEs. There were no clear expectations or experiences.

Absorption/clustering of dynamic capabilities: SMEs hold different perceptions that color their approach to changes in dynamic capabilities. The process did sense the needs on a higher level. The focus remains on the ordinary rather than dynamics (adaptation) strategies.

Disposition of knowledge: SMEs took strongly individual approaches to researching and exchanging ideas on how to train employees on new skills. Obtaining knowledge of new applications is often difficult due to the need to maintain competitive advantage.

Conversions and translations: It is difficult to use standardized objects since little is known about the available types of application, knowledge or skills. SMEs have different perceptions of what type of knowledge needs to be developed

Epistemic governance: Local municipalities, research institutes and RUAS gave clear guidance on the projects. However, RUAS had little experience in developing these pragmatic instruments for SMEs.

Temporality: This is crucial in that SMEs lack the time to explore the methodical modes. RUAS had no experience in this either.

Tensions: There is tension in the absorption of knowledge resulting from the need for new ideas and solutions to urgent problems that require certainty though pragmatic inquiry. Our data collection findings show a clear sense of the threat of new technologies but also uncovered undefined key activities such as allocation of new talent. The scenarios are not conclusive. Sensing is relatively high, seizing is low. According to the interviews, survey and meetings, a dynamic approach to capabilities confirms the reconfiguration on both micro and systems levels (transform). The process of absorption affects the horizontal distribution of knowledge, a fact our research also confirmed.

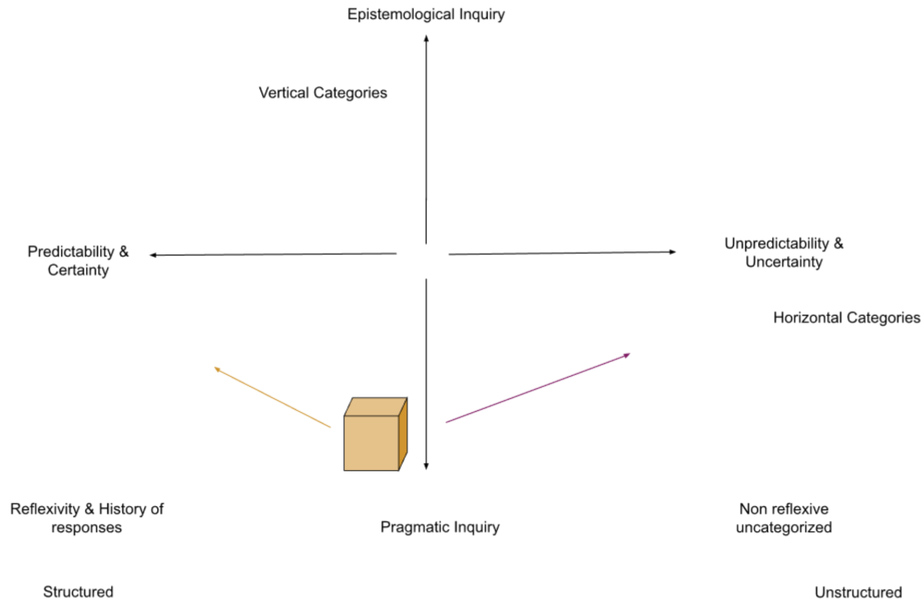


Figure 26. Tension in Case A

Key insights: structural embeddedness effects exploitation

1. Regional labor market responds inadequately to new technologies in term of skills. Organizational and sectoral structures shape the embedding and flow of knowledge. Other external knowledge sources are unavailable.
2. Triple Helix constructions require strong governance of actors’ capability to develop insights into barriers for knowledge identification and dissemination of effective routines.

Case Triple Helix (A1: Mercury)

Fragment (NL)	Translation (EN)	Code(s)	Link to Tension Cube
"Disruptieve technologieën, consequenties voor organisatie. We zijn geen maritiem bedrijf."	"Disruptive technologies, consequences for the organization. We are not a maritime company."	1. Horizontal Stretch: Situational Embeddedness & Relational Complexity 1.1 Deeply interwoven with daily operations and resource constraints	Sector-specific context limits perceived impact of disruption – knowledge/technology is deeply embedded in unique operational realities (horizontal pull).
"Robotisering, sensoren in onze kranen, veiliger, meer een gadget, geen bedreiging gaat ons werk overnemen."	"Robotization, sensors in our cranes – safer, more of a gadget, no threat that it will take over our work."	3. Observed Pragmatic Trajectory 3.1 Cost-driven, risk-reducing, flexibility-oriented	Technology seen as incremental improvement (safety gadget) rather than transformative – pragmatic acceptance without fear of job loss (green arrow dominance).
"Dat is in de maakindustrie dus wel."	"That does happen in the manufacturing industry, though."	1. Horizontal Stretch (sector comparison) Epistemic Tension (overall)	Implicit contrast with other sectors where disruption is real – highlights sector-specific relational/operational embedding as a buffer (horizontal complexity).

Fragment (NL)	Translation (EN)	Code(s)	Link to Tension Cube
"Projecten zijn vrij intensief als je kijkt naar personeel wat je nodig hebt. 1 ploeg kijkt naar getij, andere ploeg naar gewicht. Vaak dubbele bezetting."	"Projects are quite intensive... One shift looks at the tide, the other at the weight. Often double staffing."	1. Horizontal Stretch: Situational Embeddedness & Relational Complexity 1.1 Deeply interwoven with daily operations and resource constraints	High human dependency due to unpredictable factors (tide, weight) and safety needs – strong operational embedding and resource intensity (extreme horizontal stretch).
"Wij zijn afhankelijk van machine maar ook mensen."	"We depend on machines but also on people."	1. Horizontal Stretch (barrier) 3. Observed Pragmatic Trajectory	Balanced but tense dependency on both technology and human labor – pragmatic reality where people remain central, limiting full automation (green arrow, but with horizontal tension blocking deeper change).

4.2.3 Case B (Sharing logistics)

Case Description: RUAS and industry partners in the logistics sector conducted extensive research into the promising sharing economy. They carried out applied research to determine the extent to which logistics concepts based on the sharing economy can contribute to a significant reduction in CO_2 emissions and to increasing efficiency within the sector. Th study took place in a consortium of RUAS and SMEs concerned with sharing concepts in logistics.[3]

The research model focused on the sharing context and the Living lab as a way to share knowledge. Interviews were held with representatives of participating organizations, HR managers, lecturers and students. A second study, based on the results, was conducted in the field of human resources (HR case) with questionnaires— based on the preliminary research and the analysis of the relevant topics— sent to HR managers at 19 logistics companies. HRM students (n=83) helped to conduct approximately 40 interviews and their impressions of the research they did was evaluated through another questionnaire. Specific conditions and boundaries to the absorption of knowledge in organizations were examined. Participant observations were made at meetings with HRM teachers. The cases were then compared for effective transfer as a result of the specific HR knowledge advantage in relation to other knowledge boundaries in other knowledge regimes.

Uncertainty, dispositional context and sociomaterial environment: For all organizations involved in supply chain networks, sharing knowledge is a new challenge.

Accommodation and support: Some organizations were highly experienced in articulating their knowledge needs and recruiting students for specific knowledge-management projects. These SMEs used several HRM tiers for evaluation. In contrast, smaller SMEs opposite had little or no KMM and HRM support or accommodation.

Distinct relationship: The choice for RUAS was based on detailed agreements on work packages, deliverables and the lecturers and students involved.

Absorption/clustering of dynamic capabilities: Smaller SMEs had no specific arrangements for exchanging knowledge, human-resource development, or knowledge management. Students were involved in mobilizing various activities (seizing). New business models were not realized (transforming).

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[3] van Duin, R., van den Band, N., de Vries, A., Ouasghiri, M., Verschoor, P., Warffemius, P., & Wiersma, M. (2022). Sharing concepten in stadslogistiek: The Big Five. Logistiek+, tijdschrift voor toegepaste logistiek, 13, 48-73. https://www.kennisdclogistiek.nl/projecten/logistiek-tijdschrift-voor-toegepaste-logistiek

Disposition of knowledge: Because of strict agreements, the inquiry process was carefully managed in the different worlds. Outcomes were monitored both in curricula assignments and in the SMEs' use of data in information.

Conversions and translations: Standard data collection methods could be used in the comparable disciplines and domain knowledge in both UASs and larger SMEs. Most logistic SMEs were familiar with applications and knowledge distribution skills found in both worlds.

Epistemic governance: The project goals changed during the process, mainly due to the extensive program, strict time schedules that stunted involvement and curriculum demands. Carefully orchestrated dissemination was successful.

Temporality: Students knew how knowledge is used: their experience shaped their ideas on how knowledge is distributed, which supported their inquiry.

The logistics Sharing Consortium involved mostly large SMEs that were busy transforming their processes (highest cluster of dynamic capabilities involved). Participating companies considered knowledge sharing and dissemination important due to environmental changes. However, organizations had different human-resource capacity that would allow them to participate in an innovation space. Organization size and daily operating pressures played a major part in this (capability maturity).

Some organizations were more successful in transferring knowledge, using their greater capacity to extract relative knowledge advantages from knowledge production in the innovation space. The experience and skills of agents contributed to this effect. Knowledge transfer was positively influenced when actors from organizations and UASs jointly translated accumulated knowledge to necessary new knowledge about applications (procedural knowledge). This also related to efficient absorption capacity. Dissemination of formal, explicit knowledge between collaborating systems that mainly transfer this type of knowledge was particularly efficient. However, using formal and explicit knowledge for transfer was ineffective in smaller SMEs because of the large degree of differentiation in knowledge-management systems and representations. For organizations, transforming the knowledge advantage appeared to be the most difficult obstacle (pragmatic knowledge barrier), especially in the short-term. In general, it was the most difficult obstacle in the dissemination process, besides identification and transfer.

Tensions: There is tension in the distinct the absorption of knowledge process between UASs and SMEs due to differences in HRM and between KMM accommodation. Organizations find it hard to share their information and expert knowledge that come mainly from clients or partners with higher education (UAS). SMEs are often unfamiliar with new types of knowledge acquisition such as field labs.

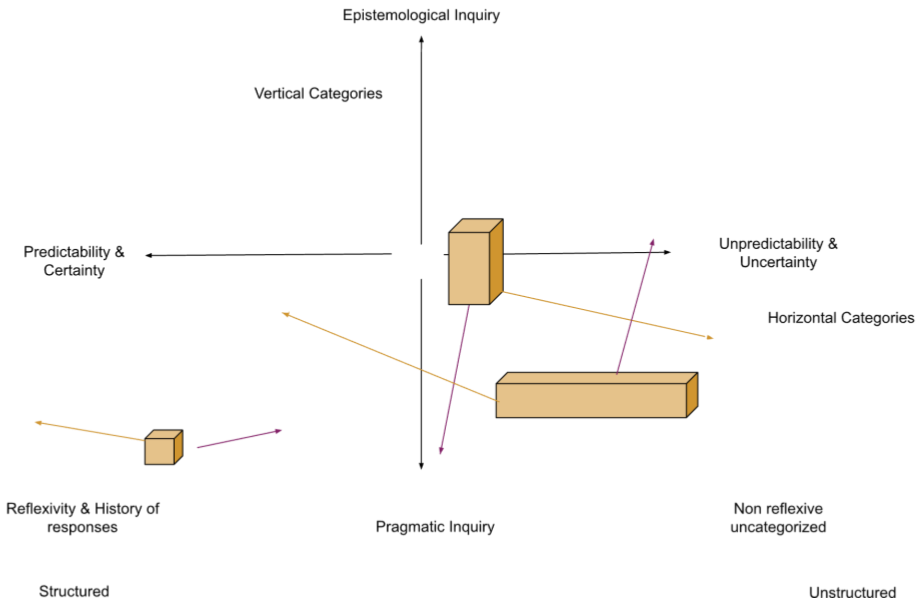

Figure 27 Tension in Case B

Key insights: contextual dispositions of SMEs

1. Collaboration of UAS in this consortium shows strong emphasis on dissemination of effective strategies.
2. Participation of SMEs shows reservations in data sharing between SMEs.
3. Smaller SMEs face different constraints for human resources and knowledge sharing in networks

Case B: Sharing Logistics (RBS team Student Team 11)

Interview was conducted in (EN)	Code(s)	Link to Tension Cube
"Not really. Most of the time, the supermarkets handle these situations themselves. This is because of the core nature of the product. Once the fresh goods are on the shelves and returned, nine out of ten times they are already past the expiration date."	1. Horizontal Stretch: Situational Embeddedness & Relational Complexity 1.1 Deeply interwoven with daily operations and resource constraints	Product perishability is inherent to fresh goods logistics – strong operational embedding limits options (horizontal pull).
"We did a little research to see if this was a possibility. Eventually we did not pursue it because the revenue it generated simply wasn't adding much more value to the business."	3. Observed Pragmatic Trajectory 3.1 Cost-driven, risk-reducing, flexibility-oriented	Small-scale experiment abandoned due to low financial return – pragmatic, cost-benefit decision dominates (thick green arrow).
"Furthermore, we had a dilemma when picking up the waste from the store. We have about three stops per truck... this means that the fresh goods (that still need to be delivered to the next client) are sitting next to the waste. This was not really appreciated."	1. Horizontal Stretch (barrier) Epistemic Tension (overall)	Practical/logistical dilemma (hygiene, space, customer perception) blocks potential innovation – relational/operational complexity overrides idea (extreme horizontal stretch).
"So, we don't pick up waste, but we do pick up 'Fust'. 'Fust' basically means all the materials needed for handling (e.g., crates, pallets). These are picked up once the goods are dropped off... old ones can be picked up and reused for the next client."	3. Observed Pragmatic Trajectory 3.2 Operational urgency and quick wins Partial 4. Desired/Normative Integration (weak)	Shift to reusable handling materials ('Fust') as workable circular solution – pragmatic reuse without risks; mild sustainability benefit but stays operational (dominant green arrow, hint of red).

4.2.4 Case C (Sharing human resources)

Case description: Collaboration between education and industry is effective when knowledge flows in both directions. These knowledge flows require transfer mechanisms to be more effective. A key element in the transfer mechanism is access to the embedding of social innovation in curricula (Saha & Sáha, 2022).In this case we studied whether social innovation is accessible in terms of identity and if HRM students can articulate it to initiate a change to the social innovation. This allowed us to find the necessary transfer mechanism to the curriculum. We aimed to analyze the knowledge representations (indicators: strategy, knowledge codifications, HR maturity and experience in collaboration) related to peer-level reciprocal exchange in horizontal knowledge distribution between UASs and SMEs. In this setting we aimed to find and explain possible barriers for transfer and transformation. This study involved 17 SMEs (seven medium-sized, six small-sized and four large SMEs).

Uncertainty: Smaller SMEs faced challenges in upskilling employees due to digitalization. We found that due to increased efficiency in production in supply chains these SMEs found it difficult to address the sustainability of the workforce, especially lorry drivers. Finding new program planning methods was complicated for some SMEs.

Accommodation or support: Most SMEs planned work schedules without sufficient HRM support. Often HR is was involved in constraints on exploitation pressure schedules and part time recruitment.

Distinct relationship: Most SMEs had no previous involvement with UASs. Nor had either party ever exchanged documents or experiences, which affected collaborative problem-solving.

Absorption/clustering of dynamic capabilities: No new plans (sensing) were identified.

Disposition of knowledge: Environmental conditions were not considered. As students had not been involved before, the situations and dispositions were new to them.

Conversions and translations: Conversion from tacit-to-explicit codification, using frameworks or suggestions for reconfigurations proved difficult.

Temporality: Students were not used to the way knowledge is distributed and articulated. Earlier difficult experiences in seizing shaped their ideas on knowledge. Access to tacit and embedded knowledge was difficult. The use of conceptual knowledge affected the inquiry. Students had more experience with explicit formulations, which in most cases was absent.

Epistemic governance: The goal of the project was to introduce social innovation as a way to modify knowledge for SMEs with little HRM support and or accommodation in terms of earlier experiences (foreknowledge). We surveyed midsized SMEs (50–100 employees) in transport and logistics.

The findings show that for all questions alpha was α0.8524. For the construct boundary-spanning capacity, it was α0.6250. This construct comprised 13 items. Variance within the construct was low on experimenting with work processes (s20.28) and high on HR network maintenance (s20.90). Sharing knowledge through collaboration gave an extremely diverse picture (s2 0.95). These SMEs said that they noticed clear changes in the organization that would have a short-term effect on business strategy, workforce, methods of innovation and the knowledge-management system.

The respondents uniformly acknowledged that technological advancements require short- and medium-term adjustments in organizational functions, partly due to increased labor productivity. A common finding among all respondents was that knowledge rapidly becomes obsolete, underscoring the importance of cooperation and knowledge sharing—particularly with customers, partners, and employees.

Knowledge sharing is not formalized in nearly all organizations, and they do not participate in PPS partnerships. Collaborative efforts, such as those in field labs or Living labs, are absent, with only three SMEs collaborating with a research center. There is no collaboration with universities beyond vocational education training programs. HR systems do not codify skills or store knowledge.

In the context of transitioning to a more sustainable economy, knowledge sharing was identified as a pivotal factor. All respondents deemed innovation adaptation as essential. There was a clear need for HR instruments to facilitate social innovations, yet students are not being effectively utilizing them. Currently, only four companies had an active policy in place to address this gap.

Embedded codes and conversion (C3): We investigated whether and to what extent the embedding of knowledge acts as an obstacle to the process of representation, transformation, mobilization, and legitimization for students.

We studied how the conversion of information occurred and to what extent students added information. This allowed us to distinguish how students identify normal capabilities (e.g., processes and task management) and dynamic capabilities, which are part of the absorption location process (sensing, seizing at the individual level, and transforming or reconfiguring by the organization).

Category (number of codes)	Random order solution topics (possible name)
Administration procedures (5)	Autonomous teams
Client involvement (8)	Happiness booster
Communication on innovation (6)	App for driver's invoices
Culture clashes (11)	Sustainability awareness training
Exploitation pressure (11)	Social media strategy
Procedural constraints (12)	Digital idea box
Human resources (26)	Employer branding
Learning culture (29)	Policy development for sustainable employability (2)
Digital constraints (32)	
Undefined (18)	

Table 28. Embedded codes in Case C

Double aspects of information in coding and transmission:

ORG: A medium-size shipping company currently using increasingly more digital systems. From initial analysis we learned that most human capital constraints deal with how to help older employees overcome learning difficulties in using the new digital systems. Dominant codes: customer relations play an important role. New codes depend on this dominance.
RESP: Respondent often repeats (lots of) information (see analysis) on the subject, e.g., how the new systems affect the work of the older generation of employees. The subject of getting older and using IT is a big problem. Respondent gives no indication of any strategy to find a solution to the problem. Near the end of the interview the student concludes that "all is clear now" yet this was not discussed. On many occasions there is a pattern: if the respondent gets no reaction to information, this is followed by even weaker reactions. During the interview the respondent clearly stated the effects of digitalization.

Table 29 Example of comparison of embedded codes

Comparison of 539 codes in 19 documents: As theory confirms: a review of students' transcriptions of their findings revealed expectations based on lack of effective earlier required knowledge in both frameworks and practices in visiting a context with different possible outcomes (in contrast with correspondence learning). The analysis showed a high density of conflicts with high-gravity information making it difficult to identify constraint situations.

Tensions: There was tension between knowledge based on experiences, the dispositional knowledge and experiences of student based on a corresponding approach of knowledge. Students may have had little experience of how knowledge 'behaves' under specific conditions. Here dispositions contrast with propositional knowledge.

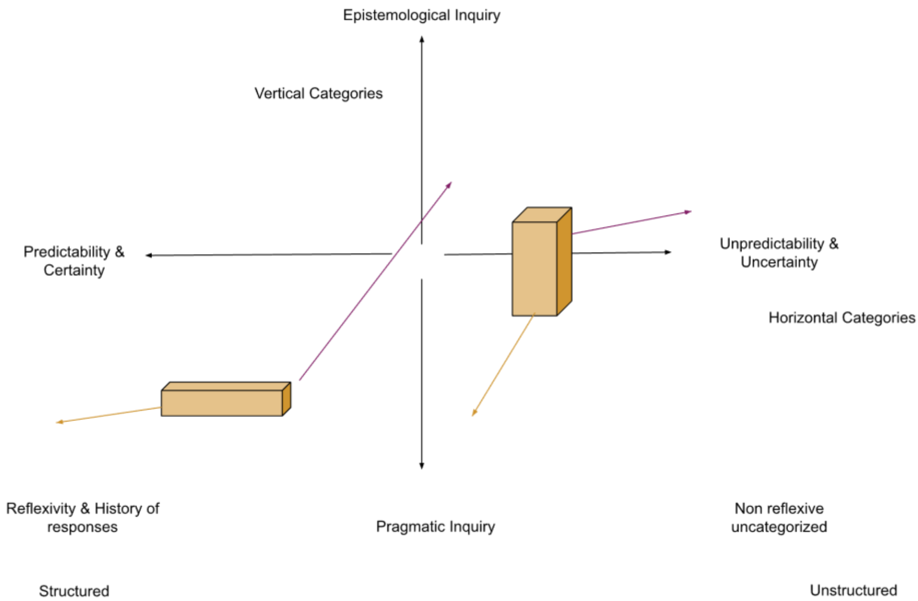

Figure 28 Tension in Case C

Key insights: higher pragmatic encroachment based on high temporality

1. SMEs are highly differentiated in their strategic diagnosis. Smaller SMEs use evidentialism based on daily routines or microprocesses.
2. This affects the persistence of existing beliefs in older organizations that have employees with lower levels of formal education.
3. High temporality creates stronger pragmatic barriers that reject risks for identification and acceptance of knowledge that come from concepts.

Case Sharing Human Resources (C8)

Fragment (NL)	Translation (EN)	Code(s)	Link to Tension Cube
"ik denk dat een van de belangrijkste dingen bij ons de samenhang tussen de afdelingen is, maar aan de andere kant vind ik ook wel het dat nu pas begint te ontstaan dat mensen beter begeleid worden in hun functies. En voorheen deden ze daar niet aan of was het geen issue."	"I think one of the most important things for us is the cohesion between departments, but on the other hand, I also feel that only now is it starting to emerge that people are better guided in their roles. And previously, they didn't do that or it wasn't an issue."	2. Vertical Stretch: Movement Across Levels of Abstraction 2.2 From local fixes to structural/strategic reorientation Partial 4. Desired/Normative Integration Trajectory	Recognition of emerging need for better guidance and inter-departmental cohesion – indicates a desired shift from ad hoc to more structured/strategic organization (moderate vertical stretch + red arrow).
"We zijn met ze alle aan de slag, maar waren we wat minder bezig met de organisatie en vastleggen van dingen. Voorheen was het allemaal maar los los los.."	"We were getting everyone started, but we were less focused on organization and documenting things. Previously, it was all just loose, loose, loose..."	1. Horizontal Stretch: Situational Embeddedness & Relational Complexity 3. Observed Pragmatic Trajectory	Historical informal, ad hoc approach ("loose") reflects pragmatic, operational focus without formal structures – strong horizontal embedding in daily practice (wide cube, green arrow dominance).
"Dus ik denk dat op allerlei gebieden moet het zich ontwikkelen. Dus misschien moet wel heel de boel innoveren..."	"So I think it needs to develop in all kinds of areas. So perhaps the whole thing needs to be innovated..."	4. Desired/Normative Integration Trajectory 4.3 Frustration over missed opportunities for structural learning and innovation 2. Vertical Stretch (aspirational)	Explicit call for broad development and full innovation – expresses desire for structural change and higher abstraction (strong red arrow, potential vertical stretch if realized).
"ik denk eerder dat mensen die	"I rather think that people who work	4. Desired/Normative Integration	Normalization of professional HR support

hier werken of komen te werken, dat ze het heel normaal vinden dat die HR-afdeling er is. En dat ze het niet normaal vinden dat die er niet is of niet geweest was."	here or come to work here find it completely normal that there is an HR department. And that they would find it abnormal if it wasn't there or hadn't been."	Trajectory Partial 2. Vertical Stretch	as expected standard – reflects a valued shift toward structured support (red arrow – desired integration into formal systems).
"Ik vergelijk het weleens met een supermarkt als Albert Heijn, die heeft alles tot in de kleinste details geregeld voor iedereen... En dat vinden mensen heel normaal."	"I sometimes compare it to a supermarket like Albert Heijn, which has everything regulated down to the smallest details for everyone... And people find that completely normal."	4. Desired/Normative Integration Trajectory 4.1 Need for cultural shift / collaboration Epistemic Tension (overall)	Benchmarking against highly structured large organization (AH) highlights aspiration for similar formalization – tension between current informal SME practice and desired professional/strategic standards (red arrow vs. current horizontal dominance).

4.2.5 Comparative analysis of Case B and Case C

Comparative analysis between the Case B (Sharing logistics) case and Case C (Sharing human resources) revealed that current HR professional products in the knowledge domain seemed insufficiently suited to actors (teachers/students) to overcome reduced HR capacity in companies. Knowledge of specific HR-related issues, contextual factors and the absorption of knowledge seemed to be a barrier for logistics companies. In the HR case, there seemed to be less transfer to systems with formal, explicit knowledge, even for distinct knowledge questions.

Of all SMEs, three had a human capital agenda. Eight SMEs had active HR employees. Four SMEs said they had no clear idea of the necessary HRM products. In nine SMEs, HR staff do not belong to an HR network. All organizations had a dynamic environment which would affect either staff numbers, innovation strategy, company strategy or knowledge-management systems. Four SMES stated that policies for climate change created insecurity.

We found that the sharing concept for knowledge integration differed among the organizations involved. Those with other epistemic contexts for HR(M) strategies required different distinct functionalities for agents. Although the sharing projects were successful in disseminating particular information, it requires more attention from a knowledge-management and human-resource perspective for the Living lab to find and reveal distinct epistemic functionalities of information in various knowledge domains and to determine the epistemic justification.

4.2.6 Case D1 (Volatility)

Case description: Most smaller SMEs are likely to be affected by the dynamic environment. Based on our quantitative data we analyzed how organization size affected the capability to make changes in their organization of knowledge and what modifications this would need. Smaller SMEs confront changes in capabilities such as digitalization and work routines.

Uncertainty: All SMEs felt high uncertainty based on political and economic changes. In some, world economics affected the supply chain due to the higher costs of transport and energy.

Accommodation or support: Little investment could be made in upskilling and forming ideas about the requirements involved in dynamic capabilities.

Distinct relationship: There were no known modifications or programs for these types of problems and or models based on earlier research at RUAS.

Absorption/clustering of dynamic capabilities: Articulation and seizing capabilities were hindered by uncertainty of environmental developments.

Disposition of knowledge: There was high differentiation in knowledge inquiries. High expertise is sometimes procedural, sometimes tacitly embedded, and sometimes based on scientific knowledge.

Temporality: unclear due to high differentiation.

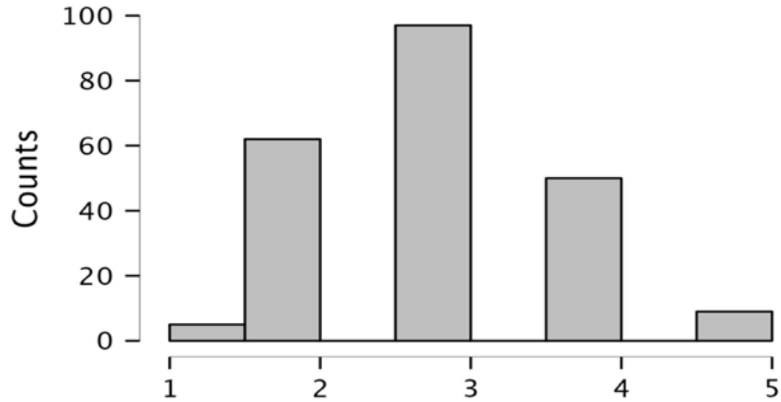

Table 30. Answers on statement: We find it difficult to determine what new knowledge needs for employees are on a 5-point Likert scale

Conversions and translations: Requirements for transfer mechanism involved deeper understanding of the mechanism needed to change dynamic capabilities (as a set).

Epistemic governance: Here the human capital agenda must involve contextual knowledge engineering rather than providing solutions. We distributed a survey among members of EVO, the branch organization of shippers in the Netherlands: 3,066 companies, of which 264 respondents completed the questionnaire. The desired minimum response (accuracy 5%, confidence 95%) lay between 342–351, which made the results representative. The limit for minimal response on a 5-point scale was set at accuracy 7%, confidence 90%. Of all the participating SMEs, half % had 0-50 employees and almost 18% had 50–00 employees. We conducted 12 semi-structured in-depth interviews. The results were discussed with experts and further interviews were conducted with an HRM manager, a logistics planner and an order picker in order to map out the codification of procedural knowledge.

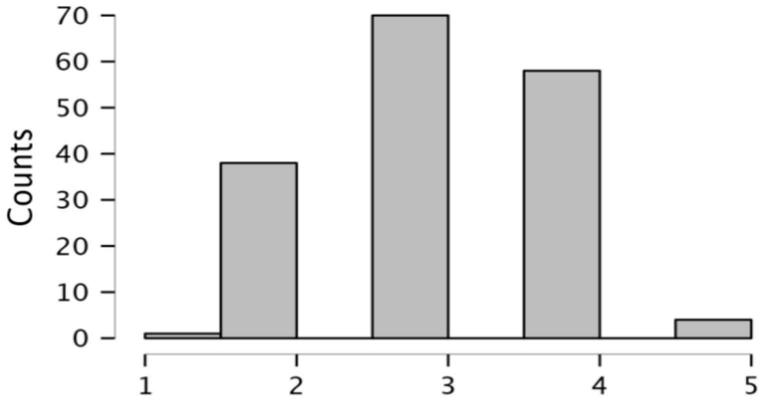

Table 31. Answers on statement: In our industry knowledge evolves rapidly

During the study we distributed multiple surveys to find consistency among the various items. In the survey on Volatility (D1), only valuable items were further examined in subsequent interviews and questionnaires. From the subsequent survey and interviews, we further explored factors that influenced absorption capacity.

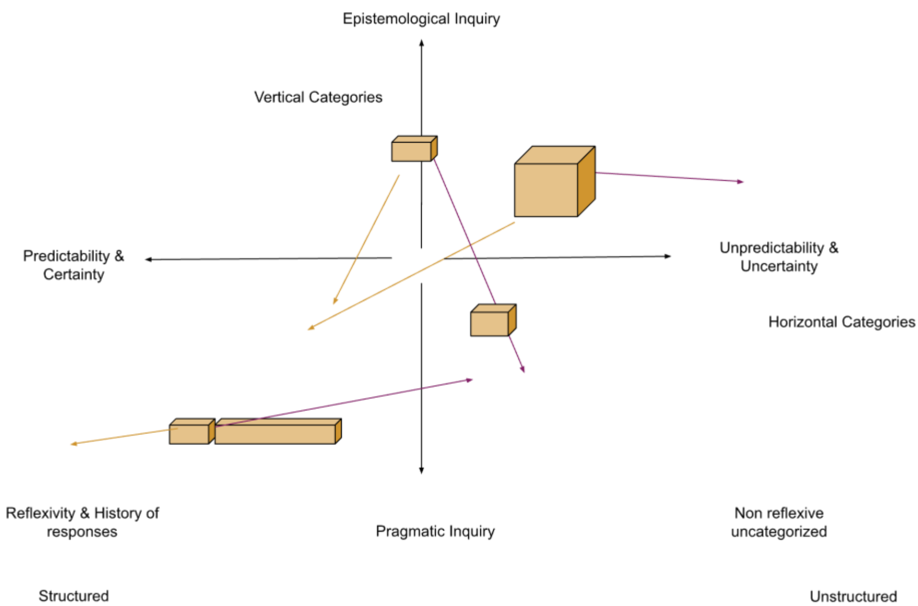

Figure 29 Tensions in Case D1

Frequency of individual survey items			
Item	**Cronbach's alpha**	**Item-rest correlation**	**Mean**
4. In our branch knowledge evolves rapidly	0.695	0.217	2.982
3. The organization needs new knowledge because of market changes	0.687	0.451	2.433
16. We find it difficult to determine what new knowledge needs for employees are	0.727	0.033	3.152
5. Our company has specific employees in charge of collaboration with external partners	0.669	0.500	2.592
10. It is difficult to assess what the effects of these developments are for our organization	0.728	0.018	2.784
12. It is important that our employees have skills to pick up knowledge	0.669	0.535	2.295
15. We document employees' requests for new professional knowledge	0.692	0.348	2.532
18. We invest in learning trajectories for our employees in order to create a learning culture	0.666	0.527	2.649
17. Our employees take initiatives by themselves	0.712	0.183	2.673
6. We have a human-resource strategy based on our organizational policy	0.661	0.512	2.767
11. We collect data to improve our work processes.	0.668	0.512	2.784
14. We find it hard to transform new knowledge for our business processes.	0.712	0.178	3.012

Table 32. Examples of questions on knowledge obsolescence

Tensions: There was tension due to high differentiation in environmental dynamics and the identification of dynamic capabilities that were independent of changes and HRM support. It required knowledge of self-sustainability to develop dynamic capabilities.

Using the survey results, we conducted further semi-structured, in-depth interviews with SMEs, guided by themes derived from earlier phases of the research and the theoretical framework. The focus was on how changes in the SMEs' environments impacted employees' routines, knowledge, and skills. Additionally, the interviews explored the SMEs' capacities to collaborate with students, particularly in relation to specific knowledge domains and disciplines.

Key insights: cognitive flexibility for modal constraints

1. Accessibility based on survey data is difficult for SMEs in the target population. This is due to operational constraints, survey fatigue and ambiguity of questions.
2. Students without pre-existing schemas of ill-structured environment find it difficult to understand absolute legitimation.

Case D Volatility (D1.5)

Fragment (NL)	Translation (EN)	Code(s)	Link to Tension Cube
"15 jaar geleden is men hier gestart met de gloeilampen. Nou, dat was een markt die werd weggesaneerd... onze algemeen directeur, die heeft gewoon pakhuizen vol met gloeilampen... daarna spaarlampen, want die kon die gewoon blijven leveren toen Philips stopte."	"15 years ago, they started here with incandescent bulbs. Well, that was a market that was being phased out... our general director simply had warehouses full of incandescent bulbs at first, then energy-saving bulbs, because he could continue supplying them when Philips stopped."	3. Observed Pragmatic Trajectory 3.1 Cost-driven, risk-reducing, flexibility-oriented 1. Horizontal Stretch: Situational Embeddedness & Relational Complexity	Opportunistic stockpiling and continuation of supply in a disrupted market – pure pragmatic adaptation to external changes (Philips exit) and operational needs (thick green arrow; horizontal embedding in market constraints).

Fragment (NL)	Translation (EN)	Code(s)	Link to Tension Cube
"Op een gegeven moment zijn ze naar China toe gegaan en daar hebben ze ons, hebben ze eigen producten onder de merknaam ont-wikkeld. Ja, en dat is explosief gegroeid en daarmee zijn wij nu toch wel de grootste in Europa geworden op het gebied van ledlampen."	"At some point they went to China and developed our own products under the Calex brand name there. Yes, and that grew explosively, and with that we have now become the largest in Europe in the field of LED lamps."	3. Observed Pragmatic Trajectory 3.2 Operational urgency and quick wins Partial 2. Vertical Stretch: Movement Across Levels of Abstraction	Shift to own-brand production in China as pragmatic response to market shift – led to explosive growth and market leadership; some movement from supply to product development (green arrow dominance with mild vertical stretch).
"En wat we vervolgens hebben gedaan is meer smarttoepassingen in de lampen aan-gebracht. Hè, dus al je lampen bedienen op je telefoon. En wat we daaraan toe-gevoegd hebben... is, ja, tuinlampen en vervolgens komen daar camera's bij... assortiment aan smarttoepassingen."	"And what we subsequently did was add more smart applications to the lamps. So controlling all your lamps via your phone. And what we added to that... was garden lamps and then cameras come with that... range of smart applications."	2. Vertical Stretch: Movement Across Levels of Abstraction 2.1 From immediate problem-solving to reusable methods/principles Partial 4. Desired/Normative Integration Trajectory	Incremental extension from basic LED to smart ecosystem (phone control, garden lamps, cameras) – shows movement toward higher abstraction and integrated product line (moderate vertical stretch; hint of red arrow in expanding smart vision).
"Ja, daar zijn we nu aan het uitbreiden. En tegelijkertijd betekent dat dat we, als je het hebt over innovatie, dat je dan nadenkt: ja, wat kan er nog meer smart?"	"Yes, we are now expanding that. And at the same time, that means that when you talk about innovation, you then think: yes, what else can be made smart?"	4. Desired/Normative Integration Trajectory 4.3 Frustration over missed opportunities / aspiration for structural learning and innovation 2. Vertical Stretch (aspirational)	Open-ended reflection on further smart possibilities – expresses ongoing desire for broader innovation and integration (strong red arrow; aspirational vertical stretch toward future strategic expansion).

4.2.7 Case D2 (Future skills)

Case description: This case researched how RUAS can sustainably develop the required dynamic capabilities for various SMEs. It involved eight SMEs that employ distinct strategies to map current developments. Absorptive capacity is fundamentally dynamic, necessitating a continuous knowledge flow between the two systems to evoke mutual learning. A prerequisite is the continuous materialization of knowledge bridging the systems.

Uncertainty: SMEs clearly expressed uncertainty regarding the need for dynamic capabilities or the specific skills required to develop new capabilities. Larger firms emphasized the need to develop these skills at the organizational level, despite lacking sufficient in-house expertise. This form of materialization aligns with knowledge codification and prototype development to sustain and steer these capabilities over time.

Accommodation or support: Large SMEs had the capacity to experiment with capabilities.

Distinct relationship: RUAS currently has no programs for this.

Absorption/clustering of dynamic capabilities: One SME expressed the need to adopt digital twins as a governance tool. An interview further revealed a demand for systemic change that can address cultural aspects at the individual level.

Disposition of knowledge: In larger SMEs, knowledge is embedded in procedures, regulations, and formal directives. While this creates a framework of control and governance systems, it remains inherently static and fails to facilitate the integration or absorption of new knowledge.

Temporality: All interviewees noted that environmental dynamics require routine, micro-level adaptations that keep operational coherence.

Conversions and translations: Although we found is a need to exchange, the organization of this requires more steps.

Epistemic governance: Especially on defining steps or procedure on micro levels for particular functions in the systems.

Key insights: relations systems and agents in the absorption of knowledge

1. Dependence on networks, customers, and suppliers reveals a socio-epistemic dependency that interacts with the economic value attributed to that knowledge.
2. In contexts with a high presence of microprocesses or routines, this also influences the willingness of individual agents to absorb and incorporate that knowledge.

Tensions: There is tension between operational processes (for example planners) and the developments on new ways to integrate knowledge: most capabilities are 'hidden'; either in procedures, tacit knowledge or what are labeled as ostensive routines. This last category is a type of formalization that lacks a double aspect of information. or what has been described as epistemic functionality.

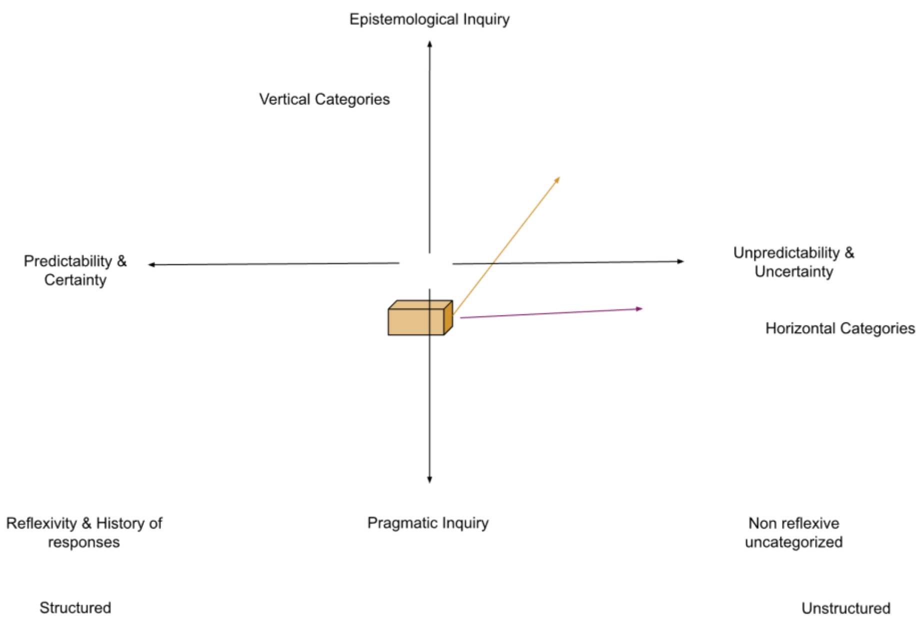

Figure 30 Tension in Case D2 based on interviews in-depth (one group of (SMEs) and shows differences from D1

4.2.8 Case E (Learning culture and responses)

Case description: This case analyzed how absorptive capacity is influenced by studying organizational learning cultures and the students' responses to these environments. The case also provided an opportunity to investigate the tension between the epistemic and practical dimensions of learning cultures. We also studied what other analysis methods proved to be necessary that students used. We evaluated the degree to which the results could be measured on the scales of realized and potential absorption.

We surveyed 1,678 employees of 18 companies. Only two SMEs achieved a response rate higher than 50%. In total, 312 employees completed the questionnaire. Students were supported by quantitative research data on learning culture in 16 organizations.

Uncertainty: The questionnaire provided only limited clarity regarding the uncertainty related to dynamic capability. However, there was significant interest in the further development of a learning culture in general. Environmental factors clearly influenced the demand for new knowledge and the associated skills.

"Clearly there was a weak link between the external environment and feeling connected to it. This was evident from the distribution of the answers: 45% were neutral and 9% disagreed, which suggested that people either had no opinion or were opposed. We then looked at the two themes that fall under the external environment, namely co-creation with customers and suppliers, and the productive uptake of knowledge from the external environment. After talking to the client, we decided to investigate and promote co-creation with customers. Why? Because it turned out from our chat that the client had conducted customer satisfaction surveys last December. However, nothing was done with the results, and nobody knows what came out of it. They had done it simply to see what the expectations were, in relation to their own ideas, and the market, and what customers thought about it. So, that's how we arrived at the main question of how to facilitate co-creation with customers." —Speaker 1, interview on Learning culture

Accommodation or support: A small minority of SMEs provided HRM support or alternative means of facilitating the research.

Distinct relationship: The evaluations of SMEs and students revealed that RUAS currently lacks sufficient knowledge about this matter.

Absorption/clustering of dynamic capabilities: In most cases, this involved improving only a minor dynamic component of an operational process.

Disposition of knowledge: In several cases, employees found it very hard to answer questions about their routine work processes.

Temporality: In particular, the ongoing processes required immediate real-time adjustments.

Conversions and translations: Students appeared to find it hard to deviate from the questionnaires or to steer interviews in a different direction.

Epistemic governance: Learning had to take place locally in most cases. No established methods were currently available for this purpose.

Tensions: There was tension between the embeddedness of learning representations in various routines and the instructional explicit representations of learning. This frustrated the direction of developments for the actors involved.

The data showed a heterogeneous picture. In the larger surveys, descriptive statistics showed dispersed distributions. We frequently observed wide dispersion—even upon repetition—along with substantial non-response rates. Notably, the high proportion of neutral responses emerged as a consistent challenge in all surveys (Paardekoper & Wiersma, 2022)**.**

Similarly, with the smaller surveys, it often proved difficult to find enough companies willing to participate. Consequently, the data was primarily used for descriptive statistics, supplemented by additional interviews at each stage of the research. Following data collection, we conducted interviews that revealed that employees often struggled to complete the surveys for various reasons.

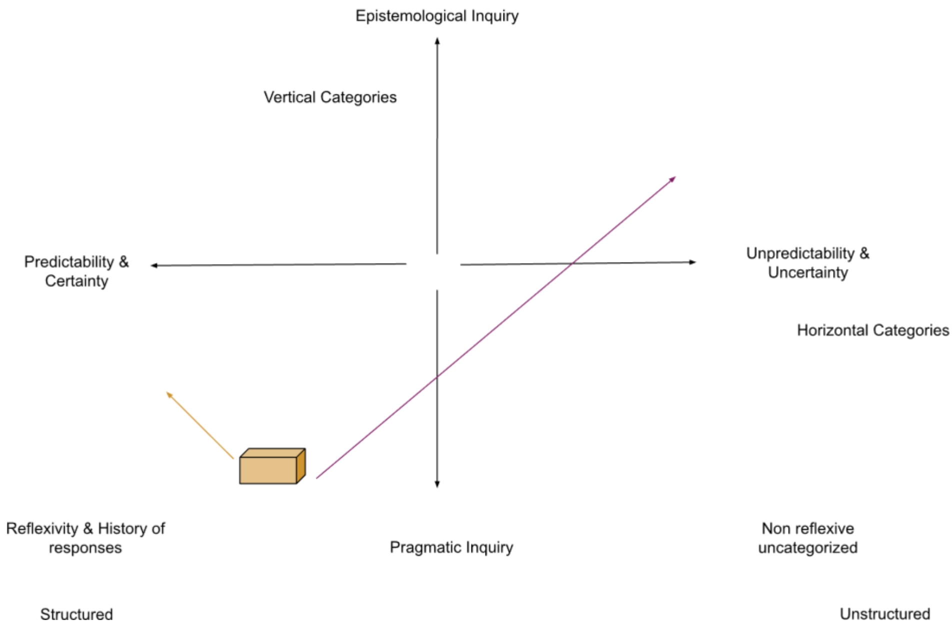

Figure 31 Tensions in case E

First and foremost, there were multiple practical boundaries: lack of access to computers, and most notably insufficient time to fill out the questionnaires. For instance, shift work made it difficult for survey administrators to organize distribution and ensure timely returns. The interviews also revealed a reinforcing effect: employees frequently expressed uncertainty about how to interpret certain questions, leading them to default to neutral responses.

Key insights: epistemic criteria for not knowing

Using various inquiry techniques revealed differing perceptions of what it means to not know. Often, theoretical inaccuracies lead to unjustified claims and misunderstandings. Our findings indicate that students struggle to understand the different epistemic criteria that define what may count as knowledge for different agents. This difficulty affects how they revise their own beliefs, interpret the beliefs of others, and subsequently engineer the necessary steps to apply knowledge in practice.

Case (E): FY8

Fragment (NL)	Translation (EN)	Code(s)	Link to Tension Cube
"Ik doe het echt veel meer op gevoel."	"I really do it much more by gut feeling."	3. Observed Pragmatic Trajectory 3.2 Operational urgency and quick wins	Speaker relies on intuition and quick assessment – typical pragmatic, operational action (green arrow).
"Je merkt zeg maar als je vijf minuten met iemand praat, denk ik al wel redelijk wat voor kleur groot zijn zeg, maar wel weer mensen gericht op taakgericht zijn."	"After talking to someone for just five minutes, I have a pretty good idea of what 'color' they are – whether they're more people-oriented or task-oriented."	1. Horizontal Stretch: Situational Embeddedness & Relational Complexity 1.2 Multiple interdependent actors and regional/personal relationships	Quick assessment of relational style emphasizes personal/relational complexity in interaction (horizontal stretch).
"Deze heeft ander soort manier van denken, dus ik pas me daarop aan."	"This person has a different way of thinking, so I adapt to that."	4. Desired/Normative Integration Trajectory 4.1 Need for cultural shift / collaboration	Adapting to another's way of thinking shows a desire for better integration and collaboration (red arrow – desired but not always achieved).
"Als ik dan heel erg ga dram op dat taakgericht ja, dan loopt het vast."	"If I push too hard on the task-oriented side, it gets stuck."	1. Horizontal Stretch (barrier) Epistemic Tension (overall)	Clash of styles blocks progress – core tension between task-oriented (pragmatic) and people-oriented (relational).
"En ja, dat werkt."	"And yeah, that works."	3. Observed Pragmatic Trajectory (positive outcome)	Adaptation leads to success – reinforces the green (pragmatic) trajectory.

4.2.9 Case F (Conceptual environments; Y0-Y9)

Case description: Data were collected in nine cases based on our selection criteria (Y0-Y9, see Chapter 3). The data came from observations, interviews, evaluation of focus groups on objects (products) and processes. We described each case in terms of its place in the MMR sequence, including a general description of the actors (mostly groups of three students), of how they actors structured the problem-solving area (see also Appendix: Non-monotonic behavior) and whether a case could be categorized as a utility, application or function.

We also described if a case exceeded contextual needs, in terms of a type of contingency or particular speculative design and how this affected experiences. Data were collected on the way students formulated propositions, or research aims if a problem was not articulated, as well as the research methods students used within the given time frame. We collected data on the (subjective) reasons students had chosen a particular project.

Uncertainty: Observations showed differences in cases and outcomes based on case organization rather than group differences. The ethnographic observations contributed to our understanding of epistemic uncertainty by providing contextual insights into how these students sense, perceive, and manage, through knowledge gaps in real-world settings.

Accommodation or support: We identified several types: collaborative environment (schema modification and knowledge refinements), stakeholder support, and educational environment (corresponding experience).

Distinct relationship: The evaluations with companies and students revealed that RUAS currently lacked sufficient knowledge about this matter.

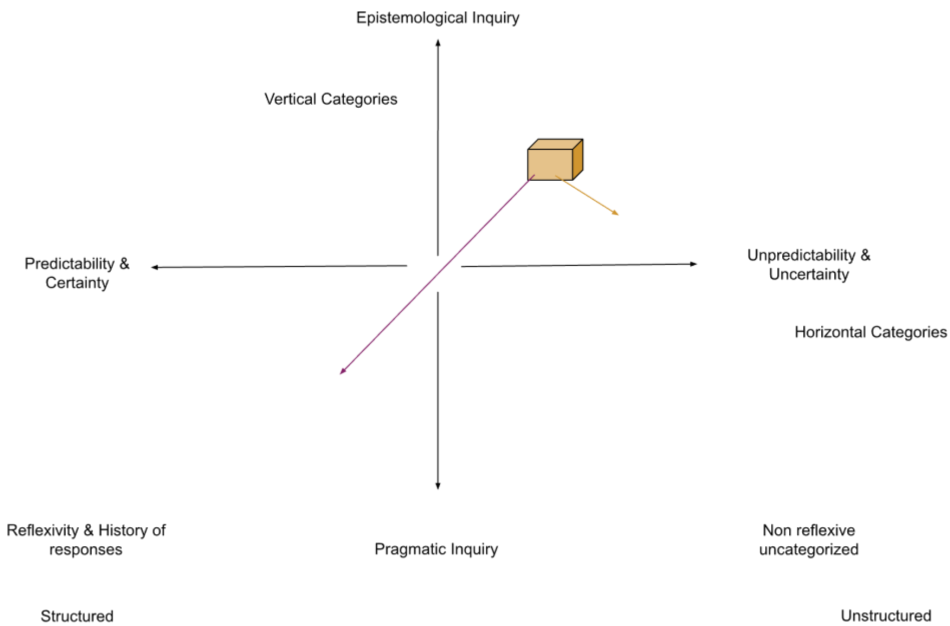

Figure 32. Tensions in cases in Case F, Stage 2

Absorption / clustering of dynamic capabilities: the group dynamics affect how identification of a problem or constraint is identified. In most cases iterations on possible outcomes create problems in innovative performances of the groups.

Disposition of knowledge: In all cases we observed that students had little experience with the absence of prerequisite codifications (instructions).

Temporality: In most cases we saw that new experiences required accommodation in terms of planning and goals.

Conversions and translations: Students seemed to find it difficult to deviate from the questionnaires or to steer interviews in a different direction.

Epistemic Governance: We noted differentiation how cases are epistemically governed.

Key insights:
Students generally lack familiarity with meta-knowledge, knowledge about knowledge and established theories and practices in knowledge management for applied contexts. Navigating stronger ill-structured environments, involving epistemic uncertainty, demands a priori reasoning skills that many students have yet to develop.

This sub-study shows that students, shaped by their particular learning cultures, have no experience in decomposing complex, highly embedded problem situations. Sometimes, they struggled to generalize the decomposition process from concrete, real-world cases. This highlights how the mode of reasoning surrounding the functionality of an application directly influences the design of potential solutions. When presented with multiple options for knowledge modeling, students often found it unclear which framework was most appropriate. Constructing accurate models of the knowledge employed in actual situations proved challenging.

Our data reveal difficulties in formulating research questions on new concepts and their applications. Mostly this concerned techniques essential for advancing inquiry. Students reported lacking experience in inquiry methods and often felt the research had little relevance to their own knowledge domains. This may be explained by the RUAS’s approach to training students in handling complex contemporary issues. However, formulating contexts in which realistic, adequately learned knowledge can be transformed into practical applications proved highly challenging for students.

4.3 Main conclusions

One of the greatest challenges of Industry 4.0 and consequently Industry 5.0 lies in defining the phenomenon itself and interpreting the implications of its consequences in terms of dispositions. This thesis focuses on how these developments create uncertainty on conceptualization knowledge and therefore its functionalities. In several cases we focused on tensions (T) to define distinct constituents of functionalities of knowledge under epistemic uncertainty.

T1 We found that most smaller SMEs more often show inertia in adopting new technologies due to the lack of existing capabilities and capacities (personnel and time constraints).

T2 Our research shows that knowledge engineering necessitates an understanding of the epistemological consequences arising from uncertain future epistemic states and the necessary requirements of dynamic capabilities and knowledge representations. We labeled this as modal awareness.

T3 This understanding involves reasoning on knowledge and its functional consequences. Students lack knowledge of the semantic tools for distinct contexts such as SMEs. We found that the epistemic environments of SMEs are not clearly (enough) distinguished through governance and that evokes doubt and consequently involves making changes that are feasible on the varying levels of learners and agents in the different organizational systems. We labeled this as modal consciousness that requires epistemic advancements for effective knowledge engineering.

T4 Knowledge on knowledge-in-use requires reasoning on time constraints in relation to possible future states. Rejection of technology adoption, we found, is often related to a lack of supporting mechanisms for maintaining dynamic capabilities after changes have taken place. We term this modal shifts. New extensions of microprocesses require time and on-the-job training (learning) and changes to the overall dynamic capabilities which are difficult to predict when HRM and KMM support is absent.

T5 Learning in complex environments needs (more) support in terms of principled mechanisms for advanced knowledge engineering. However, such principles are often conceptual and require knowledge of the practical consequences for SMEs in terms of skills and future knowledge requirements.

T6 Revisionary semantics are difficult to express in financial costs and long-term benefits.

T7 Sharing strategies and objects effectively requires multiple semantic dimensions for knowledge storage and retrieval, (such as an interface) enabling effective recombination of objects and artifact properties within distinct environments spaces by students and SMEs.

The findings of this study reveal that knowledge transfer and absorption in student-mediated UAS-SME collaborations are profoundly shaped by epistemic tensions between pragmatic, operationally embedded trajectories and desired pathways toward higher abstraction and structural integration. Across the cases, innovation spaces show situational constraints which consistently pulled knowledge processes toward immediate, intuitive adaptations and quick operational wins, manifesting as a dominant green pragmatic trajectory in the Tension Cube.

Vertical movement toward strategic or conceptual renewal remained limited, while normative aspirations for fuller integration (red arrow) were often acknowledged but rarely realized due to embedded daily realities.

Methodologically, solution experiments emerged as highly iterative and learning-oriented, fostering open exploration and collaborative discovery when their educational intent was clearly communicated, rather than pressuring participants for direct solutions. Field labs proved more technology-focused and suited to longer-term validation (e.g., risk assessments for electric vehicles or airport digitization), delivering incremental technical improvements aligned with SME pragmatism. Living labs, incorporating diverse non-corporate stakeholders (e.g., local residents and non-profit organizations alongside small enterprises), offered the greatest potential for systemic co-creation but encountered the strongest horizontal barriers, limiting deeper epistemic shifts.

Overall, knowledge transfer in these contexts rarely targeted formal organizational systems, prioritizing instead tacit, context-specific adaptations that were accessible for practitioners yet challenging for students seeking structured theoretical insights. These patterns also emphasize the distinctive practice-oriented nature of UAS-SME ecosystems complementary to research university with large firm dynamic ecosystems and suggest that maximizing transfer requires aligning innovation space methods with pragmatic constraints while explicitly framing activities to encourage exploratory learning and mitigate operational tensions.

Cross-case analysis patterns

Case Pattern	Modal System	Key Interpretation	UAS Research Implication
Horizontal-dominant (A,B,E)	K/KD (basic, serial/non-reflexive)	Doxastic trajectories (green arrows): beliefs in operational fixes without truth guarantee; relational barriers fail symmetry (B axiom absent). Epistemic states cluster at cube base—agents "believe" adaptations work but lack strategies.*	UAS verifies factivity: deploy to convert feelings, quick wins) to proven routing data), adding T reflexivity via empirical closure.
Vertical-aspirational (C,D)	KT/K4 → S4 aspirations (reflexive/transitive)	Red arrows seek positive introspection (and structural factivity, but "loose" embedding blocks; Cube tilts upward as doxastic states evolve toward equivalence frames.	UAS enables vertical climb: sequence from KD45 beliefs (consistent but false) to S4 knowledge via data abstraction, formalizing "what else smart?" as modal validities.
All cases	Cube distortions (non-equivalence)	Tensions erode S5 ideals—real SMEs reject negative introspection (5); instead, frame conditions reflect embeddedness (non-universal accessibility). Non-deterministic semantics.	**Research as epistemic engineering: UAS adds modal operators to strengthen frames, tracking axiom inclusion via cube progression for scalable knowledge.

Table 33. Cross-case Analyis Patterns example

* Managers: Cannot "know" changes without data validation (e.g., Case D stockpiling was belief until LED growth proved factive).
Teams: Horizontal tensions (relational complexity in Case E) create non-reflexive frames—gut assessments succeed pragmatically but lack
SMEs overall: High-gravity bases favor green pragmatic paths (KD-like beliefs), but UAS tools add reflexivity by supplying data that verifies
** In Sharing case two different modal operators were used across cases

Conclusion for improvements:

Recognizing that SMEs typically operate with practical beliefs rather than perfect knowledge, UAS should implement a "Knowledge Ladder Policy" structured in progressive stages to ensure project success. Below is an example based on our cases

Stage 1: Belief Validation based (Add Truth - T Axiom)

Start every UAS pilot with data verification. Prove operational claims are actually true before scaling. For example, data on specific constraint, number of employees involved to work on the problem, type of routines, strategic policies.

Stage 2: Team Alignment (Relational Symmetry)

Conduct cross knowledge research to eliminate information silos. UAS advices or reports only proceed until all relevant agents (shifts, managers, operators) share verified facts resolve horizontal tensions where for example beliefs differ across teams.

Stage 3: Strategic Learning (Introspection - 4 Axiom)

Document lessons learned (continuous evaluations) from each project to build UAS self-awareness. Document in a knowledge base the operational impacts through shared case studies and metrics.

Monitoring & Epistemic Governance

Move from pragmatic beliefs (bottom) to structured knowledge (top) as in the Consortium case.

<table>
<tr><th>Case</th><th>Dominant Tension</th><th>Cube Position</th><th>UAS-SME Case Use Advice</th></tr>
<tr><td>A (Maritime)</td><td>Horizontal stretch (operations)</td><td>Wide base, high gravity (K/KD-like)</td><td rowspan="4">The case analyses through the modal cube reveal SMEs operating predominantly in weak modal systems (K/KD-like at high-gravity bottoms: non-factive, pragmatic doxastic states) rather than strong ideals (S4/S5 tops: factive, introspective knowledge). Horizontal stretches map to relational frame conditions (non-symmetric/non-transitive accessibility), while vertical aspirations signal potential axiom additions (T for factivity, 4 for introspection).</td></tr>
<tr><td>B (Logistics)</td><td>Horizontal barriers + pragmatic</td><td>Green arrow dominance, blocked red</td></tr>
<tr><td>C/D (HR/ Volatility)</td><td>Vertical aspiration vs. loose embedding</td><td>Moderate vertical stretch, explosive green-to-red</td></tr>
<tr><td>E (Relational)</td><td>Relational complexity + adaptation</td><td>Horizontal stretch with green success</td></tr>
</table>

Table 34. Case use monitor advice

Answers to research questions

Our main and sub-research questions were (see also 3.1.1):

How can UASs and SMEs co-develop the absorption of knowledge strategies to enhance their mutual capacity for identifying, transferring, and applying knowledge under epistemic uncertainty?

RQ1. How can UASs and SMEs share knowledge about tools and instruments for continual advancements in dynamic capabilities under epistemic uncertainty?

RQ2. What differences among SMEs affect the dynamics of the absorption of knowledge and how does this in turn affect the ability of UASs and SMEs to develop strategies together?

RQ3. What is the effect of pragmatic and semantic boundaries of co-development and knowledge exchange processes between UASs and SMEs?

RQ4. What design of an innovation environment or innovation space contributes to effective and efficient mutual absorption of knowledge by UASs and SMEs?

This table gives an overview of how the cases contributed to answering the research questions.

Case	Contribution to research question:
Case A	RQ2, RQ 3: The governance construction must be based on a challenge-driven context that finds its pace in the UASs' curriculum developments.
Case B	RQ2: The effects of knowledge distribution, beliefs and embeddedness. External organization (PPS) has stronger advanced planning for knowledge dissemination.
Case C	RQ2, RQ 3: Stronger microprocesses and/or routines affect identification and legitimation of peripheral knowledge.
Case D1	RQ 1: Strategies must be developed based on coherent SME practices and uncertainty types.
Case D2	RQ 1: Skills must be developed to increase proficiency levels of individual agents to decide which extensions for expert knowledge are needed.
Case E	RQ3 Sharing data on pragmatic knowledge enhances inquiry instruments and methods for students.

Other cases	**RQ2, RQ 3: Knowledge-in-use requires continuous evaluation and updates and high levels of HRM and KM maturity.**
Overlap in all cases	RQ 4: There is a lack of epistemic governance for immersive learning using different objects of knowledge engineering that can be adapted in time to make continuous epistemic stances under epistemic uncertainty. RQ 1: This involves knowledge interfaces and repositories between UASs and SMEs to enhance these objects in both embedded practices and learning (epistemic advancements). RQ1: This requires immersive learning for future agents based on an awareness of different knowledge modalities under epistemic uncertainties and conscious actions derived from this awareness.

Table 35. Contributions of cases to research questions

CHAPTER 5

Materializing practices by analyzing cross-case patterns

Chapter 5. Materializing practices by analyzing cross-case patterns

This empirical chapter proceeds as follows:

5.1 Introduction

5.2 Summary of MMR systematic analysis and its quintain

5.2.1 The importance of prioritizing potential absorption

5.2.2 Dynamic vs ordinary capabilities

5.2.3 Habituals, routines, situations and events

5.3 Cross-case analyses

5.3.1 The Field study

5.3.1.1 Field lab

5.3.1.2 Consortium Field lab

5.3.1.3 Comparison of Triple Helix and Consortium sub-cases

5.3.1.4 Conclusions to the field study

5.4 Case C: HRM Characteristics in SMEs

5.4.1 Examples of semantic code analysis

5.4.2 Conclusions to cases 1–3

5.5 Remaining sub-studies, cases Y01 to Y9

5.6 Conclusions to pattern-searching analysis

5.7 Cross-case findings answering the research questions

5.1 Introduction

Education, especially vocational education, requires being able to operate in different worlds: one based on the epistemics of knowledge and the practical world of functional knowledge. Both worlds have come under pressure as a result of emergent technologies in Industry 4.0 that are destabilizing existing epistemic and functional certainties, necessitating dynamic capabilities. Such capabilities can be cultivated by augmenting organizational routines with new information and knowledge. This process requires critical inquiries into which routine elements in which SME settings have become obsolete and demand adaptation. Different types of routines often function as interdependent sets, or configurations, meaning that abolishing established routines may introduce systemic risk. However, new routines in terms of dynamic capabilities are indispensable to leverage new technologies, enabling innovation and responsive adaptation through reconfigured practices.

Our data reveal that the dynamic environments of differentiated SMEs generate different tensions between epistemic concepts and their practical translation into necessary new capability elements for routines. Achieving such distinct, intrinsic translations requires awareness of epistemic and practical dimensions. Following a sequential exploratory design (Creswell, 2014), this chapter triangulates survey data (n=39 firms) in sets of 13 projects using surveys (including a survey on volatility n=264), interviews and observations with ethnographic fieldwork (four sites) and ethnomethodological analysis (Garfinkel, 1967). The latter aimed to uncover implicit operational codes, addressing our research on tacit knowledge materialization.

5.2 Summary of MMR systematic analysis and its quintain

The systematic cross-case analysis allowed us to gain a better understanding of how knowledge absorption processes take place and under what conditions the process is effective. We aimed to find specific themes in each case that are grounded in our research questions. Our findings suggest that knowledge absorption requires a 'modal approach', meaning that inquiry requires one to consider the specific dispositions that affect translations between epistemic and practical dimensions. Therefore, we conceptualized a model for knowledge absorption (quadrant matrix) that acted as a quintain to which data and findings were added in each sequence (Stake, 2006).

A quintain is a representation of prior conditions to the cases studied, an epistemic model in our case. This lets us determine what strategy of inquiry and modal approach contributes to what type of knowledge absorption and the capability requirements of SMEs, human agents, and students involved in the inquiry.

The objective of this data analysis was twofold: first, it pursues a phenomenological aim to establish epistemic uncertainty and its relation to knowledge absorption and second, it seeks to explain how this affects knowledge absorption between UASs and SMEs. Our framework posits that knowledge absorption is affected by uncertainty, which generates a gap between the epistemological and functional dimensions of applied knowledge.

Levels and dimensions of cross-case analysis in MMR sequences

This study systematically mapped the boundaries between epistemic and practical dimensions that affect knowledge absorption. We distinguish objectives in SMEs at two levels: influencing the potential for knowledge absorption (assimilation) and realizing knowledge absorption (integration). Among small to micro-SMEs, we nearly always found assimilation as a means to respond through minor contextual adaptations, such as leveraging with customers, suppliers, and increasingly, external experts. This is exemplified in cases where SMEs outsource portions of ICT capabilities they lack internally.

Framework & data		Framework & analysis of dualism in UAS-SME knowledge bases			
Themes	Tensions	Direction	Capability	Absorption	Goals
Consciousness of modal and temporal logic					
	Semantic	Horizontal: epistemic, practical	Ordinary	Sense-seize-adapt to reconfigure (incremental/ individual) Realization involves integrating new routines	Exploitation purposes Potential-(AC-I) Realized -AC (AC-R)
Functional					Necessity
	Practical	Vertical: practical, epistemic	Dynamic	Identify-transfer-transform reconfigure system Realization involves integrating new sets of routines	Exploration purposes Potential (PAC-I) Realized (AC-R)
Cases			Modal Flexibility		
Relations	Themes				
Actors		SMEs & agent inquiry motives	UAS & student inquiry motives	Disciplines and domains	Learning Responding

Table 36. Levels and dimensions of cross-case analysis in MMR sequences (AC-I) is absorption Integration.

How consciously do we know? Boundaries for a posteriori and a priori knowing

Our findings demonstrate variation in characteristics among SMEs that shape the capacity to absorb knowledge from collaborating with UASs. These differences show how SMEs perceive knowledge (e.g., as a strategic asset versus a procedural necessity), establish relationships with the RUAS to acquire or exchange knowledge, or seek external support. SMEs also show intentional strategies to restrict knowledge sharing, we found in some cases to safeguard proprietary information or that enhances their market position.

Our findings have significant implications for policy formulation and intervention designs, or in our research context, for modeling sets. Our study shows that larger SMEs often have more superior knowledge recruitment capabilities through their institutional channels. Such transfer channels like universities, may provide these SMEs strategic advantages in evaluating cost-benefit analyses for potential knowledge development initiatives.

	Description	**Purpose**	**Direction**
B.1	Create internships for RUAS research students	Exploration	vertical
B.2	Articulate research projects for UASs	Exploration	vertical
B.3	Knowledge recruiters, company campus	Exploration	horizontal
B.4	Informal recruitment on regular informal basis		horizontal
B.5	Using data collected from projects and potential commercial activities	Exploitation	vertical
B.6	Creating new functions that act as knowledge provider	Exploitation/ dispositions	horizontal/ vertical
B.7	Using materials for curriculum and dissemination	Exploration	horizontal/ vertical

Table 37. Development of potential absorptive capacity in project B

5.2.1 The importance of prioritizing potential absorption

The development of a priori knowledge (foreknowledge) plays a critical role for both UASs and SMEs individually as well as in their collaborative efforts. Creating future-state models with expected knowledge representations can serve as incremental learning strategies. Exploring the required capabilities helps to set out learning trajectories. For some medium-sized SMEs we found this a method to weigh the cost of potential redundancies, especially with older employees involved.

However, this requires systematic modeling of potential properties of new capabilities and their possible dynamic extensions in routines (based on a SME’s typical characteristics and environment). Such strategic trajectories also require continuous evaluations, both within individual systems and across interconnected systems. We found that most micro-small SMEs have no maturity tiers to evaluate.

Our research shows that organizational characteristics like size and age only partially explain variations in absorptive capacity-realized (AC-R) systems and absorptive capacity-potential/ incremental (AC-I) on an individual basis. A key limitation in fully explaining AC-R and AC-I dynamics comes from the complex processes underlying collaboration formation, planning and eventually and motivations for temporary partnerships.

Larger SMEs show greater accessibility in initiating temporary relationships, this accessibility does not necessarily translate to reciprocal or beneficial engagements. Evaluation based on further developments or further testing requires systematic knowledge flows. Furthermore, the problem statements formulated for collaborative projects can misalign between educational programming cycles, and knowledge transfer- and transformation processes.

Our data show that SMEs that actively participate in projects and research initiatives sometimes create knowledge for risk assessment capabilities, particularly in evaluating the viability of new applications (see Case C.14). In this case a small shipping company faced critical challenges for their employees to learn new skills as a result of electrification of its ships. This is relevant since we found exactly the same challenge as in E6. Our study revealed a lack of individual sensing capacity (employee level) and organizational identification tools, such as chosen strategy, often stemmed from resource rather than capability constraints.

5.2.2 Dynamic vs ordinary capabilities

Our analysis shows that nearly all firms in our study establish multiple external relationships, primarily driven by environmental uncertainty and dynamism that create capability uncertainty. Specifically, these SMEs doubt their current capabilities and their ability to adapt to respond to new challenges. These findings also show a critical distinction SMEs make between ordinary and dynamic capabilities. Dynamic capabilities (central to our objectives; see Chapter 1) may involve a reconfiguration of various interdependent sets of capabilities and employees involved. We found only a few cases in which an SME expressed this need, but also realize this is not possible in a single project collaboration. We found some SMEs changing strategies, for example, for a shift to servitization (case A, e.g., A2) and (D1.5 using existing capabilities for new markets; Y 9, production changes as a result of using electric cars). This involved both smaller and larger SMEs, either with or without specific KMM or HRM strategies.

Ordinary capabilities focus on operational optimization, either through processes or employee capabilities to achieve incremental improvements in, for example, workflows. Most SMEs in our study aimed to do so since it mitigates risks. Micro-small SMEs are often stuck in the middle, as we will see later.

5.2.3 Phenomena, habituals, routines, situations, events and actions and behavior

Our study shows that individual dynamic capabilities range along embedded individual routines (habituals) to flexible configurations of interdependent practices (events). At one extreme, we observe highly repetitive, historically rooted micro-routines that show stability across all projects studied. Such habituals often function as institutionalized schema that constrains adaptation.

Situated routines are based on contextual dispositions. For example, a steel factory (D1.10) in heavily depends on the fluctuation of steel prices that are checked every morning.

Most dynamic in terms of external dynamics are event-driven capabilities that focus on more future-oriented tasks. This typology helps us distinguish between the preservation of historical practices (characteristic of habituals) and real-time operational adjustments (seen in situated routines) that require different approaches and adaptations. More strategic, event-driven capacities often have operational or procedural codes. Habituals are found to create complex tensions in adaptation-innovation initiatives, as these highly embedded routines require careful modification to meet the environmental pressures for change. The most adaptive firms in our study have a wider range across (internal differentiation) this spectrum.

5.3 Cross-case analyses

Our research question takes on the analysis from a dispositional epistemological perspective. Using this perspective, we cross-examined how knowledge operates or 'acts' against the background of the phenomena of Industry 4.0 and 5.0, its potential impact on knowledge absorption between RUAS, including students and lectures, and SMEs due to epistemic and functional uncertainties.

This approach allowed us to distinguish between ordinary dynamics versus dynamics resulting from epistemic and functional uncertainty, a paradigm shift for new learning that is still in development, and the typical approach from vocational institutes with specific goals associated with them. Our study revealed a tension between students' learning for and through their education and the new role in the purpose of research. Based on our framework, we found a difference between knowledge domains and horizontal discourse. In Case B, we found absorption of knowledge is affected by the knowledge distribution in participating SMEs. Their semantics of objects are similar which aligns SME languages with curricula and thus students compared in Case C. In contrast, it means more involvement in ordinary capabilities.

5.3.1 The Field study

This study focused on the governance, actors and collaborative production and sharing of knowledge in a Triple Helix environment. The solution labs sub-study analyzed how knowledge integration takes place in an innovative environment to remove institutional and knowledge boundaries for knowledge integration.

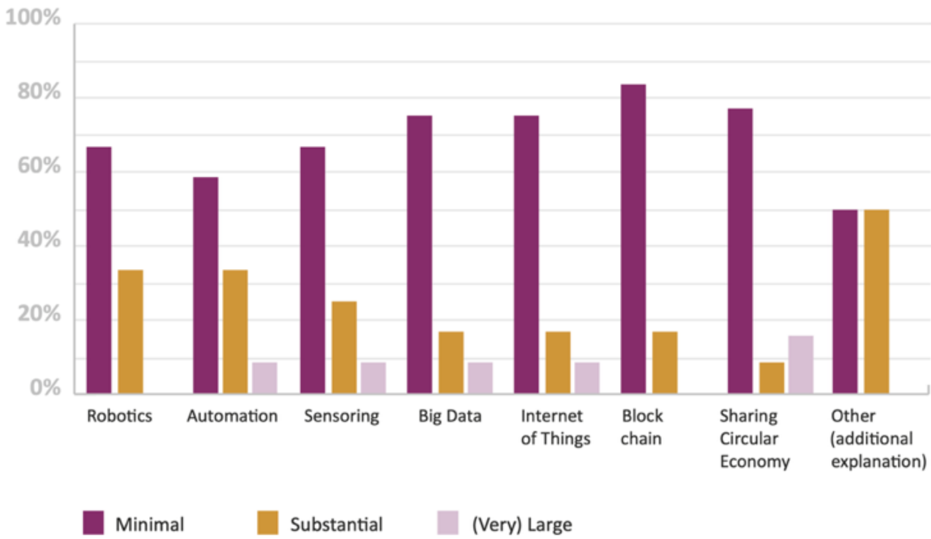

Table 38 Perceived environmental threats of SMEs in the Volatility study

This table shows the answers to “Which new (disruptive) technologies or developments do you perceive as a threat for your organization in the coming years, and to what extent?”

5.3.1.1 Field lab

This sub-study explored the evolving landscape of skills and knowledge in digitalization and organizational collaboration. The findings suggest that stakeholders perceive an increasing need for advanced skills and knowledge, driven by technological advancements and shifting market demands. While digitalization is expected to significantly impact the sector, its precise effects on knowledge development remain uncertain. Respondents anticipate that higher-level executive tasks will be automated, but the emergence of higher-level cognitive capabilities is seen as a long-term prospect.

The importance of inter-organizational collaboration is underscored, with stakeholders emphasizing the need for cooperation both within and outside their sector. This collaboration is deemed crucial for the development of new products and services, particularly in service-oriented scenarios. However, the desirability and likelihood of such scenarios highlight the necessity for diverse knowledge and skill sets.

Interestingly, while staff development is often cited as important, it is perceived as less critical in service development. Conversely HRM themes such as talent acquisition, training, task analysis, and organizational development are prioritized. These findings suggest that HR policies, alongside labor-market regulations, play a pivotal role in facilitating collaboration and enabling organizational adaptability.

In conclusion, this sub-study shows that digitalization and collaboration influence the evolution of skills and knowledge in dynamic sectors. It underscores the importance of strategic HR practice and regional cooperation in navigating these changes.

Future research should focus on quantifying the impact of digitalization on knowledge development and exploring the role of HRM in fostering collaborative innovation across sectors.

Category	**Minimal**	**Substantial**	**(Very) Large**	**Total**
Robotics	58.33% 7	25.00% 3	16.67% 2	12
Automation	16.67% 2	41.67% 5	41.67% 5	12
Sensing	7.69% 1	38.46% 5	53.85% 7	13
Big Data	30.77% 4	30.77% 4	38.46% 5	13
Internet of Things	23.08% 3	46.15% 6	30.77% 4	13
Blockchain	75.00% 9	25.00% 3	0.00% 0	12
Sharing / Circular Economy	35.71% 5	42.86% 6	21.43% 3	14
Other (additional explanation)	0.00% 0	0.00% 0	0.00% 0	0

Table 39 The amount of threat by SMEs in this part of the Triple Helix environment

Table 39 shows the respondents' perceptions of the amount of threat. While lifelong learning is important especially for upskilling and retraining, too little is being done on this. Flexible, scalable workforce and region are important. The latter may indicate the relationship with labor-market policies for knowledge development, skills and product development. Cooperation in training takes place less often with public schools. Business is seen as leading in this.

Modal awareness and absence in semantics

This field study explored the dynamics of epistemic stances of students in the Triple Helix. It showed that innovation can generate ambiguity through an intermediate state (space) that requires new functions of knowledge and in capabilities. This demands an awareness to ensure distinct new epistemic representations for each function. However, ambiguity can evoke epistemic doubts in advancement, leading to the reinforcement of existing beliefs.

Our preliminary research shows the challenges faced by agents and students with limited awareness of the impact of changes that require modifications that fit the systems. These challenges create boundaries needed to be overcome to make epistemic stances against existing knowledge boundaries. This is particularly seen when organizational vocabulary for innovation is relatively unfamiliar to students. We found that the exchange of inquiry propositions between different actors and students reinforced earlier epistemic positions and beliefs. The causes agents to default to existing beliefs due to a lack of informed modal choices. Default beliefs are ideas or perceptions that shape the interaction without being aware of these beliefs.

This research underscores the importance of developing modal awareness in navigating complex knowledge environments and suggests that future studies should focus on enhancing modal cognition to facilitate more effective epistemic stances in innovation contexts.

Technical	**Decreases**	**Remains the same**	**Increases**	**Total**
Vocational (MBO)	33.33% 4	58.33% 7	8.33% 1	12
College (HBO)	0.00% 0	50.00% 6	50.00% 6	12
University	7.69% 1	30.77% 4	61.54% 8	13
Administrative	**Decreases**	**Remains the same**	**Increases**	**Total**
Vocational (MBO)	41.67% 5	58.33% 7	0.00% 0	12
College (HBO)	23.08% 3	61.54% 8	15.38% 2	13
University	8.33% 1	75.00% 9	16.67% 2	12
Management	**Decreases**	**Remains the same**	**Increases**	**Total**
Vocational (MBO)	33.33% 4	58.33% 7	8.33% 1	12
College (HBO)	0.00% 0	75.00% 9	25.00% 3	12
University	0.00% 0	61.54% 8	38.46% 5	13

Table 40. How respondents view employment development in the coming years

“You need to guide the process well. We are a fairly conservative company. We need people who dare to take responsibility, but a few senior managers don’t want that. You have to deal with a certain culture. Now, we’re working on new automation systems, trying to get everyone on board. You see differences in character there again.”— CEO, Field lab A7

5.3.1.2 Consortium Field lab

Complex social and technological challenges accelerate the demand for innovation in the logistics sector. The demand for proliferation hinders a more long-term accumulation of knowledge (KIA, 2019). In the Field lab both solutions and knowledge sharing are necessary conditions to address these challenges. This requires research into practical methods and applications and into sharing knowledge to accelerate the necessary innovations for the sector.

We held interviews with representatives of SMEs, HR managers, lecturers and students. Based on the interview results, we conducted a second study in the field of human resources (HRM case). We distributed questionnaires to HR managers at 19 logistics companies and students helped conduct 40 interviews of employees. This questionnaire was based on the preliminary research and analysis of relevant topics from the previous sequence. We also collected evaluation questionnaires from 83 HRM students. Observations were made at meetings with teachers in the HR case. We then compared the cases on effective transfer resulting from the specific HR knowledge advantage related to various knowledge regime boundaries.

This sub-study examined the knowledge absorption capacity in a collaborative arrangement among multiple stakeholders, focusing on the dynamics of knowledge dissemination and diffusion in helix configurations. We specifically researched how collaboration between the RUAS and SME consortium can achieve throughput of both the process and results of research into education, practice, and society. We also did a comparative analysis of the Triple Helix organizational form of the consortium and its effect on developing (new) capabilities that enhance knowledge absorption focused on how new knowledge concepts relate to unlocking embedded tacit knowledge.

Sensing and/or identification in the process

This study revealed that firms emphasize the importance of knowledge sharing and dissemination in response to environmental changes. However, there is a notable difference in the capacity of organizations to position human resources effectively in their innovation spaces. The size of the organization and operational pressures play significant roles in this capability maturity. Some organizations are more successful in transferring knowledge, leveraging their capacity to create relative knowledge advantages from knowledge production. The experience and skills of actors also contribute to this success. Effective articulation of needs facilitates quicker identification of necessary new knowledge with knowledge accumulation from previously acquired knowledge also playing a role. It shows the complexities of knowledge absorption management.

“The goal of our research was to investigate how the sharing economy operates in logistics. When we asked B6, they seemed unclear about what we were referring to. However, they tried to avoid the question. Responding to ‘Do you know what a sharing economy entails and do you use it in your business?’ they gave an explanation that didn't quite align with the concept of the sharing economy. There was essentially a misconception about the entire concept.”— Interview, student B8)

Knowledge transfer is positively influenced when actors from organizations and knowledge institutions collaborate to translate each other’s conceptualizations or applications to transfer knowledge to their own knowledge domains. For instance, SMEs can use the data on curriculum that students have collected. This kind of production does not affect the UAS’s and SMEs’ different methods for acquiring and storing knowledge. Generally, formal, explicit knowledge, related to efficient absorption capacity, is predominant in knowledge institutions.

The dissemination of formal, explicit knowledge between systems that primarily utilize this type of knowledge in collaboration makes for particularly efficient transfer. However, handling formal and explicit knowledge occurs to a lesser extent. There is significant differentiation in knowledge-management systems and regimes. For many SMEs, transforming knowledge benefits proves to be the most challenging pragmatic knowledge barrier, especially in the short-term. Alongside identification and transfer, this remains one of the most persistent obstacles in the dissemination process.

"Yes, I want to test many scenarios. One is, what would happen if we had ten tuk-tuks and ten bicycles? Another is about maximizing leverage for every customer. How would the customer react if we delivered their order in two batches instead of one? Because with a big truck, you can deliver an order all at once on pallets. But with the vehicles we have now, if a customer's order exceeds 250 kg (the absolute maximum), how would they react? Is it okay to deliver in separate batches? Or would the customer say, 'No, I’m not into that?' It depends, and that’s one research scenario I’m trying to explore."—Interview C2.1

Among SMEs, differences in human resources capacity are complemented by variations in systemic knowledge management, particularly in the evaluation of sharing for accumulation and application (transformation). SMEs that evaluate formal, explicit knowledge seem to benefit more from it for future use. SMEs that communicate strategic choices internally often have facilities for knowledge acquisition and human-resource deployment. This dynamic capacity varies in terms of participating in networks that contributes to identifying necessary new knowledge by engaging with actors connected specifically to one another. Larger companies, for instance, are more likely to participate in innovation forums and knowledge exchanges, while smaller companies focus on partnerships and customer interactions.

Governance
The project had a clear governance structure describing the goals of disseminating knowledge.

Awareness & responsiveness
In the comparative analysis, it seems that current HR professional products of the knowledge domain do not adequately align with actors (teachers and students) to compensate for reduced HR capacity in companies. Knowledge about specific HR-related issues, knowledge about contextual factors, and knowledge absorption in logistics companies seem to be barriers here. We also found that transfer to systems with formal, explicit knowledge, transfer was minimal, even when the knowledge requests are specified. Selecting stakeholders in collaborative partnerships and using a differentiated knowledge-management system focused on the knowledge absorption capacity of individual organizations helps to optimize the effectiveness and efficiency of knowledge absorption. For instance, there are significant differences in the size of companies in construction logistics. These include micro-SMEs that lack the capital or resources to develop applications or capabilities by themselves. To share logistics concepts, this means that setting up labs and gaming sessions can provide more insight and trust in the 'unknowns' of these concepts, leading to their increased acceptance.

5.3.1.3 Comparing Triple Helix and Consortium
The capacity for knowledge absorption is enhanced in SMEs that can easily identify functional knowledge and quickly translate it into their specific business context. In both cases, we observed that awareness and trust are crucial conditions for SMEs, particularly concerning the potential effects and risks of new applications. Larger companies often seize opportunities in this area, while smaller SMEs more frequently encounter obstacles due to a lack of support. This implies that companies should be approached differently when translating concepts into applications. We also observed this in other projects (e.g., D2.2 and D5).

These cases emphasize the importance of a KM model that facilitates both vertical and horizontal dissemination of knowledge. Vertical dissemination allows for scaling knowledge across different environments to enhance improvements and adaptations, while horizontal dissemination ensures that stakeholders share experiences and insights within similar contexts at the same level. We explored potential KM instruments and protocols for various boundary objects, and the roles of individual employees and lecturers and students in the processes.

The comparison between the two cases shows that in the Triple Helix case uncertainty is driven by changes in production that require necessary skills, with significant uncertainty in regional development. Uncertainty about future knowledge representations creates doubts about the development of new capabilities or applications. The Field lab consortium is primarily a network environment, where a sense of risk is associated with data sharing.

Absorption type

Both cases focus on potential absorption (PAC) aimed at exploring and possibly developing objects. Concepts align well with horizonal knowledge distribution in SMEs because the data students used matched the data of medium-sized SMEs. Students were familiar with the operational codes for processes. However, these codes are not dynamic; they require reconfigurations of interrelated capabilities of employees.

5.3.1.4 Conclusions

Larger SMEs focus on exploring adjustments in their configurations (e.g., A14, B2, 3). Surprisingly, we expected a larger share of realized absorption (RAC). Two reasons may explain this. First, larger companies have more resources to support these ideas with research into changes in a set of capabilities and subsequently make reconfigurations. Second, the number of employees in the same function leads to risk spreading, a situation less common in smaller organizations.

Among the larger SMEs, HRM is often involved in these cases. Additionally, PAC aligns better with iterative processes when students conduct the research. These iterative processes are characteristic of knowledge-production mode 3/4. However, this study only partially revealed the precise characteristics of effective iterative processes (Triple Helix case). We observed that iterations with ICT users that directly translate into tools increase user engagement, leading to integration (AC-R in Case x1). However, there are some sporadic exceptions among small businesses (B6, B10). We will discuss this further later, but clearly, maintaining and developing the outcomes of iterative processes require a greater exploitation capacity in SMEs. This explains why they often want to utilize students' expertise as a form of exploration that can be experimented with internally, for example, after a student completes an internship. We also saw this reflected in developments around servitization as a way of acquiring knowledge.

Clearly, developing capacity for knowledge absorption (AC), both for integrating and realizing (AC-R) and for assimilating (AC-I), requires systemic support. This support can be in the form of evaluating procedures and protocols related to HRM or KM development of skills and necessary knowledge. In AC-I, uncertainty seems primarily to revolve around the effectiveness of existing processes in relation to market changes. We observed this in all projects, where thematic questions led to various possible explanations. In Triple Helix, we saw that a different type of industry raises questions with SMEs regarding the methodical use of possible scenarios.

Materializing practices

In the vast majority of cases, absorption concerns assimilation (AC-I). This is not solely due to the capacities and capabilities for knowledge absorption of SMEs. Project structuring at RUAS, for example, in a non-explicitly developed question, contributes to this. In Case B (Consortium), we saw this question being developed in collaboration with SMEs, facilitated by senior lecturers and professors participating frequently mutual sessions (innovation tables), keeping their finger on the pulse more informally. Such informal approaches, particularly with operational employees, led to deeper insights and sharper articulation of agreements, as seen in examples like Z1.

5.4 Case C: HRM characteristics in SMEs

This case study builds upon the insights gained from the Sharing logistics case, with a focus on examining the impact of external drivers on various organizational configurations. Specifically, we aimed to investigate how external drivers influence internal drivers of innovation particularly related to exploitation and exploration. A significant challenge encountered in the ICT Solution Labs was the acute shortage of experts, a concern also highlighted in the Schiedam case. This raises important questions about the predictability needs and advanced planning requirements of HRM.

Most SMEs in our study did not codify knowledge, and coded skills rather than operations. This affected transfer and transformation of extended codes (developed elsewhere) such as upskilling. We often found a system of relations in SMEs as a semantic domain in which sender and receivers are related through a latent disposition which gave (non-formal) meaning to the information. This disposition is latent when non-instantiated for the student or a naïve learner. In contrast, teachers often characterize new knowledge by a stronger semantic density (concepts) and a weaker semantic gravity (examples) which may be tied to specific contexts and disconnected from other meanings to build on previous knowledge. The use of legitimate codes was therefore problematic when analyzing real-world practices. Each SME may have its own legality (Bourdieu, 2004) and a history of mechanisms that govern the circulation of information.

In our study this meant we had to recode information to a level that made recombination (integration) possible. This approach enabled students to interpret the absorption capacity (epistemic dimension) of firms in terms of human-resource capabilities and capacities (see Appendix C.2 for data collection details). Students were tasked with articulating solutions (practical dimension) for the problems. Groups of three to four students were randomly assigned to conduct further interviews with the SMES. This method allowed us to gain a comprehensive understanding of how students can make conversions based on the SME characteristics.

Temporality and governance

Codification of knowledge in semantics take place on different levels. The denotational code describes the functionalities of knowledge. Operational codes refer to execution of knowledge.

Given the highly differentiated characteristics of SMEs and their potential knowledge absorption capacity, specific modifications of knowledge were required to enable human agents to connect (sense) existing knowledge to new information without contradictions or ambiguity in semantic coded representations. The highly differentiated nature of knowledge absorption steps and absence of archetypical SMEs made developing uniform coded objects difficult. Consequently, this necessitated modal flexibility based on the different contexts. The student's new role as both observer and practitioner required differences in inquiry and use of instruments to provide knowledge on knowledge systems and operational codes. The inquiry required distinct modifications of knowledge to enable human agents to adapt their routines. The researcher conducted a preliminary document analysis which determined 12 possible groups of constraints, categorized by axial coding the interviews.

From	To	What	How	
Tacit	Tacit	Experiencing skills	Imitating, oral instruction	
Tacit	Explicit	Abstract reasoning, frameworks	Observe, job shadowing, interviews	Manuals, procedures
Explicit	Tacit	Mentoring, sharing experiences, feedback	Evaluations, reflections	Intuitive sense

Table 41. Conversion table

5.4.1 Examples of semantic code analysis

The analysis of semantic codes, configured by semantic pane analysis, revealed important insights into how organizations cope with changes in the labor market and the resulting demand for new skills and knowledge. The findings show that many organizations struggle to adapt to rapidly changing demands, particularly when it comes to using social media and sustainable transportation methods (Meta codes 5 and 6). The data also revealed a clear relationship between demographic changes, environmental factors, and explanations of ambiguity in HR strategies. However, students did not perceive these relationships as constraints, suggesting a gap between theory and practice.

Furthermore, it became clear that prerequisite knowledge is essential for understanding complex issues, such as transitioning from SD+ to SD- and using special techniques to analyze cultural influences (C.2 OrgC2.1.IAZ/5:56). The difficulty in recognizing lean procedures and the focus on social relations rather than improving practices (C.2 OrgC2.1.IAZ/5:68) indicated a lack of differentiation through experience.

Case 1: This SME is a medium-sized shipping company that is increasingly using digital systems. From the initial analysis we learned that most human capital constraints concern such questions as how to help older employees overcome problems using the new digital systems.

Dominant codes: Customer relations play a dominant role and that influences new codes. On many occasions there is a pattern: when respondents do not react to information, this is followed by even weaker reactions. The interview highlighted various constraints, including sustainability, older staff, and the organization's competitive position in logistics (C.2 Org (C2.1. SGNK/11:13)). These factors emphasized the need to combine pragmatic and theoretical analyses to develop effective solutions for the challenges the organization faces.

Code analysis: *Rhizomatic field*; context independent and higher complexity (SG-, SD+) / Theoreticist. *Score*: (SG-= -1; SG--= -2; SD+ = +1; SD++ = +2)

Rarefied field; context independent and low complexity (SG-, SD-)/novice

Score: (SG-= -1; SG--= -2; SD-= -1; SD--= -2)

Constraints: The respondent clearly stated the effects of digitalization and gave a lot of information on, for example, how their new IT systems are affecting the work of the older generation of employees. Getting older and IT use is a big problem. The respondent gave no indication of either a strategy to deal with this or a concrete solution to the problem. Near the end of the interview, the student concludes that all is clear now but this was not discussed.

"… ultimately you want to work on a problem and give good advice. But then you get results that are actually average, that don't really don't provide anything clear to focus on. At least, you want to meet the expectations in the field, so you need to know about a learning culture and focus on that. And then you have to think: okay, together, what can we focus on? And that was a real challenge, because we didn't have a specific guideline, we had to figure it out ourselves."—

Case E2, HRM student

Now two more sample cases present the conclusions of the analysis of weaker code labels (from (C.2 Org C2.1.IO & (IO C.2 Org; C2.1. SGNK)).

Case 2: This transportation SME has a stable workforce of more than 100 employees and has been in business for well over 90 years. The mainly medium-skilled staff have an average length of service of 11 years. New technologies have relatively little impact on productivity. Staff tasks are easily adjusted. Developments from the environment are not shared with staff. Knowledge does not age quickly in this organization. Innovative entrepreneurship within the organization is supported.

The SME has no problem estimating the consequences of changes in its locality. It does not collaborate much, if at all, in innovative spaces such as field labs. HR uses strategic analyses (e.g., SWOT) to enhance staff employability and quality of work. The SME shares knowledge mainly with other companies in the network. New knowledge is gained by having employees attend conferences and branch organization meetings. The SME also takes part in PPS collaborations. It does not use HR systems to preserve or store knowledge from collaboration with education. Most important new skills required for the coming years is the problem-solving ability of the employees.

Dominant codes: The thematic transcript made it hard to give insight into direct responses. Dominant codes are pragmatic; the constraint clues are relatively easy to identify. This large SME has to cope with planning for instruments to enhance the sustainability of employees. Other constraints are related to the large number of employees, limited capacity of HR and the employee's preference for earning salary instead of attending courses to learn how to tackle sustainability. Working in shifts takes a heavy toll on older staff.

Constraints: Respondents state the history of events clearly. More than 20 constraints are mentioned on the topic of sustainable employment and HR planning.

Case 3: This small SME is scaling up in staff and assignments. It currently has some 20 specialist employees, mostly higher educated (UAS), average age 27 years. No indication of consistency in staff turnover. Collaboration with UAS is seen as important.

High dynamics in the SME's environment affect staff. No strategy instruments for either the short- or long-term. Staff see themselves as volatile. Management shares communications on changes with staff. Knowledge and skills are very important in a setting where knowledge of developments in software, AI and big data become obsolete extremely fast. The SME has an entrepreneurial approach and regards learning and professional development as essential, and attending conferences as important, as is that learning from projects is coded. HR plays no role in knowledge dissemination in networks or HR networks, but HRM is supported on its own digital system. The SME does not take part in PPS.

Dominant codes: The response codes were low on both density and gravity. Problems with digitalization were explained on meso- and macro levels. There is a shortage of staff, however schools (UASs) do not offer an effective option for organizations in a scale-up situations. Especially when information codes are denser and pragmatic, it is more difficult for learners with more SD-SG-

Code analysis: Two patterns. First, a SD+SG+ was immediately followed by a weaker code (C.2 OrgC2.1.IO/1:90/ 1{94) and second, going back and forth in topics (C.2 OrgC2.1.IO/1:98). This could be either a lack of technique or an attempt to confirm/identify what had been said. The student interviewer also used many low SD- and SG codes, indicating social relations affinity rather than disciplinary and operational (C.2 OrgC2.1.IO/1:109) codes.

Constraints: This small specialist in digitalization had a number of constraints. The respondent said that staff recruitment and corporate identity play roles in attachment and connectedness.

5.4.2 Conclusions to Cases 1–3

In summary, these three sample analyses show that organizations struggle with managing change and need an integrated approach that combines both practical and theoretical insights to develop sustainable solutions. In almost all cases we found that SMEs have no HRM/KMM tier system with capability or skills codes. Informal language is based on contextual information and social interaction rather than formal logic. The codes in informal language are used less often than systematic codes and differ in syntax (demanding often longer and more intensive research). In most cases we found that students found it difficult to modify knowledge in the absence of explicitly articulated routines (instructions). Also, developing codes for dynamic capabilities often risked having to make complex rearrangements for which SMEs have little capacity.

When urgent change was a priority, other design principles came into play. For instance, a specific change in the environment required immediate changes to functions. This can be regarded as a short-term solution and has its epistemic consequences in terms of not using conceptualizations.

Weak codifications in semantics and strong codes in operations: In some of the cases that shared a common theme, we saw (possibly) similar constraints. By bundling these constraints (semantically coding), various possibilities emerged for creating absorption (transfer) in SMEs with similar characteristics, allowing us to compare the students' designs simultaneously, under the condition that comparisons must be subject to testing. In three instances, we compared design only iteratively. A major problem was the semantically weak structured codifications, both operationally and epistemically. This was ineffective and did not lead to mutual comparison or testing (efficiency).

Distinct relations: Our findings show that exchanging knowledge on existing support, established routines, and other types of boundaries is difficult in highly differentiated environments. Our research also indicates that within several educational programs, students do not gain business experience in related companies. For instance, the logistics sector is unfamiliar to HRM students when it comes to projects and skill development. Virtually no lessons on HRM are provided in logistics education apart from only one hour per week for logistics engineering students. In Field lab Y9 (see below), we experimented with sharing knowledge obtained through the research with groups of students following the same education, observing how they shared that knowledge with each other. It proved to be very challenging for them.

“I got most of my new knowledge by communicating with various companies. Only then did I truly realize how many differences there can be between companies and that not every company faces the same problems. In this process, I focused on asking critical questions in conversations to gather as much information as possible.”— Field lab Y9, LGH student

The tradeoff between semantic and operational codes affects knowledge representations (2 Org C2.1.IO (IO)). Semantic codes, however, have the tendency to include address codes, meaning that such codes (intensional) are more difficult to overlap with operational codes as we have seen in the comparison between project B and case C.

Our research showed that students in different cases do not share their experiences, which is an obstacle to learning conceptualizations. Overlapping codes may be conditional for working in multidisciplinary teams using statements that address both epistemic and functional uncertainty. We found the language used does not address either uncertainties in functionalities or applications of knowledge.

5.5 Remaining sub-studies, cases Y01 to Y9

Case Y01, Y02: Duration of the project was 10–12 weeks and involved two groups of third-year students from RUAS Business School (n=2x4). The Y01 fell under the students' domain. Most students are familiar with the theories on skills and competencies, as they deal with these in their assignments and assessments. However, they found it hard to make assertions about knowledge that does not come from their assignments.

Y02 is comparatively complex since it involved changing the behavior of employees who have fixed routines and have been working on the same level for a long time. The research focused on the production of routines and aimed to discover what is needed to change these routines. The students researched potential skills descriptions for the future. However, students showed little awareness because they had no experience (no active memory) of such an inquiry.

The problem-solving area: The main concern was the quality of basic working conditions like coffee breaks, lunch and salary. One interesting observation, which was also discussed with the students, was a kind of social proximity. Students preferred doing questionnaires rather than having conversation or conducting interviews.

"Given that the employee knows this, they only need to perform optimally for a few months beforehand. In other words, with our measurement tool, we can highlight the employees' pain points. After changing the evaluation process, we also have a tool (questionnaire) to measure the effect of the changes." Manager A 2.4

Case Y01.1 A large SME that due to the changing requirements of food production techniques wanted to know how this would affect existing routines and requirements of their employees. A monodisciplinary team of RUAS Business School took part in the project. The knowledge base contained high information on logistics processes for distribution, quality control and safety. However, knowledge management for these staff changes lagged. The SME agreed to let the students research various possibilities but preferred having them start with employees who worked in production since they had few function descriptions and, based on their background, would face new challenges in their work routines.

The students changed the initial problem statements of changing routines after interviewing some employees.

"After drafting the initial problem statement and submitting the proposal, the project group continued talking to the HR manager about the organization and the desired situation. It became apparent that production staff feel a sense of 'neglect' compared to the office staff. For example, the flat cafeteria was recently renovated, and leisure activities such as games are available there. Also, production staff feel that they are only allowed to carry out what the office staff order, including implementing increasingly complex ideas." Observation notes by researcher.

Case Y01.2: An inquiry into a skills assessment tool for the SME.

Problem-solving area: The initial target was to interview 15 employees, but we decided to use a questionnaire instead. The research was conducted without clear examples of the relationship between routines and required dynamic capabilities.

Absorption capacity: An important symptom of AC is capability atrophy: no renewal of existing routines for a longer period of time. This and the absence of codification of (new) operational codes, or inadequate codification is the second symptom. Our findings reveal that students are given information on the lack of codification, however the focus is on a habitual: the field of logical routines that deals with emotions and habits in the routines. Information was given on the coordination that needs to be developed since routines have complex interdependencies.

Ambiguity and modification: There is functional uncertainty, and strong interdependencies based on (epistemic) changes in the organization. It requires developing potential AC, for example, in new operational codes.

Case Y4, Y5, Y6, Field lab: Project duration was 12 weeks with students working in groups of three. Most of this time was spent on orientation.

These cases examined the input of RUAS into driving innovation within a regional ecosystem. The project had two key objectives. First, to explore the conditions required to establish a field lab that engages both SMEs and UASs. Second, to develop a field lab dedicated to mission-driven innovations. Central to this initiative was the application of advanced professional knowledge engineering. RUAS selected this assignment based on its documented interest in experimenting with innovative environments, such as field labs. However, the term field lab lacks clarity across different domains, particularly in social sciences and technologies, where varying approaches lead to distinct research methodologies.

The projects were monitored as experimental contributions to the human capital agenda, emphasizing RUAS's role in advancing these efforts. The Y4 and Y5 assignments centered on identifying future competencies for airport staff in response to digitalization, which impacts tasks related to safety, check-in processes, onboarding, and luggage handling. Students analyzed aviation industry trends and situational factors while developing actant models or narrative schemas to support their findings.

The Y6 assignment addressed emergency scenarios involving electric towing vehicles (E-GPUs) catching fire at airports. Four RUAS students collaborated with the airport fire department on risk assessment and studied differences in battery types and firefighting equipment. Their work stemmed from stakeholder-defined questions and leveraged their previous experiences in risk analysis. These initiatives demonstrated RUAS's commitment to fostering innovation through collaboration while addressing complex challenges within diverse domains. A clear aim was to develop conditions for inquiry with UASs students. This is a type of potential AC aimed at researching the role of RUAS in missions.

C**hallenge:** This kind of field lab is challenge driven. There is a significant differentiation between conceptual and pragmatic knowledge, making it difficult for students to shift between these dimensions. Problems are challenge-driven and require multiple rearrangements of knowledge.

Inquiry and sensing: Students are not accustomed to the type of problem presented by the client (lack of question articulation). There is an absence of instructions (principled mechanisms), which leads students to investigate functional requirements rather than epistemic requirements without involving external SMEs. In this case, the functional requirements were hypothetical. In Y5, students from the art academy creatively developed a system to build potential prior knowledge. Here, weakly structured knowledge (systemic blind spots) arose due to unfamiliarity with this type of environment. In Y6, however, we saw that students addressed this by calling on external expertise.

Accommodation and support/dispositions: This scored low. Students needed help and support to develop directions for their research. Students lacked skills in knowledge engineering, and first they had to explore the relationship between human capital and new technology.

Potential absorptive capacity: The realization stopped at sensing a few possibilities. This was mainly due to time constraints.

The project initially intended to be Y6 was terminated due to Covid restrictions.

Case Y1, New skills solution lab: This project paid **s**pecific attention to the role of design in converging and diverging ideas, and comparing the design with other projects. Adhering strictly to the timeline, seven students working in two groups completed the project by week 11.

Problem-solving area: Compared to other municipalities in the Netherlands, the project municipality had a significantly higher unemployment rate, exceeding the national average. It faced challenges related to a low level of education and consequent mismatch between educational attainment and labor-market demands. If this gap was not properly identified and addressed, it risked widening further.

Accommodation and support: A design course was incorporated into the project, including the traditional stages of thinking and research. The project demanded various deeply interconnected forms of testing and problem-solving. Both technical and content-related challenges arose simultaneously throughout the process. The instrument would require ongoing maintenance by the municipality, necessitating agreements on ethical considerations, legal requirements for data usage, and active involvement of municipal staff to modify and adapt the instrument's technical and content features. Finally, it was essential for the instrument to be robust and sustainable to support policymaking effectively.

Complexity and ambiguity: Ambiguity was avoided because the design provided a clear structure. Students focused on developing a (prototype) app that incorporated relevant information needed for the tool, something that we observed was not always the case in our other design assignments.

With the support of weekly meetings and agreements with clients, as well as task distribution, the students managed to create an app. However, the app could not be tested by the IT department and so, ultimately, it was not put into use.

“The research team will send the technical specifications of the app to the municipality, along with this report for reference. The tech specs outline how the app works. The questions it addresses will be relevant for the next five years. After then, the municipality will need to re-examine which social developments contribute to unemployment.” — Student, Case Y1

Capability atrophy vs obsolescence: This case (Y1) was separately compared with cases Y8, Y2a, Y2b, and E(z) regarding the use of design. Evaluations showed that only Y2a and Y2 contributed to the integration of new knowledge. In Y2, this could be clearly explained by the existing knowledge on the topic, accommodation and (HR) support, and the need for innovation in tools within this area.

“I found it hard to think outside the box. I also struggled to express all my ideas. That was the creative aspect of the project, such as coming up with a tool.” —Student, Case Y2a

Absorption by assimilation: AC on knowledge on design took place during the development of the prototype. Less knowledge was seized on how it related to the dynamic capabilities (reconfiguration of other existing tools).

Cases BY3 and BY4: We compared and merged the results of the questionnaire and interviews with SMEs operating in the supply chain sector. The findings showed that smaller SMEs face significant challenges due to their reliance on temporary staff instead of permanent contracts, which limits their ability to invest in personnel development. While this approach provides flexibility, it also makes core teams vulnerable and less stable. Small organizations often lack proper staff planning and are unable to invest in development programs. The use of external contractors eliminates responsibility and incentives for skill development. Recruitment strategies focus on offering competitive salaries rather than educational opportunities, which creates a major challenge in attracting younger generations.

As digital skills and protocol training become increasingly important, the high costs of development programs remain a barrier for many branch organizations that cannot afford them. Older employees, particularly order pickers working night shifts, face physical strain with few opportunities to innovate or adapt their tasks. Drivers encounter limited career advancement opportunities, as promotion to roles such as planner is rare and requires overcoming significant skill gaps. HR strategies are often absent or reactive, primarily addressing client demands rather than focusing on long-term workforce planning in a dynamic environment. Many drivers are unfamiliar with HRM concepts, indicating a lack of engagement in strategic workforce development. Additionally, drivers frequently switch employers in larger organizations, chasing higher salaries and better secondary benefits (e.g., phone cost coverage).

Some supply chain operations rely on minimal staff despite managing large-scale turnover, which increases pressure on the workforce. In small, family-owned organizations, reliance on tacit experience and informal structures creates challenges in innovation, process management, and employee involvement. Decisions on innovation are often based on informal hierarchies and seniority due to the absence of formal job descriptions. Many processes depend on repeated instructions from managers rather than being documented in formal procedures.

SME-driven challenge: AC of students was mostly affected by seizing, in terms of mobilizing resources by possible designs. This sub-study showed the strains on the various levels of conversion that are needed to design, develop and implement necessary contingent innovations. An SME-driven challenge affects earlier possible or necessary knowledge, that is, even if students were familiar with the contextual conditions, they still required modal knowledge. Highly differentiated challenges made AC even more ineffective when SMEs required differentiated knowledge modifications for absorption. The conversion sub-study showed that absence of a knowledge representations framework (or epistemic model) creates multiple possible solutions.

Case Y8a: Entrepreneurs in the local area primarily relied on physical stores for revenue, lagging in adopting digital business practices. The COVID-19 pandemic and subsequent lockdowns forced store closures, putting many entrepreneurs at risk of going out of business. This makes it crucial for these entrepreneurs to develop digital and business skills that can enhance their flexibility and resilience. Case Y8a focused on how business school students can create new revenue models, such as digital entrepreneurship, for these businesses.

Case Y8b: Here the challenge focused on addressing energy poverty in older residential areas where houses suffer from poor insulation and lack sustainability, resulting in higher energy consumption compared to modern, energy-efficient homes equipped with proper insulation and smart meters. Families in these areas spend a larger percentage of their income on energy costs compared to wealthier neighborhoods, leading to financial strain. This issue conflicts with the broader municipal goals of creating a green and sustainable city powered by renewable energy sources like solar and wind. Stakeholders expressed interest in supporting initiatives to tackle these challenges through innovative solutions. Students were tasked with researching and developing strategies to improve housing energy efficiency, reduce costs for residents, and align local practices with sustainability policies, as well as promoting social innovation while fostering collaboration between the municipality, housing corporations, and residents.

Case Y8c: Local residents were not using their courtyard garden because it failed to meet their expectations. To address this issue, we formulated a design question: How can the garden be modified to encourage its use by local residents? This problem served as the starting point for the assignment, which involved conducting research on the garden, its users, and the surrounding environment. Students were tasked with designing solutions to improve the garden's appeal and functionality.

Case Y8d: Problem-solving areas in the purpose economy were one of themes RUAS collaborated on with stakeholders. This kind of challenge-based engineering limits the conversion or semantic barrier for AC. At the same time, the areas lack operational codes and, as we saw in Y8d and in all our other design cases, the designs primarily researched solutions and, importantly, lacked testing.

Schema codification for knowledge construction was absent in all design cases, which affected the students' assimilation of knowledge. The feedback/reflection round often created more diverse than converging views. Complexity in these situations is relatively low. The absence of routine forced more conceptual thinking, which the students found very difficult to do.

"We had to jump from one step to the next in the Design Thinking process and complete the different steps, without what I felt was enough time for this. The tight deadlines often did not match the time we were given to do this. There were also many uncertainties, and although I mention tight deadlines, what exactly was expected was usually not entirely clear."— Student, Case Y8

Y9 Field lab: In this design-oriented, practice-based research project, students contributed to a sustainable solution (impact and knowledge creation) for a self-chosen problem within the theme of leadership (focus), set against the backdrop of Industry 4.0. This theme of leadership is closely connected to other key themes at RUAS, such as digitalization, sustainability, and the purpose economy, all of which have a significant impact on SMEs.

“When conducting research, you shouldn't always stick to what you initially plan to investigate. Through interviewing people in the company, for example, the research often takes a different direction than anticipated—one that is more relevant to the company and the study. I’ve learned from this and aim to be more flexible in future research projects.”—Student in Y9

Problem-solving area: The problem-solving area lay between being curriculum-driven and SME-driven. There was no focus on the human capital agenda, nor were specialized tools or previously acquired knowledge available on this topic. Students found it challenging to translate the theme in relation to technology.

Functional uncertainties & SME differentiation: Students discovered that SMEs often have ambidextrous leadership. Students also observed that changes were difficult to research within the given time limit. Trade-offs played a role here: companies assess where they can gather information and weigh it against the associated risks.

“We haven’t had any specific courses on digital developments. If there are uncertainties, we mostly try to clarify things by ourselves. We do have a number of trained key users, who can answer the users’ questions once everything has been implemented.”—SME Manager, Y9b

5.6 Conclusions to pattern-searching analysis

The findings reveal a distinct relationship between epistemic and functional uncertainties.

Answer	Percentage	Contacts	Question type
Robotization and automation	41,5%	73	Multiple answers per respondent Total responses 176
Digitization	74,4%	131	
Artificial intelligence (AI)	7,4%	13	
Blockchain	9,7%	17	
Big data	21,0%	37	
Technological development is not important to us	13,6%	24	
Other, namely	5,7%	10	

Uncertainties

Our data show that SMEs are uncertain about the impact of technology on their organization. Most are aware of the strong technology-driven dynamics that disrupt affect the functionalities of knowledge of which SMEs are aware. The SMEs in our study were differentiated by age, management structure, and educational level that in most cases originated from single modes of highly tacit and embedded knowledge production. When we set these SME characteristics against the capabilities required for responses (innovation), we saw distinct patterns.

Capabilities

Capabilities differed in habitual routines and standard routines that can vary in response to situational factors and events. Habitual routines are recognized more often in tasks rather than in skill descriptions. These are also easier to switch or replace, which we observed regularly. The acquisition of new capabilities often occurred among SMEs, even small ones, when it involved habitual routines and routines. The learning process was often informal. Habitual routines and routines are typically not epistemic.

Routines were more frequently grounded in cognitive habits, where habituals provided structure without contributing or even diminishing cognitive development it. The distinction between skills and capabilities was strongly present. Particularly, when it came to skills, it often involved technical skills that had been learned earlier (or somewhere else). In our research, capabilities involved a combination of skills and experiential knowledge within a specific situation or context.

Answer	Percentage	Responses	Question type
Strongly disagree	2.8%	5	Multiple answers per respondent Total responses 176
Disagree	15.9%	28	
Neutral	40.3%	71	
Agree	38.6%	68	
Strongly agree	2.3%	4	

Table 42. Impact of technology

This table shows the number of SMEs that find it difficult to know the impact of technology (data from survey in case D). We observed that many SMEs adapted their functional capacities, for example, by placing additional emphasis on tasks or increasing tasks, rather than refuting, relocating, or even reconfiguring these capabilities. There was little adjustment in epistemic functionality as a result of environmental dynamism.

Absorption capacity and epistemic governance

In the case studies, we noted no distinct difference between strategies aimed at potential absorption via reconfiguring individual capabilities and those focused on absorption through integrating a set of capabilities from interdependent individual agents. There was a distinction in the need for adjustments to operational capabilities versus the need for dynamic capabilities among businesses. The characteristics of the situation or context influenced the ability to change capabilities. Except in cases A and B, it was challenging to get SMEs to participate in the study. In many cases, the students did the approaching.

The fact that there is less talk of generalized absorption of applied knowledge often relates to time pressure, experience with environmental factors influencing knowledge uptake, and the impact of these factors on the execution of student research measured over time, as well as differences in the complexity of tasks that hinder the exchange of information.

5.7 Cross-case findings answering the research questions

In summary, this study aimed to advance knowledge in the field of applied epistemology. The focus was on characteristics of critical situations in which existing knowledge can no longer be applied or the application of knowledge does not distinctly address the problems the actors face in their context and associated routines. Accordingly, we investigated the characteristics of these critical situations, as well as the attributes of the actors involved, situated against the backdrop of emerging technologies that impact the application of knowledge within UASs and SMEs.

Viewing these routines as levels of structured embeddedness in terms of the actors' approaches, the findings reveal how these crises create epistemic and pragmatic uncertainties in the distinct worlds of UASs and SMEs. Our conceptual framework led to the following key insights

The next table (35) shows how the cross-case findings direct a conceptual topology for immersive learning spaces.

Dynamic capability and -capacity for effective knowledge absorption based on modal consciousness in UAS-SME relations under epistemic uncertainty.

SME-Production Mode (1-4) and possible Quadrant position (A-D) and types of knowledge representations	**Access to history and available tools for to assess what is known and required reconstructions**	**Learner type (archetypical)**	**General description**	**Consciousness of modalities and effect on functionalities** **Effect on contribution to (potential) absorption capacity in terms of reconstruction of functionalities SME-UAS and necessary process steps**
Mode 1: B	*Access based on curriculum and/or horizontal domain knowledge* *Clear history footprint*	Novice-Professional Requires instructions from experts to have access to new information for deeper understanding	A novice is an innocent or naïve learner and has still little prior knowledge in pragmatic domain and little access to the conceptual foundations of a knowledge field. A novice relies heavily on specificity of contexts **(high semantic gravity)** and converts **little semantic dense information (either tacit or theoretical)**, meaning their understanding is relatively undifferentiated in terms of consciousness of modalities and in behavior relies on	Developing, awareness of new information and how to access this information is limited. High uncertainty: The learner requires simulation types of knowledge (Rattan, 2006). Reconstruction of curriculum

			concrete examples rather than abstract or general conceptualizations.	
Mode 1-2: (C-D)		Disciplinary - theoreticist	A learner (student) or professional who engages deeply with highly abstract and conceptual knowledge, shows an advanced ability to integrate knowledge from a specialized domain. A theoreticist uses mainly dense and abstract frameworks to understand and explain phenomena beyond immediate contexts, showing independence (maturity) in navigating more complex knowledge systems. Uses mainly theories for reconstruction as (self)reflexive system.	Using disciplinary knowledge in differentiated possible situations only. Developments of making extension based on experiential knowledge to similar situations. Reconstruction of functionalities based on making and playing (Valente & Marchetti, 2005)

SME-Production Mode (1-4) and possible Quadrant position (A-D) and types of knowledge representations	Access to history and available tools for to assess what is known and required reconstructions	Learner type (archetypical)	General description	Consciousness of modalities and effect on functionalities Effect on contribution to (potential) absorption capacity in terms of reconstruction of functionalities SME-UAS and necessary process steps
Mode 2-3: (D-B-C)	**From:** Methodical Professional: Guided, structured problem-solving	**To:** Methodical - Analytical Professional: Developing analytical skills; application of concepts	A professional knows to distinguish situations that complement theoretical gaps. Uses the functionality of roles (input output) and situations (semantic externalism (Putnam, 1975))	Reconstruction (adjustments) of prior knowledge based on high dynamic environments (divergent information) over longer periods of time. Scenario reconstruction rather than response. Reducing on uncertainty in diverse possible situations by using different knowledge claims and statements. Support absorption by synthesizing diverse knowledge across sectors and promoting innovation within complex systems

Mode 3-4 (A-C)	**From:** Analytical professional;	**To:** Reflexive disciplinary professional	Absorption enhanced by critical reflection, social accountability, and inclusive dialogue, recognizing diverse forms of knowledge	Continuous reconstruction based on dense information and quantification of epistemic modalities. Dynamic environments integrate modalities and changes descriptions of output based on contingencies that are acceptable
Mode 4 and beyond				Unknowns (plausible)

Table 43. Representation of necessary epistemic governing

This table shows a representation of necessary epistemic governing of diverse types of learners over different situations (quadrants). It shows how epistemic advancements (logical move) for a type of learner and accessibility to new representations of knowledge. It indicates learners' capability to make statements on different situations (epistemic states) types of functionalities and ability and capacity of agents involved to adopt to reconstructions in a knowledge configuration (Dynamic capability for knowledge absorption based on modal consciousness under epistemic uncertainty in UAS SEM relations). it shows the topology of an innovation spaces that requires extensions based on inferences of coherent practices. The last column shows requirements for the interface, knowledge evaluations and type of codification of knowledge in knowledge bases of UAS and their different domains.

CHAPTER 6

Discussion of key findings

Chapter 6. Discussion of key findings

This chapter discusses the key findings of our research into the capacity of UASs and SMEs to absorb knowledge. It proceeds in the following sections:

6.1 Introduction

This study examined the capacity to absorb knowledge through both epistemic and pragmatic lenses. From an epistemic perspective, we researched the uncertainties and limitations inherent in acquiring, evaluating, and integrating new knowledge. From a pragmatic perspective, we focused on how knowledge is applied in real-world contexts, emphasizing the decision-making processes and actions that follow from knowledge acquisition.

Utilizing a mixed-methods research design, we systematically explored how varying environments, organizational contexts, situational demands, and established routines shape the ability of agents to reflect upon their own practices, assimilate new information, and extend their sets of skills and tasks. We paid particular attention to the ways in which these factors influence agents' capability to respond adaptively to challenges posed by emerging technologies.

This dual-perspective approach allowed us to capture not only the cognitive and epistemic conditions that enable the absorption of knowledge but also the practical mechanisms and constraints that affect its application and utility in dynamic organizational settings.

6.1.1 Conclusions (C) on the research framework and MMR sequence

In this study, we approached the capacity to absorb knowledge from both epistemic and pragmatic perspectives. The results of each of these stages were iterated to create a model that distinguishes epistemic states that require distinct strategies for the absorption of knowledge.

This model also helps to understand different epistemic and pragmatic boundaries and their effect on various UAS and SME systems for the absorption of knowledge. By systematically comparing our empirical findings with the theoretical framework, we iteratively refined our model at each stage. This refinement was operationalized using a quadrant to develop a comprehensive model that describes how essential knowledge representations need to be constructed in alignment with environmental dynamics and the absorptive capacities of SMEs.

C.1. Learning is conceptualized in the conceptual framework as a dynamic process involving transitions across epistemic and pragmatic dimensions. It shows tensions between the dimensions and levels of routines and the response requirements tasks and available time. The framework is aimed to improve the identification of new knowledge required in a given context and the boundaries of that world.

C.2 Analysis revealed that heightened environmental dynamism increases pressure on pre-existing belief systems developed by organizations and agents.

C.3 Analysis showed how the practical domain is constituted by varying configurations or assemblages of routines and a variety of (external) agents. Specific extensions of applying knowledge through skills are closely intertwined with the type of routines and how systems and (external) agents facilitate and support agents engaged in these routines.

C.3 Our findings discovered an ambiguous relationship between epistemic and pragmatic elements of functionalities of knowledge. This ambiguity has several causes. For example, based on Gardenförs, (Gärdenfors, 2017), semantics based on informal languages cannot be categorized in a knowledge domain in UASs, nor does it comply with informal semantics. As a result both the inferences and transfer of effective new functionalities to comparable situations are not possible.

C4. More importantly in terms of ambiguity, we found that absorption of critical knowledge requires conceptual understanding and that has practical implications for learners. It also involves inquiry to determine the necessary capabilities, available time for agents to learn, and supporting mechanisms need for changes in the configurations of tasks in SMEs. We found that being aware of what is necessary is important to understand the effect of prior knowledge.

6.1.2 Necessary absorption of knowledge in UAS- SME relations

New technologies introducing new applications accelerate the obsolescence of knowledge. However, this creates ambiguity and epistemic and pragmatic doubt for further epistemic advancements and applicability. This ambiguity and dualism between epistemic and pragmatic doubt slows down the necessary absorption of new knowledge.

Mitigating risks

Our findings show that SMEs often recognize obsolescence of knowledge and acknowledge their need for new knowledge disciplines and domains. However, many SMEs in our study had little experience of changing their capability to create future knowledge representations that would support the incremental absorption of knowledge. These SMEs confront the higher impact of needing to reorganize or reconfigure both prior knowledge and existing processes and skill formations. In smaller SMEs such reconfigurations potentially lead to economic risks.

From innocence to awareness to modal consciousness

Our research shows that SMEs tend to reject new technologies due to insufficient knowledge of what the possibilities of existing application entail and so what could be new functions for existing routines. Consequently, changing or expanding existing routines requires certainty about the extension functionality in relation to the other work activities of agents. An expansion is accepted more often when based on predictive or posterior knowledge on upskilling or its required modifications in the systems configuration. SMEs prefer information about this from customers and/or suppliers and to a lesser extent from other SMEs. However, these sources sometimes contain structural holes in information, especially when contributing to developing, validating, and testing knowledge extensions before these are introduced. If knowledge functionalities are not developed and validated first, transformation is the most decisive legitimation of the absorption of knowledge, given the specific capabilities of agents with demanding routines or microprocess and related tasks.

Showing epistemic innocence

When students navigate as observers rather than inquirers or problem solvers, we found that their attitudes were strongly related to their vocational background and knowledge domain. Students without strong ties had more difficulty navigating between epistemic and pragmatic dimensions. Using our framework we researched students' activities and found stronger persistent beliefs when the pragmatic world differs from their prior knowledge (Spiro, et al., 1988; Bendixen, 2016). (Bartolotti, 2020; Willard, 1979). This behavior is a type of innocence that affects the students' integration knowledge, resulting from their lesser ability to develop priori knowledge further.

The following table shows the relations between our framework and the themes found in our research.

Axioms	Reflexivity		Transitivity		Symmetry		Temporality
Dynamic type	Technology	Function-ality	Capability	Routine	Language	Future state	AC type
Lack of knowing	Application and domains	Epistemic	Ordinary	Ha-bitual, situa-tional	Pragmatic	Necess ary	Potential/ individual
In between						Contin gent	
Lack of knowing methods	Societal challenge	Functional	Dynamic	Routine and eventful	Semantic	Possibl e	Realized/ systemic

Axioms	Reflexivity		Transitivity		Symmetry		Temporality
Dimensions of knowledge about the absorption of knowledge	Modal consciousness						
Modification by epistemic capability and capacity	Being aware of the conditions that influence knowledge transformation and being able to influence these conditions based on epistemic and practical motivations and experiences.						
Dynamic capabilities	The ability to distinguish between necessary types of capability and acting accordingly.						
Disruption/ uncertainty	The ability to distinguish between practices of knowledge and epistemic conditions necessary to realize that knowledge in different practices.						
Epistemic governance to assess & span boundaries	Determining different epistemic spaces based on the type of experiences of agents, students, and the complexity of practices.						
HRM and/or KKM support and/or accommodation	Realizing systematic knowledge management between different SMEs to achieve epistemic progress.						
Absorption–dynamic capability divisions	Identifying different forms of the absorption of knowledge and the associated processes.						
Distinct relationship participation/ collaboration	Creating conditions for students and agents from different contexts to gain experience with various epistemic models.						
Conversions & translations	The ability to make translations and conversions to facilitate the absorption of knowledge by human agents in sets of interdependent processes and agents.						
Learning knowledge Integration	Creating different conditions in spaces (games, scenarios) that enable agents to learn to deal with changes in knowledge over time and decide on the conditions (necessary, possible) to actively integrate knowledge and reconfigure routines.						

Table 44. Synthesis of the results based on the framework and sequences of themes found for a model for an epistemic space

6.2 Key findings

Changing the capabilities of agents depends on the properties of their epistemic system, their reasoning capabilities, the time they have available to reflect on evaluations of extended routines and their attitude to pursuing new epistemic functions. We found that epistemic uncertainty results from the agents' lack of knowledge of their epistemic state.

Access to and identification of knowledge by students

"Everyone had worked there for over 40 years. Clearly, people had worked there for so long and felt part of the team. They even talked about it being like a club, saying 'this is my club,' and if someone new joined, they were still a tight-knit group because they'd known each other for 20 years and trusted each other's abilities."—Student, Case E

In smaller SMEs we found informal, tacit knowledge is often dominant. Tacit knowledge is based on pragmatisms, in real time by skilled agents using a range of codifications of knowledge. This pragmatism is often based on 'oral culture' (Orr, 1996). Tacit oral knowledge formulates constraints and problems based on participation in a knowledge culture, making it a functional belief system. Knowledge conversion from contextualized environments requires an awareness of tacit knowledge of the differences in relation to its environment. This type of knowledge often adjusts to the physical or practical environment. It is a form of self-referential closure (Luhmann, 1990).

As for students, we studied their capabilities in converting tacit knowledge to explicit knowledge and back to a natural language. We found that they struggled to make distinctions in beliefs, environments and communication. In other words, they perceived knowledge as being equal in all circumstances and all contexts.

Set routines receive less than dynamic responses

SMEs accept changed in their set routines that involved extending higher-level routines when the set processes were less repetitive and context-specific. The problem-solving identification of extended routines also extended over time and involved multiple (human) agents that required movements beyond direct and reactive responses.

The expression of extensions in micro-routines is more uncertain in that it is hard to measure. It is also uncertain how these extensions relate to other tasks and in consequences that involve the absorption of knowledge. We found that possible extensions of routines often affect employees who have been performing these routines for a long time. Often these are structured tasks based on established patterns or procedures and offer little variation or creativity.

Most organizations in our study had strongly routinized, interconnected work processes. In many of our cases, it remained unclear which specific tasks within a set of routines could be modified for individual employees. Often tasks or functions were not thoroughly documented, except in terms of (often very accurate) time allocations. The cognitive process of learning from systematic routines is challenging. Routines that involve more varied tasks often necessitate horizontal expansion, such as task enrichment, which involves adding more tasks of the same level. However, the dynamic capabilities required for innovation and adaptation demand tasks at a higher level of complexity.

Experiences in routines are often also involving physical experiences and tacit knowledge transfer. Modern technologies are often based on formal expressions of tasks. We found that digital documents are sometimes printed before use. Software requires expensive updates for tasks extensions that are not used or required in particular routines.

Transformation: the substantive, practical dimension

Small SMEs frequently lacked HR support in organizational development, which could hinder their ability to adapt and innovate effectively. Very few organizations have a human capital agenda. This suggests that while HR personnel and or tasks are present, strategic integration is limited. Organizations found it hard to determine the impact of HR functions on their operations. Smaller SMEs usually did not belong to an HR network, indicating limited knowledge sharing and/or best-practice sharing. If they did take part in project, as we saw in project B, very few HR employees discussed the effect of the results for their organization.

All organizations operate in dynamic environments that affect their strategies, staffing, innovation approaches, and knowledge-management systems. However, we found that few organizations see innovation in terms of capabilities as part of job requirements.

Developing knowledge engineering (governance strategy)

We found that societal challenges generally require challenge-driven learning based on knowledge engineering. Addressing these challenges to learning in knowledge domains or disciplines also requires varying inquiry approaches. Epistemic governance can select levels of students’ experiences of different types of inquiry. Such governance requires distinct knowledge-management interfaces that support knowledge flows and evaluations of different contexts to integrate different types of knowledge codification for dissemination, storage and retrieval. This allows existing experience and instances of good practices to become communal knowledge and part of its social ontologies, and to deepen the knowledge needed to integrate the epistemic and practical dimensions. Changes in the paradigm of knowledge, especially the production of knowledge-in-use, requires principles and ideas on new types of knowledge constitution from several (interdisciplinary) domains. Furthermore, it needs more awareness and accessibility to authoritative sources of information. Differentiating students in teams or projects required methods to construct knowledge and constitute functionalities according to both context-dependent and context-independent criteria.

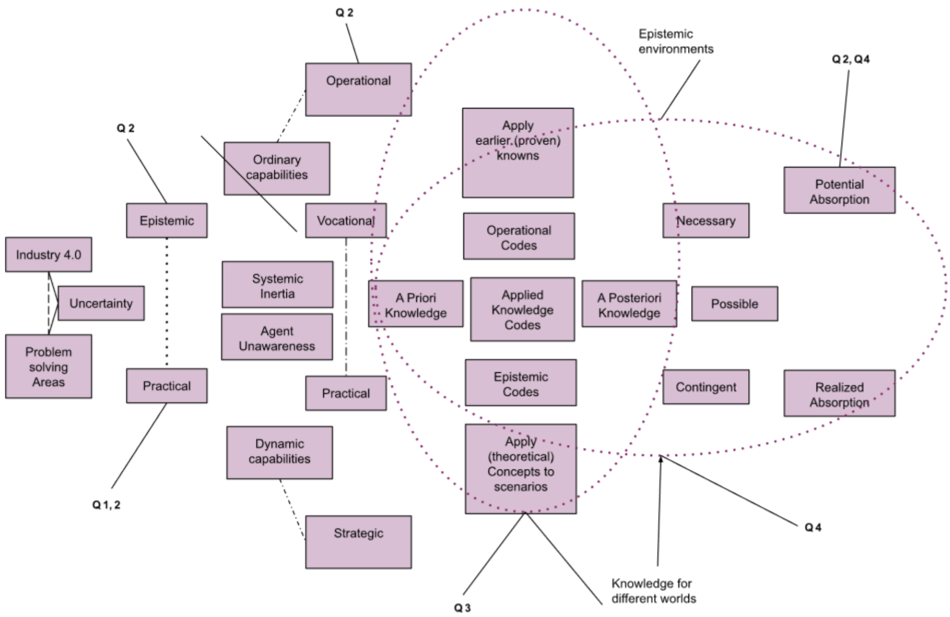

Figure 33. Framework and contributions to research question from our research

Selection of SMES and a synchronicity

"We had a bit of a shift in the theme. We were a bit off track at first because initially we focused on, well, leadership, since the talks were mainly with just the HR officer. It was also a bit of a consultation, where we really wondered, 'What can we do?' Once someone mentioned that another group had created some kind of game. So we thought, 'Oh, maybe that's a fun idea too.' But eventually, the director showed us the email he'd got from a group at the school. But it was a very short email, and you thought, 'What's the actual purpose of that project?"—Speaker 2, Case E

In the cases we studied, SME participation was often arranged shortly before the start of a program, or even after the program had begun, except for Case A, B (PPS). This was partly due to the large number of requests SMEs receive from local educational institutions and/or time constraints. However, when students were asked to invite SMEs to participate in their research, it became evident that differences emerged in the interpretations of the problem-solving area to be investigated. As a result, we found outcomes differed from a range of other possible learning goals, such as organizational sensitivity or impact on stakeholders, communication, interdisciplinary perspectives and ethics.

Solving modern challenges requires creating knowledge-in-use, practical insights that come from applying ideas in real time. This involves testing ideas in actual situations, changing how people think about problems, and understanding the impact of existing methods. Our experiments in the solution lab showed that turning broad challenges into actionable plans required a focus on beliefs and logic, not just technical steps. A comparison with the Living lab revealed similar difficulties in developing practical solutions. Overall, managing knowledge in complex projects involved changing how people think and collaborate, and even the best plans needed flexibility to adapt to real-world challenges.

Pragmatic diversity and explanatory reasoning, hard knowledge

Epistemologies, particularly the epistemology of modals, aim to articulate how knowledge is constituted and justified in modal frameworks (Becker & Zhao, 2023). We researched the conditions under which certain knowledge claims are necessary or possible, independently of the specific knowledge held by any given agent. By modeling diverse cognitive frameworks, we sought to explain how agents, with the help of naïve or innocent learners, relate to and interact with knowledge claims under varying epistemic states.

This endeavor required the development of a comprehensive epistemological framework capable of adapting knowledge representations in accordance with the differing cognitive structures and informational states of agents and systems. Our framework had to accommodate the modal dimensions of knowledge; that is, it had to specify not only what is known but also what could or must be known given particular epistemic constraints. This modal approach facilitated understanding how knowledge can be flexibly constituted, revised, or extended depending on the epistemic capacities of agents and their interaction with their informational environments.

Challenges, dynamic capabilities and the absorption of knowledge

To influence absorption capacity, we also researched the dominant type of capabilities. Responding to challenges requires integration of new knowledge. In most cases this was the responsibility of human agents. In every project we found SMEs mentioning that their employees required more capabilities and their routines were often highly repetitive.

Dynamic capabilities enable SMEs to reconfigure responses to environmental changes (Eisenhardt & Martin, 2000). Such capabilities involve routines that facilitate the transformation of existing capabilities using new information. In contrast, however, we found that smaller SMEs had more non-dynamic capabilities in core operational routines. These highly repetitive capabilities are aimed at exploitation (Teece, et al., 1997).

Our reconstruction approach: The formal logic of practice for innocent learners

Chalmers (Chalmers, 2011) defines epistemic spaces as the conceptual set of all epistemically possible scenarios about how the world might be consistent with what is known a priori. This maps out a range of conceivable knowledge states given our current epistemic constraints. In contrast a pragmatic maximum (Peirce, 1929) focuses on the meaning and truth of ideas in terms of their practical consequences and usefulness.

Our findings show how epistemic spaces act as broad conceptual or logical structures that require complementation by focusing on knowledge and truth in terms of human consequences and practical relevance under epistemic uncertainty to affect knowledge absorption. Such spaces bridge a priori possible knowledge and knowledge use, making reconstructions possible and necessary.

Using this, we researched the extent to which this influences the interaction between two distinct systems, each with its own language and internal logic. Drawing on our framework, we hypothesized that less experienced researchers encounter particular difficulties because subjective qualia (Bourdieu,1990) resist formal conceptual descriptions involving the extension of existing routines. Qualia are “pragmatic signals that materialize phenomenally in human activity as sensuous qualities.” (Harkness, 2015).

This process is anchored in the authority of empirical evidence, as opposed to informal, tacit, or context-dependent (soft) knowledge. Our research demonstrated that most SMEs rely heavily on information obtained through trusted relationships—such as clients and customers—when developing and refining their knowledge practices. We found that these organizations have difficulties in conceptualize and describe their external environments using an ontological objectivity, that is a shift toward adopting abstract or generalizable perspectives to interpret environmental dynamics (Thompson, 2011).

Across our case studies, we observed that smaller and micro-sized SMEs tend to invest in short-term strategic tools, valuing their immediate practicality and alignment with ongoing operational routines. We found that these established routines appear to have a stronger effect on strategic responses to changing environments than organizational size alone.

This distinction is exemplified by the companies depicted in 12A and 12B, both operating in the same industry. Company B, the larger firm with around 100 employees, contrasts with Company A, which has about 20 employees. In Company A, organizational processes move fluidly between ontological reflection, conceptual modeling, and practical implementation, often in relation to shifts in market position. In contrast, Company B's more complex routine structures necessitate frequent expansion of both knowledge and skill sets to manage day-to-day operations.

Adaptations in organizational knowledge and skills align closely with the practical needs and existing competencies of each firm. Our framework conceptualizes this as an equivalence between SMEs and UASs, particularly regarding the constitution and application of hard knowledge. Environmental dynamics represent a central concern for nearly all SMEs in our study. However, we found that smaller SMEs (with fewer than 50 employees) often lack both formal and informal processes to effectively update or adapt their knowledge and skills. Importantly, these firms also differ in their awareness of how such adaptations—or the lack thereof—impact their organizational routines and future capacity to respond to change.

“One of our sales employees is very knowledgeable on the technical side. So, they know whether something is possible or not. And then we have another company linked to our supplier, with other people who have even more understanding and technical knowledge to say whether it will work or not. Ultimately, we discuss it with the supplier, where the real tech experts are, and that's where it gets produced.”—CEO, Case D1.2

The different ways these SMEs respond to environmental changes show the importance of tailored knowledge-management strategies. Strategies not only concern organizational structure and size, but also the interaction between practical routines and evolving epistemological frameworks.

“Well, on the one hand, you look, let's say, who takes on that part. You try to look further ahead and have your real multi-year plan, at least in your head, even if not on paper, about where we want the organization to go. But at the moment, you could say that what’s thought up today can turn around completely tomorrow.”—Manager, Case DE1.3

Absorption of knowledge requires knowledge of the requirements for semantic integration (conversions) and demands reasoning across multiple modalities and cognitive modes.
Another example we analyzed further explains how dynamic integration of semantic epistemic logic is required to understand the multiple modalities concerned:

- A formal, explicit mode, which relies on the systematic correspondence between observed extensions in employee-involvement practices and their semantic representations;
- An extension mode, involving broader sets of knowledge representations that accommodate evolving, fluid interpretations beyond rigid formalizations.

Conversely, we observed another case in which a student researched ‘data corruption,’ supported by clear, direct, and concrete examples embedded in the announcements for the agents involved. This explicit semantic representation engendered immediate trust and epistemic acceptance, even though the student (the target agent) initially lacked substantive knowledge of the domain. For example:

The initial (i) knowledge (K) : Ki(p)represent “Agent 1 knows that p”

- By making extensions a student can reason on different knowledge representations, for example, the design of a specific function in a semantic representation (as if that is an extension). The extension is new information represented as announcement (Ann) that acts as semantic epistemic stance.
- Ann(q): The extension is represented in Ann(q)→Ki(q) stating that when the extension is made the agent knows about the extension after the announcement. Knowing this syntax, we can make consequences in the syntax. For example, it is necessary for other agents to know that this is true. For the students conducting research this explains why other agents must understand and trust the extension. This is the important reason for not using natural or colloquial language that relies on intensions.

Together, these cases demonstrated how semantic operators amplify conceptual extensions in different knowledge representations, mediating a belief revision depending on the (level of) formality of the semantic context. It showed the necessity for educational frameworks and epistemological models to support multiple modes of reasoning (e.g., in the design properties of objects) to facilitate meaningful the absorption of knowledge and conceptual adaptation.

6.3 The concept of modal consciousness

Our framework is founded on deliberate and reflective navigation between the epistemological and practical dimensions of knowledge, thereby deepening the understanding of knowledge as a dynamic process encompassing its production, constitution, and eventual absorption. This dual-dimensional approach recognizes that knowledge is not only constructed and justified in various epistemic contexts but also enacted and transformed through situated practices.

Central to our framework is the concept of modal consciousness. Modal consciousness is a necessary condition for human agents to develop distinct technological, epistemic and sustainable functionalities of knowledge as a response to continuous technological developments. The concept of modal consciousness seeks to enhance epistemic validity by making explicit such conditions as necessity, possibility, and contingency that govern knowledge use. By fostering this awareness, modal consciousness helps to mitigate epistemic uncertainty associated with knowledge application, thereby improving the reliability and legitimacy of knowledge claims in complex, often ambiguous environments.

The integrative nature of the framework supports epistemic advancement in applied knowledge, particularly for agents operating in dynamic organizations and social systems. Crucially, by disambiguating the relationship between the epistemic (knowledge-as-justified-belief) and the practical (knowledge-in-action) elements, the framework facilitates a nuanced and context-sensitive applicability of knowledge.

The epistemological dimension attends to the diverse contexts, cognitive dispositions, and underlying assumptions that influence how knowledge is identified, transferred and transformed, as well as validated, legitimated and supported for maintenance. Our findings showed the modal variations based on different situational factors such as social norms, beliefs that shape epistemic stances and more importantly accept the stances from UASs.

The practical dimension emphasizes the enactment of knowledge in concrete, real-world scenarios. It focuses on how knowledge is operationalized through routines, practices, and decision-making processes, thus enhancing its effectiveness and relevance.

By embracing and integrating these epistemological and pragmatic frameworks, it supports present and future agents with the capacity to extend and adapt their knowledge across multiple modalities. This adaptability is critical for navigating complex semantic landscapes, where belief systems, habitual practices routines and contextual contingencies interact to influence the absorption of knowledge and transformation.

6.4 Answers to the research questions

1. **How can UASs and SMEs share knowledge about tools and instruments for continual advancements in dynamic capabilities under epistemic uncertainty?**

Ongoing learning is perceived as both necessary (pragmatic) and possible (epistemic). At the substantive level, not all potential knowledge can be transformed into existing routines. Modeling distinct epistemic environments enables us to learn from possible new tasks and routines (identification) and to validate and modify their associated expressions according to the characteristics of the system and its users. To be more effective and efficient we need to determine coherent inference sets of practices and environments. The absorption of knowledge requires exploring between corresponding practical and epistemic worlds where the knowledge of both systems depends on a joint ability to imagine and develop a priori (epistemic) knowledge or foreknowledge (practical) for assimilation.

The characteristics of objects thus depend on the context and acceptance of uncertainty. Here integration of coherence and correspondence means that judgments or knowledge claims are evaluated both for their logical consistency and their alignment with real-world facts. The role of judgment is consistent in epistemology (Löf, 1996). The answers to our first research question are as follows.

i. Compared with our framework, knowledge interfaces support knowledge in sets of organizations based on the ability of agents and students to create potential capacity for the absorption of knowledge. For smaller organizations, a UASs may act as a knowledge base for consulting best practices. Establishing an interface increases the knowledge flows necessary for collecting data that can reduce uncertainty. An interface can be used to create and refine epistemic models for codifications at different levels of routines, using new semantic concepts that express extensions of routines. In this way, exchange between a set of similar SMEs becomes possible.
ii. Evaluate and integrate. The experiences gained from SME projects were not evaluated enough to create potential capacity for the absorption of knowledge.
iii. Not only develop knowledge management for UAS-SME relationships, but also integrate it into education, especially within HRM to teach students how to develop knowledge about knowledge.
iv. Develop human resources as it is crucial for acquiring the new skills demanded by new technology. Working practices and the labor market are changing rapidly. Therefore, new interdisciplinary tasks for working in multi-agent networks must also be developed. Human capital must be put prominently on the agenda. This is already the case in the top sectors, but our

cases revealed that it receives too little attention overall. Human capital is a key element for challenge-based learning (Malmqvist, et al., 2015).

v. We defined epistemic governance as power relations in the modes of creating, structuring and coordinating knowledge. This concerns institutional-level (Vadrot, 2011) choices on types of knowledge (Pearce & Raman, 2014), language and language formats (Williamson & Hogan, 2020). A paradigmatic structure of knowledge production for higher education is required for UAS-SME relations (Carayannis & Campbell, 2021). We developed a framework to research epistemic governance in different sub-studies of higher education. The observed challenges require various knowledge modes including production of knowledge-in-use; experience in developing applications in real time and changing the beliefs of the actors involved; awareness through inquiry into the effects of existing modes, the consequences of a type of challenge and level of experience of students involved. In sum, these challenges required epistemic advancements in terms of attitudes and changing beliefs away from the practical.

2. What differences among SMEs affect the dynamics of the absorption of knowledge and how does this in turn affect the ability of UASs and SMEs to develop strategies together?

In the context of Industry 4.0, epistemic uncertainty affects both UAS students and (SME) agents because of ambiguity and uncertainty about changing knowledge functionalities and applications. Our research showed that knowledge production varies strongly across SMEs making it difficult to make statements, personal or systemic, about which knowledge is necessary to continuously add to earlier or newly acquired knowledge. UASs need to adapt their educational approaches to teaching about (learning in) complex, real-world situations.

Autonomous adaptations

Students with (prerequisite) knowledge characterized by higher knowledge density found it harder to move from the epistemic to the practical dimension. We also found that students with higher knowledge gravity are better at identifying domain constraints in organizations with strong horizontal knowledge distribution, while the more specialized knowledge domain supports the integration of students' knowledge horizontally. Students found synthesizing knowledge challenging but possible. Researching necessary new knowledge in ill-structured knowledge spaces that students were unfamiliar with created greater challenges that could lead to simplistic solutions in terms of cause and effect (Bendixen, 2016). This hindered using standard (boundary) professional objects that had been developed earlier. These spaces require engineering capabilities and applied knowledge in real time.

3. **What is the effect of pragmatic and semantic boundaries of co-development and knowledge exchange processes between UASs and SMEs?**

Innovation spaces can act as experimental environments for exploring new epistemic states, focusing on developing new knowledge representations and corresponding dynamic capabilities. The spaces were designed to model various types of knowledge representations based on different SME profiles, their knowledge systems, characteristics, and boundaries to critical the absorption of knowledge. By differentiating levels of absorption capacity, these spaces functioned as learning environments for students discovering how to develop modal consciousness. This approach enabled the exploration of various levels of consciousness and their relationship with knowledge modification and engineering processes. The spaces facilitated the identification, transfer, and transformation of knowledge for the SMEs involved, addressing their specific needs and challenges

Epistemic twins as classrooms

One purpose of knowledge is to actually use it. Great differences among SME caused problems for the transitivity of knowledge to other systems. At the same time differentiation is a truth. A set can be seen as a collection of individual replicas or epistemic twins. The innovation space became primarily a modal space when we used set theory to systemically organize (individual) types of SMEs. Methodically applying epistemic modal logic on different SMEs in the sets enabled us to make inferences on the properties of objects in relation to comparable individuals in a set. We found that abstract reasoning on the epistemic and practical dimension was crucial. Learning from the abstractions, students could determine which properties of objects all equal individuals in a set must be able to access. The notions of possibility and necessity are conceptual tools.

4. **What design of an innovation environment or innovation space contributes to the effective and efficient mutual absorption of knowledge by UASs and SMEs?**

An innovation space can be a conceptual design or a representation model (Gärdenfors, 2004) of activities defining the scope of change as a solution. On a micro-economic level, it can be a place that stimulates innovative behavior. It can be an opportunity space or a vacuum that creates or attracts innovation. It can support the networking needed to develop new skills.

In our study, innovation spaces functioned as crucial epistemic environments that helped to reduce uncertainty by facilitating dynamic movements between the epistemic and practical dimensions of knowledge. They addressed challenges in UAS-

SME collaborations, for adaptive knowledge engineering and design of solutions. Our concept of the innovation space enabled the modification and modeling of knowledge in diverse SMEs, their characteristics, agents and their current and future epistemic states based on the absorption of knowledge capabilities and -capacities. By using semantic frameworks as modal quadrants, these become learning spaces for inferences of coherent situations, enhancing the efficiency of knowledge application across varying contexts as well as epidemic advancements of agents and students.

The outcome of our concept of modal consciousness was a modal epistemic space that supported distinct functionalities created by specific contexts, situations, learners (students and agents), and learning processes aimed at integrating knowledge and belief systems.

Key mechanisms shaping epistemic innovation spaces include epistemic governance, polymodality, knowledge objects, and agents, which collectively manage the conversion and codification of information into actionable knowledge. Using these mechanisms, we aimed to reduce tensions between epistemic and practical dimensions of knowledge and navigate between theoretical knowledge and practical applications.

To this purpose we modeled different contextualities in a conceptual quadrant (Lewis, 1986) as a type of semantic guidance to determine efficiency in terms of making inferences of coherent situations. The output was a modal space that facilitated the attainment of epistemic goals in new epistemic states. The aim was to realize efforts through learning processes, integrating beliefs and constituting modal consciousness with members in a temporal relationship to create solutions in differentiated contexts.

CHAPTER 7

Conclusions

Chapter 7. Conclusions

This chapter addresses our key research question:

How can UASs and SMEs co-develop the absorption of knowledge strategies to enhance their mutual capacity for identifying, transferring, and applying knowledge under epistemic uncertainty?

7.1 Main findings

7.2 Conclusions

7.3 Contribution to applied epistemology

7.4 Contribution to the fields of HRM and vocational education

7.4.1 Vocational education

7.4.2 SME practices

7.5 Research impact and relevance

7.6 Recommendations for further research

7.1 Main findings

This study explores the uncertainties that arise when new information is added to a knowledge function, especially within complex organizational and societal systems. Additional information creates uncertainty about both its effects and its epistemic legitimacy. These uncertainties are particularly critical in interdisciplinary and transdisciplinary contexts, where diverse stakeholders bring varied perspectives and knowledge forms. New information transforms the knowledge function into a composite system, generating tensions between the added information and the new values produced. These tensions affect the conscious and effective use of knowledge, how value is attributed, and the expressions necessary for accessing and utilizing this evolving functionality.

Different worlds and their particular semantic knowledge barriers

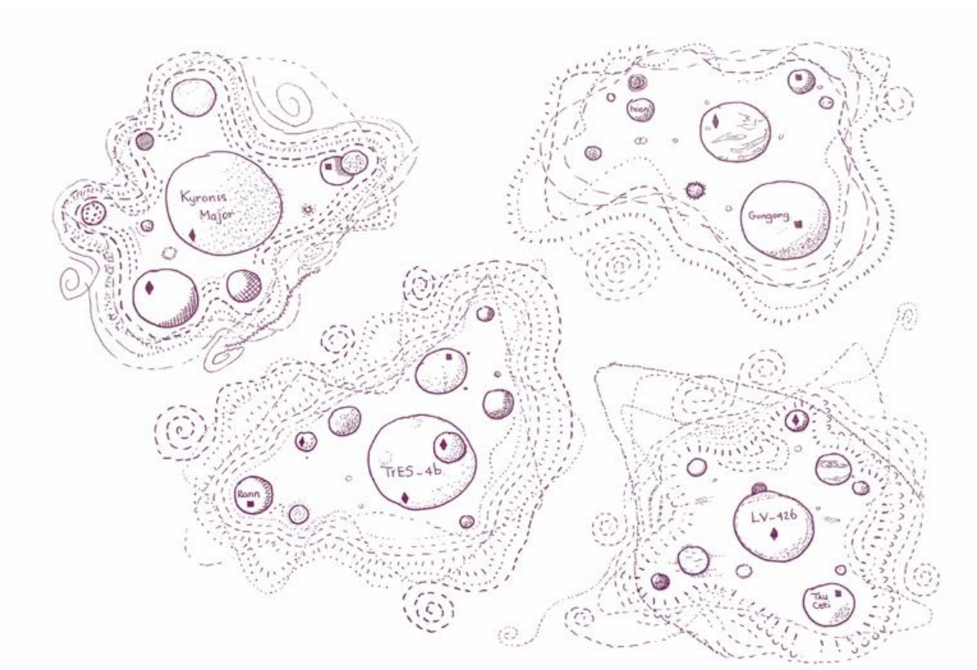

Figure 34. Intensional Contexts in different worlds

This figure reflects, based on Carnap (Carnap, 1937), that modal statements incorporate intensional contexts (e.g., belief, knowledge). In classical logic a substitution principle does not change depending on the context. These truth-functional semantics complicates formal analysis. We therefore conclude this affects developments of distinct ontologies. This has consequences for individual(s) and learning, as well as effectively reconstruct exiting knowledge and or beliefs in terms of policymaking.

In the context of knowledge absorption between UASs and SMEs, dealing with modal statements expressing necessity, possibility, belief, and knowledge involves complex intensional contexts. These contexts and their particular semantic barriers in Figure 34 is an artist impression of the findings (by B.A.E. Dekkers) and shows why classical substitution of equals as a principle from extensional logic, breaks down in intensional contexts in terms of beliefs or types of knowledge such as pragmatisms, where the truth value depends on meaning rather than just truth conditions.

In our research we found that when organizing or classifying organizations by their knowledge absorption capacity, and if this capacity is based on modal logic, such a classification can act as a defining property or attribute that groups together particular organizations which can be considered equivalent.

This means that organizations with the same (potential) knowledge absorption capacity based on modal statements can be into sets or categories with coherent practices where they can be treated interchangeably.

This allows new types of equivalence-terms (for example risk mitigation, or human-resource capability, or ethical considerations) under shared absorptive capacity between UASs and SMEs. It enables a classification based on states or possible world similarities despite (and or) different other characteristics like size or industry phase and of course capability for knowledge assimilation by individual agents. However, it also shows, as we have seen in the research, that such substitutions cannot act as universal quantifiers and as a result we suggest making continuous inferences of coherent practices that act as reconstruction mechanisms for adaptations.

Our research shows that in SMEs where epistemic permissiveness or tolerance for new and/or conflicting beliefs is low, for example when there is little capacity in HRM support, this affects continuous knowledge absorption in terms of reconstruction time. Effectively scaling this differentiated absorptive capacity of SMES requires inferences based on distinct characteristics of these intensional contexts (e.g., risk mitigation, types of values involved, capability HRM and KMM capabilities, knowledge and willingness of agents) as coherent practices and organizing them under a framework of non-arbitrary epistemic governance. This approach supports SMEs in managing different knowledge dynamics by ensuring that knowledge integration is both pragmatic and justified, allowing them to respond adaptively to evolving practical and epistemic demands.

To better understand these dynamics, the study distinguishes between epistemic consciousness, primarily focused on knowledge, its beliefs and justification, and modal consciousness, which relates to the awareness of different knowledge modalities and their interactions. Drawing on philosophical insights like Chalmers' zombie argument Chalmers (Chalmers, 1996), which demonstrates the insufficiency of physical facts to fully explain conscious experience, and Trestman's view that new experiences disrupt existing internal modalities states (Trestman, 2014), the research emphasizes the importance of conscious awareness in managing knowledge tensions (such as in our findings) and uncertainties. By focusing on modal consciousness, the study aims to enhance how knowledge can be exchanged, codified, and expressed across contexts, supporting knowledge management and human-resource principles in complex, dynamic environments where diverse knowledge forms converge.

The evolving landscapes of Industry 4.0 and 5.0 are characterized by an exponential growth and diversification of information across multiple domains, often resulting in contrasting and sometimes conflicting claims (Mize, 2020). The analysis and processing of heterogeneous information take place with varying semantic frameworks, with various agents operating in different time frames that require continuous adaptation in response to new technologies.

Time to 'apply and justify' is under pressure since SMEs have exploitation pressures in very competitive and volatile markets. Consequently, managing knowledge has become vital for SMEs in terms of extending the capabilities of human resources.

Our research saw these challenges accelerating many projects in which UASs participate as part of a third mission. We found a significant knowledge-to-knowledge gap between UASs and SMEs hindering their effective absorption of knowledge for practical applications.

Our main findings show:

I. The absorption of knowledge depends not just on access, but on agent-level epistemic awareness.
    - Higher functionality shifts require insight into types of epistemic uncertainty

II. Epistemic uncertainty is magnified by organizational routines, especially in SMEs.
    - Higher response requirements in microprocess routines affect expressions for learning capabilities and extensions of complementary tasks for all agents

III. UAS-SME collaboration requires differentiated HRM frameworks and practices that involve knowledge management and role change to be effective.

7.2 Conclusions

I. The absorption of knowledge depends not just on access, but on agent-level epistemic awareness.

We found that students and human agents navigate multiple reasoning approaches, both informal and formal, each bearing significant implications for how knowledge functions are constituted. Crucially, an agent's awareness of these diverse approaches influences the epistemic possibilities of truth and functional applicability of knowledge across varying contexts and environments. This reflective stance, which we term modal consciousness, depends on the individual's capabilities, attitudes, and situational factors that shape beliefs about potential outcomes.

In the context of learning new capabilities within highly routinized tasks, modal consciousness becomes especially significant. Modifying structurally embedded routines requires shifts in belief systems about what is possible or necessary, driven by new practical experiences and that requires alternative functional possibilities. Because such changes demand new justifications for knowledge and its practices, we found that the students' inquiries, attempting to establish new justified functionalities, are inherently epistemic. Such inquiries often have distinct epistemic values that must separate from other, non-epistemic value systems.

We found that SMEs rely most on effective output, and less on how this is constituted. The emphasis in research in UASs often focuses om empirical-based evidence. Our research underscores the criticality of this distinction, especially in environments where competing value frameworks coexist. The successful constitution of new functionalities that are either extensions or new capabilities in routinized tasks requires effective epistemic governance of inquiry, which regulates SME relations among different value systems, diverse knowledge representations, and the human agents involved.

With regard to awareness, our framework uncovered patterns in the behavior of agents and students that we labeled 'monotonic', following Bartolotti (Bartolotti, 2020) and Kuhn (Kuhn, 1962). This refers to the idea that when more information is acquired, the belief set remains consistent; that is, agents and students do not (automatically) retract previously held beliefs when new evidence comes in. Their knowledge or belief system monotonically expands, as we found in terms of emphasizing existing beliefs, which may provide evidence that agents in these situations tend to hold on what they know. However, this is could not be found in all cases and can also be a consequence of what we found as mitigating the risk of adopting technology and extending capability.

We found that students facing problem-solving areas drawn from current societal challenges sometimes lack information or knowledge from their knowledge domains. We also found that groups of SMEs are very innovative and have state-of-the-art system configurations for advanced learning.

Such environments create epistemic doubts that go beyond the participants' existing experience and knowledge domain. Therefore, we found that the heart of the problem lies in making epistemic advancements between UASs and SMEs for present and future agents, in terms of functionalities of knowledge that are identifiable, transferable and transformational in the different worlds.

- Higher functionality shifts require insight into types of epistemic uncertainty

The absorption of knowledge is (affected by) the awareness of various possibilities to transform information into distinct responses. These responses are either ideas or methods that make it possible to consciously experience that information both in a non-practical sense, and in responses that sense the practicality of experiences.

As a consequence, we see that *when a function is indistinct, it is not distinct in its consequences*. It lacks epistemic functionality. This affects the engineering of effective solutions that may enable continuous responses to challenges. Awareness of these conditions requires conversions between different epistemic and pragmatic dimensions to constitute functions in each possible world rather than one possible function in all worlds.

II. Epistemic uncertainty is magnified by organizational routines, especially in SMEs.

- Higher response requirements in microprocess routines affect expression for learning capabilities and extensions of complementary tasks for all agents

In this study, we integrated concepts of organizational routines beyond mere learning, proposing that partnerships between heterogeneous actors instantiate new sets of routines. By exploring epistemological frameworks of knowledge management, we also investigated how stakeholders perceive and valorize different types of knowledge, illuminating the complexity of shared meaning-making under uncertainty.

Our empirical observations underscore our theoretical frameworks. For example, students tasked with designing employee-involvement frameworks struggled to create solutions that simultaneously met organizational, individual, and technical constraints. Their models tended to be static and context independent, due to their limited experience in these settings. Sometimes restricted or limited engagement with employees in combination with insufficient observational data resulted in incomplete and uncertain problem representations. This ambiguity hindered the articulation of potential solutions and illustrates how epistemic uncertainty constrains effective knowledge translation into actionable routines.

Economic risks and epistemic uncertainty affect the adaptation of new routines by SME agents. Our research identified critical gaps in habitual patterns, routines, situational contingencies, and events (Anon., 2024). Our conceptual quadrant shows that these critical gaps affect the differentiation of goal states, from necessary and possible to contingent, needed to address the emergence of new knowledge functionalities. In conditions where goal states are unclear (ill- structured environments) reasoning must emphasize experimentation and simulation to construct knowledge-producing, conscious agents capable of navigating such complex environments.

The absence of effective codification complicated knowledge modifications, making it difficult to structurally determine knowledge content related strongly to specific contexts, situations, or events. More novice learners struggled with semantic engineering and translating abstract knowledge into a practical routine. Routines requiring revision lacked predictive certainty for SMEs, particularly because they relate to experiential and design-based learning that depends on progressively developing both conceptual clarity and concreteness (Boghossian, 2006; Fisenko, et al., 2019).

Our framework enhanced the epistemic functionality of knowledge needed to address these learning dynamics in the long run. As a result, epistemic uncertainty amplifies the role of micro-level routines as organizations responded through localized, habitual actions rather than relying solely on formal or institutional mechanisms. This microprocess orientation enables more agile adaptation, supports knowledge integration across diverse actors, and underscores the importance of modal reasoning and experimental inquiry in navigating the uncertain organizational landscapes characteristic of contemporary knowledge ecosystems.

III. UAS-SME collaboration requires differentiated HRM frameworks and practices that involve knowledge management and role change to be effective.

The exponential growth in information production increasingly spans multiple domains and disciplines, necessitating new interpretations and justification of knowledge. This expansion amplifies epistemic uncertainty in institutions and among their human agents. SMEs operating under intense exploitation pressures in highly competitive and volatile markets face significant constraints regarding the time available to apply and justify new knowledge. Consequently, effective knowledge management, particularly HRM becomes critical for SMEs’ capacity to navigate these challenges. Our research demonstrated that these pressures accelerate collaborative projects involving higher education institutions as part of their third mission, where knowledge sharing acts as a pivotal mechanism for recombining and co-creating knowledge. However, the rapid pace of information generation demands multiple, efficient conversion processes to transform raw data into actionable knowledge.

A core difficulty lies in the oft-indistinct conceptual properties of epistemic objects. This ambiguity frequently leads to misattributions or false conceptual attributes and logical fallacies that commonly arise among novice or naïve learners who have rudimentary knowledge of engineering conceptual semantics. Addressing such challenges requires diverse and sometimes multiple methodological approaches to knowledge conversion, including both observational techniques and qualitative interviews. Most SMEs, however, find it difficult to advance toward mature knowledge-management practices partly due to their limited codification (practices) of internal knowledge. Accessing SMEs for formal, explicit knowledge elicitation is complicated by their tight operational constraints; participation rates in structured questionnaires tend to be low, and responses often suffer from bias and lack granularity.

In response, we developed a conceptual knowledge-management interface tailored to act as an innovation space. Bridging UASs and SMEs, this space aimed to uncover the complex dynamics and boundary conditions that arise across the phases of absorption of knowledge. Our findings underline that not only the structural patterns of relational networks (quadrant) but also the underlying types of logical reasoning employed are decisive. In our theoretical topology, knowledge distribution corresponds to the distribution of axioms and their symmetrical relations. Of particular importance is the role of temporal logic, which frames reasoning about changes in knowledge over time and space. For example, in one of our workshops, students were trained to reason about the spatiotemporal constraints involved in goods transportation. Here, axioms formalized constraints according to the system's notions of 'here and there' as well as 'now and then,' emphasizing how temporal and spatial differentiation critically shape knowledge dynamics and operational decision-making.

7.3 Contribution to applied epistemology

Applied epistemology studies how knowledge is acquired, justified, shared, and applied in real-world settings. The insights drawn from the complex interactions between SMEs and UASs, in epistemic uncertainty and dynamic knowledge environments, enrich this field by demonstrating the far-reaching implications of how epistemic processes unfold in practice.

Bridging theoretical epistemology and organizational practice

Theoretical concepts, such as the role of primitive constituents, modal consciousness, and epistemic modal semantics, translate directly into practical mechanisms for the absorption of knowledge and transformation in SMEs. This contextualizes how epistemological ideas, such as belief revision and knowledge functions, are conditioned by epistemic modalities in tangible organizational routines and decision-making processes. It exemplifies applied epistemology's goal of connecting formal knowledge theory with lived cognitive and social realities.

The core challenge of epistemic uncertainty

As discussed previously, increasing information complexity and ambiguous conceptual properties of knowledge objects generate epistemic uncertainty in SMEs and in their collaboration with UASs. Applied epistemology benefits from this by focusing on uncertainty not merely as a statistical or informational problem, but as a fundamentally epistemic issue. It shows the difficulty of representing, justifying, and operationalizing knowledge in contexts where goal states and routines are ill-defined. Understanding this deepens epistemology's relevance to organizational change, innovation, and learning theory.

SMEs under high exploitation pressure often show limited capacity to absorb new knowledge effectively. To sustain competitiveness, policymakers emphasize the necessity for SMEs and UASs to engage in active knowledge sharing and exchange. Despite this, many SMEs lack the knowledge-management capabilities and experience required to extract and assimilate external knowledge that is essential for innovation and growth.

Emerging technologies have created shifts in vocational education at UASs, that aim to equip future professionals with the advanced skills and knowledge demanded by Industry 4.0. Students *moving* beyond traditional educational boundaries face complex, often ill-structured challenges that require innovative, interdisciplinary solutions. These environments demand higher-order cognitive and social capabilities, including the ability to navigate ambiguity and make informed *judgments* about diverse stakeholders.

How can UASs contribute to the absorption of knowledge?

Most organizations are aware of rather than responsive to dynamics that can affect their knowledge base and organization. According to our research, older organizations have more traditional, ordinary capabilities In terms of path dependencies, which may stop them from participating frequently with UASs or prevent them from initiating mutual innovation activities. Our findings from the interview focus groups and inspiration sessions revealed that innovation also needs changes in roles and hierarchies. This means that older, smaller SMEs may have to make drastic changes to their traditional roles and hierarchy as well as ordinary routines to meet the demands of emerging technologies such as AI.

Realizing potential knowledge absorption requires key actors (such as students) that can identify new information from the inside. When these actors are unavailable, it affects all phases of knowledge absorption, especially transformation.

The findings underscore practical implications for UAS-SME collaborations in Industry 5.0 contexts, where epistemic tensions drive knowledge transfer toward pragmatic, short-term adaptations rather than strategic renewal. Smaller SMEs exhibit knowledge inertia in technology adoption (T1, T4), necessitating on-the-job training and HRM/KMM support to build dynamic capabilities and modal awareness (T2), that enable agents to reason on uncertain epistemic states and functional (compound) knowledge shifts. Educational interventions should prioritize solution experiments and field labs to foster iterative learning and modal consciousness (T3, T5), explicitly communicating exploratory intent to students while aligning with SME operational realities via interfaces for semantic knowledge recombination (T7). Living labs hold promise for systemic co-creation with diverse stakeholders but require governance to overcome horizontal barriers, ultimately bridging tacit practitioner adaptations with structured theoretical insights for sustainable innovation.

Secondly, and based on the previous, to maximize knowledge transfer in UAS-SME collaborations, practitioners should strategically select innovation spaces based on their epistemic fit: solution experiments for iterative, low-pressure exploration that builds modal awareness among students and SMEs; field labs for pragmatic technical validation in time-constrained settings like the EV risk assessments at the Airport field lab and living labs for systemic co-creation with diverse stakeholders, This alignment counters the dominant "green pragmatic trajectory" shown in the tension in the cubes by fostering vertical progression toward conceptual renewal, while bridging tacit operational adaptations with structured theoretical insights

This is aimed at ultimately complementing research university ecosystems with UAS's practice-oriented strengths for sustainable Industry 5.0 innovation.

SMEs can enhance knowledge absorption capacity (AC) by systematically integrating HRM and iterative student-led processes into their reconfiguration strategies, starting with resource allocation for exploration using dedicated budgets and or cross-functional teams to research capability adjustments Iterative assimilation (AC-I) through ICT-user engagements that may support tangible tools, as seen in Triple Helix case, to boost user integration (AC-R); or post-internship exploitation by internalizing student expertise via servitization pilots (Sharing Logistics Case) , ensuring outcomes beyond project phases, Most importantly systemic support via protocol for developing HRM/KM evaluations and scenario-based planning to address environmental uncertainties, complemented informal UAS collaboration sessions (e.g., innovation tables) for sharper problem articulation.

7.4 Contribution to HRM and vocational education

The emphasis on microprocesses—habitual routines, individual and small-group interactions— experimentation and simulations offer a micro-foundations perspective that applied epistemology can adopt to model how knowledge evolves at the fine-grained organizational level. The notion of modal consciousness and the ability of agents to reason on possibilities, necessities, and contingencies states that epistemic reflexivity as a learning capability is essential for adapting routines.

As a result, there is a need to develop and implement new HRM knowledge-based and innovation-oriented practices. Especially knowledge-driven HRM practices can enhance the SMEs' ability to manage knowledge flows, foster open innovation and build dynamic capabilities. HRM practices must align with the development of vocational and interdisciplinary skills, in complex, networked settings. This focus on knowledge-based HRM facilitates more effective partnerships between SMES and educational institutions which, we found in our research, are necessary to reduce epistemic uncertainty.

This allows the design of epistemic tools to facilitate knowledge sharing and extension, especially where routine codification is difficult. Recognizing diverse epistemic logics in SMEs and UASs helps tailor knowledge integration methods and mitigate knowledge fragmentation.

7.4.1. Vocational education

Epistemic uncertainty fundamentally challenges students to develop a deeper understanding of how knowledge itself is constituted and legitimized, recognizing that these processes critically influence their capacity to effectively apply knowledge in practical contexts. This entails not only mastering content but also gaining insight into the epistemological foundations that underpin knowledge claims, including the criteria and social practices by which knowledge is validated within different domains.

Moreover, students must become increasingly aware of the need to navigate and exchange knowledge using diverse semantic frameworks, or ' languages', as the variety of SMEs they engage with often operate under distinct epistemic cultures and terminologies. This sensitivity to differing semantic expressions and frameworks enables students to adapt communication and collaboration strategies suitable to the specific organizational contexts they encounter, thereby enhancing knowledge transfer and innovation potential. This equips students to fluidly interpret, translate, and integrate new knowledge across heterogeneous SME environments, a skill that is indispensable when it comes to the ambiguities introduced by technological change and evolving innovation ecosystems.

7.4.2 SME practices

The insights discussed above contribute significantly to SMEs' knowledge management and organizational practices, especially under epistemic uncertainty and in dynamic environments. Firstly, the emphasis on the capacity to absorb knowledge and modal consciousness highlights how SMEs can develop reflexive awareness of different knowledge forms (tacit vs. explicit) and reasoning modes. This enables SMEs not only to recognize external knowledge but also to critically assess and adapt it into (mature) functional routines. Since SMEs often operate with limited codification and face high exploitation pressures, epistemic reflexivity and more formal codification support exchanges of knowledge with UASs and other networks or communities.

Secondly, the integration of epistemic frameworks and knowledge conversion theories enable SME practices to articulate how knowledge sharing with UASs supports innovation. In such networked settings, HRM evolves into a knowledge-driven function that facilitates the flows and transformations of knowledge assets critical for continuous organizational learning.

7.5 Research impact and relevance

This dissertation makes a significant contribution to understanding how UASs can support SMEs in navigating technological change and epistemic uncertainty. By combining case-based empirical research with a novel applied epistemological framework, it addresses a critical gap in how organizations absorb, legitimize, and apply new knowledge in real-world innovation contexts.

At a theoretical level, the study advances the concept of epistemic functionality, the dynamic relationship between knowledge, its use, and its organizational relevance. It introduces original constructs such as epistemic innovation spaces, modal epistemic quadrants, and epistemic twins, which offer new ways to understand how knowledge operates under conditions of complexity and uncertainty. These ideas extend the discourse on Mode 2 and Mode 3 knowledge production and provide new vocabulary for applied epistemology, educational design, and innovation studies.

At a practical level, the findings have direct implications for the development of workforce competencies in technology-driven economies. The research highlights the crucial role of reflexive, adaptive, and 'epistemically aware' agents in SMEs employees and students alike who must navigate tacit knowledge cultures, unclear routines, and fragmented HR systems. It shows how collaboration between UASs and SMEs can foster the epistemic agility necessary for meaningful innovation.

At a policy level, the study supports the strategic development of innovation ecosystems, particularly those centered on vocational and practice-oriented education. It offers guidance for designing institutional mechanisms—such as cross-boundary HRM structures and regional foresight strategies—that enhance the absorptive capacity of SMEs while preparing students for real-world epistemic complexity.

Overall, this study contributes actionable insights for educational leaders, policymakers, SME managers, and researchers committed to building resilient, knowledge-driven regional innovation systems. It supports a shift from knowledge delivery to knowledge co-creation, where uncertainty is not simply a risk to be managed, but a productive condition for transformation.

7.5.1 Limitations

While this study offers robust insights into epistemic tensions and knowledge transfer in UAS–SME collaborations through its innovative modal epistemological framework, certain limitations open opportunities for future research. The deliberate focus on in-depth cases within specific Dutch sectoral contexts give rich, contextualized findings on pragmatic pathways as well as method-specific dynamics. To broaden this foundation, the researcher also included exploratory visits to UAS in other regions of the Netherlands, as well as internationally to Denmark, where UAS often collaborate with research universities on ecological challenges, Belgium, and L Luxembourg. These visits revealed how cultural, normative, and regulatory boundaries (e.g., differences in time horizons, procedures, and legislation) can influence epistemic and modal processes, that might show variations in stakeholder inclusion and innovation space design. This emerging cross-national perspective with systematic comparative studies across additional sectors, regions, and international UAS settings may help to refine and generalize the framework.

Similarly, the emphasis on qualitative richness and exploratory mixed-methods triangulation captured authentic practitioner and student voices, but incorporating longitudinal data in future work could illuminatingly trace the longer-term evolution of short-cycle pragmatic adaptations into structural changes.

The deliberate spotlight on student mediation highlighted valuable challenges for academic learning in pragmatically dominated spaces, opening promising directions for intervention-based research that tests targeted pedagogical strategies to enhance mutual epistemic awareness. Overall, these focused choices strengthen the study's foundational contribution while positively framing clear, productive pathways for building upon its insights in future scholarship and practice.

Secondly, this research has only partly examined AI's role in knowledge integration, yet it illustrates how modal logic properties—reflexivity (T: ensuring factual grounding), transitivity (4: positive introspection, $\Box p \rightarrow \Box\Box p$), and symmetry (B: mutual awareness)—exert benevolent effects when transitioning raw information f to modalized knowledge F in organizational settings. These properties reduce epistemic uncertainty by resolving inconsistencies across possible worlds (e.g., SME scenarios), as new data aligns beliefs without fabricating perfect S5 introspection ($\neg\Box p \rightarrow \Box\neg\Box p$), which our cases show can erode valuable "redundant" overlaps fostering group dynamics and creativity. However, ideal integration risks losing subconscious/implicit knowledge and "unknown unknowns," highlighting AI's potential for partial augmentation—such as reflexive validation tools or transitive learning algorithms—while preserving asymmetries that sustain innovation connectedness, an area warranting deeper AI-specific exploration beyond this study's epistemic modeling focus.

As the AI revolution increasingly delegates decision-making to probabilistic systems, Bayesian statistics offers a powerful framework for modeling and refining these human judgments, treating beliefs as updating probabilities conditioned on evidence while preserving modal commitments to necessity and possibility. Drawing on the modal logic principle which states that if something is currently false and an agent necessarily knows it to be false (negative introspection across all accessible worlds), then it remains necessarily false in all futures, precluding any possibility of it becoming true.

Crucially, sets of SMEs can strategically incorporate variance through diverse portfolios of expertise, cross-firm collaborations, or modular knowledge networks to introduce the necessary heterogeneity for reacting to highly integrated information flows, that create dense and compound functionalities of knowledge that enhance both collective understanding and efficiency in knowledge and skills management. By assigning differentiated priors across SME ensembles and enabling evidence-based updating, AI systems augmented with Bayesian methods can reduce (expected) cognitive rigidities and support human agents in reopening possibilities that modal negative introspection might otherwise close .

7.6 Recommendations for further research

We need further research to better understand how variations in the absorption of knowledge and conversion abilities affect the consistency and effectiveness of knowledge in innovation spaces. Specifically, studying the formation of coherent sets of knowledge—how different pieces fit together logically and pragmatically—can improve knowledge-management models.

Such research requires gathering larger and more diverse datasets that capture the relationships and dependencies among various types of knowledge objects, including their semantic (meaning-related) and pragmatic (use-related) aspects (Börner, et al., 2003). By combining reasoning based on factual alignment (correspondence) and logical consistency (coherence), organizations can better prepare for unpredictable changes.

Scenario-based predictions are useful tools for forecasting shifts in knowledge and skills. This helps in planning for innovation. Additionally, developing epistemic modal logic and logical tools that capture how knowledge changes and how uncertainties are handled can provide practical instruments to support applied knowledge work. Innovation spaces, particularly those connecting UASs and SMEs, can serve as opportunities for advancing knowledge, provided that proper governance structures are in place. Successful governance depends on identifying and managing different types of innovation spaces at various organizational levels.

Our research concludes that defining the functionality of knowledge requires clear differentiation of meanings across contexts and situations, and this process benefits greatly from formal logical methods. Informal reasoning can sometimes be unclear or inefficient because it lacks precise meaning. Establishing meaningful connections between different categories and semantic distinctions poses a significant challenge, not only for organizations but also for educational institutions preparing future professionals.

We propose a new topological framework, a structured way of thinking, which allows room for creative methods, probabilistic approaches to different contexts, and typologies that describe artifacts and their functions. One exciting area for future study involves developing three-dimensional semantic representations that capture object properties more richly, though this remains difficult when applying such models across different fields.

Using formal logic informed by applied epistemology helps evaluate knowledge accurately across various situations and supports creating ‘semantic closures’ or coherent knowledge systems in context. This promotes effective learning by fostering modal consciousness, meaning the ability to reflect on different possibilities and reasoning methods during inquiry.

Implications for education and change agents

Teaching epistemic skills becomes crucial in innovation spaces that naturally raise questions and doubts about knowledge. These doubts focus attention on the problems faced by those involved. Epistemic objects—concepts that embody knowledge claims and acknowledge ambiguity—play important roles in determining truth and guiding solution development. Designing semantic and/or modal spaces means considering function, meaning, and output at multiple levels and learning stages.

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Appendix A: Papers

Wiersma, M. (2021). Smart Knowledge Sharing. Logistiek+, (11)

Logistics faces a major challenge. Current social issues surrounding energy and sustainability require new solutions and applications at an accelerated pace. Multidisciplinary collaboration between knowledge institutions and companies in particular offers opportunities for developing knowledge with a greater impact. However, the process of knowledge exchange between companies and knowledge institutions is often still inefficient. This contribution presents an instrument that aims to influence knowledge dissemination between small and medium-sized enterprises (SMEs) and higher vocational education (HBO).

Wiersma, M., & Paardenkoper, L. (2022). Toward an integrated scan for technological and non-technological aspects of digitalization.

This study explores how small and medium-sized enterprises (SMEs) can better assess and improve their readiness for digitalization. It highlights the need for an integrated approach that considers not only technological factors (like infrastructure and tools) but also non-technological ones, such as organizational culture, employee skills, and business model innovation. The authors propose the development of a maturity scan and roadmap to help SMEs identify their current position and plan next steps in their digital transformation journey.

Van Duin, R., van den Band, N., de Vries, A., Ouasghiri, M., Verschoor, P., Warffemius, P., & Wiersma, M. (2022). Sharing concepten in stadslogistiek: The Big Five. Logitiek+, tijdschrift voor toegepaste logistiek, 13, 48-73.
https://www.kennisdclogistiek.nl/projecten/logistiek-tijdschrift-voor-toegepaste-logistiek

Sharing unused and/or underutilized resources can bring new improvements to the logistics value chain. In five sectors of urban freight transport, namely city logistics, construction logistics, transport & warehousing (retail logistics), healthcare logistics and service logistics, service sharing concepts are studied for the entire city of Rotterdam. Based on our main case study findings, it can be seen that there are quite a few differences within urban freight transport sectors with regard to the maturity of sharing. This paper shows the next implementation steps per sector.

Wiersma, M., & Paardenkoper, K. (2023, March). The new Latin the language of digitatlization in logistic companies: the language of digitatlization in logistic companies. In 28ste Vervoers Logistieke Werkdagen 2023.

There was a time that Latin ruled the world. Now it is a forgotten language, used only by doctors and botanists. In its heydays, it was the vehicle of progress. Mastering this language was a precondition for access to scientific knowledge. Nowadays, digitalization is a major challenge for logistic companies. To perform the digital transformation, companies need new knowledge. However, they find it difficult to identify, transfer and apply this knowledge in their organization. In this paper we explore specific, language related knowledge barriers, that cause these problems and how to overcome them, which accelerates logistic companies to digitalize.

Wiersma, M., & Paardenkoper, K. (2023, March). A new knowledge absorption model for stimulating digitalization in logistics. In 7th PROLOG/PROLOG–PROJECT LOGISTIC 2023.

This paper addresses the knowledge absorption capacity of SMEs in relation to their adoption of new technologies. Due to technological developments, major companies reap the advantages of industry 4.0. At the same time SMEs, especially the smaller ones, lag behind, which endangers their business models. This is mainly because they have insufficient knowledge management experience. The solution for this problem is increasing their knowledge absorption capacity and capabilities. The contribution of the research presented in this paper is a new knowledge absorption model for stimulating digitalization in SMEs. The research is performed along seven steps, the last of which is the development of a model. The model classifies companies along a differentiated quadrant according to their level of knowledge absorption capability. Based on the position of the companies in the quadrant, specific advice can be given to them. Further empirical research is needed in order to develop more specific, differentiated protocols and knowledge management instruments per quadrant.

Appendix B: SME short descriptions

Appendix SME descriptions

The descriptions below provide a brief explanation of the anonymized tables in the manuscript. It is intended to give the reader a better understanding of the sector, innovation focus, and main activities. We use both scientific and non-scientific names of planets. This approach aims to prevent any associations between the fictitious names and existing organizations and any specific behaviors.

A. Data Survey: Characteristics RNE / Preliminary research /Scenarios**
A1. Mercury innovation focus on the development of vessels and integration of digital technologies for performance optimization, and pioneering efforts in floating renewable energy platforms. It supports industry shifts toward sustainability, efficiency, and resilience in complex offshore environments. This organization combines marine engineering expertise with renewable energy adaptation.

Human Capital developments: employees must update and expand their competencies to keep pace with emerging technologies, such as digital monitoring systems, and sustainable energy solutions. The emphasis is on broad interdisciplinary expertise and adaptability as the environment changes. Pragmatic uncertainty is moderate, concerned with current innovations and operational shifts.

A5. Venus is a company in offshore drilling, emphasizing eco-friendly and sustainable practices while exploring deep-sea energy reserves. Core business strategy is fundamentally built on innovativeness within the marine and energy sectors, pioneering solutions and operational efficiency. Human Capital developments: employees must acquire advanced competencies in automation, digital monitoring, and environmentally sustainable drilling techniques. Requires acquisition of advanced skills in automation, environmental compliance, and renewable integration. Strong emphasis on ongoing training related to regulatory standards, safety, and digital systems. Combines pragmatic uncertainty (operational efficiency demands) with epistemic uncertainty (novel technologies evolving rapidly).

A6. Uranus' activities span the offshore oil and gas sector as well as the rapidly growing offshore wind industry. The company provides advanced engineering consultancy and operational support to optimize the performance and safety. Innovation is a core element in its operations, and designs that integrate advanced technology and sustainable solutions.

Human Capital developments: employees must continually upgrade technical skills related to marine engineering, renewable energy technologies, and digital tools used for performance optimization and safety enhancement. Focus on operational resilience and advanced engineering methods supporting evolving offering create higher epistemic uncertainty as new engineering techniques and diversified services evolve.

A7. Saturn specializes in providing comprehensive water treatment solutions and the supply of high-quality water for maritime and offshore industries. Its core activities include the delivery of custom water treatment installations, specialized equipment tailored to meet the unique needs of vessels, offshore platforms, and industrial applications. With a global service network, it offers technical support, consultancy, and training to ensure water quality and system efficiency.

Its innovation supports evolving industry standards through improved water management and plastic waste reduction initiatives.

Human Capital developments: employees require continuous skill development in water treatment technologies, system optimization methods, and compliance with evolving environmental regulations. Training is driven by changing standards and sustainability innovations. Pragmatic and epistemic uncertainties both present but more regulated and incremental.

A8/A9. Jupiter specializes in ship repair, maintenance and refit services. Their activities include general repairs, engine and electrical repairs, steelworks, painting, and specialized services for various vessel types across offshore, yachting, and dredging sectors. Innovation plays an essential role in its operations with a focus on improving efficiency, safety, and environmental performance through advanced repair techniques. Human Capital developments: employees must develop expertise across multiple disciplines such as welding, corrosion protection, electrical systems maintenance, and project coordination. Training often involves a combination of theoretical knowledge and practical application, including standards compliance, advanced tooling, and digital diagnostic methods. Uncertainty is pragmatic and practical and requires familiarity with advancing tooling and diagnostics.

A10. Pluto specializes in engineered transport, of large and heavy structures across multiple sectors. Its extensive operations leverage state-of-the-art equipment and deep engineering expertise for complex logistical challenges. Innovation is demonstrated through continuous development of advanced technologies, software for project optimization, and sustainable solutions. The organization invests significantly in research and development.

Human Capital developments: employees need to regularly acquire and update technical skills related to engineering principles, logistics planning, and use of transport equipment. Proficiency in software tools for project management, optimization, and digital simulation becomes more essential.

Strong emphasis on digital tools and complex logistics requires continuous learning to adapt to changing technology. This involves both pragmatic uncertainty (efficient operations) and epistemic uncertainty (optimization technologies evolution).

A2. Data Interviews: phase 1
The interviews cover the interplay of SME cultures and their learning processes, focusing on how gaps between SMEs and UASs influence student involvement in research. This includes exploring the dynamics of the stakeholders, such as Triple Helix culture collaboration, Lab Cultures between academia, industry, and government and how path dependencies and dynamic capabilities shape innovation and adaptation. Additionally, the context embraces collaborative solution labs in municipalities as a form of applied research aimed at co-creating the Roadmap for Next Education, in relation to the integration of research in practice in complex local environments.

B. Data Interviews: phase 2/ case Sharing Logistics -> C1 case
B1. Ceres focuses on digital transformation, improving operational efficiency through smarter collaboration across the logistics chain, and significantly investing in sustainability projects such as carbon capture and storage shore power for ships, and initiatives aiming for climate neutrality by 2050.

B2. Haumea is an organization specializes in aerospace engineering and manufacturing with a focus on supplying advanced aircraft components, landing gear, electrical systems, and integrated maintenance services.

B3. Makemake is a global leader in marine construction and dredging, originally founded as a small dredging firm over a century ago. It has expanded to offer coastal protection, offshore energy services, and large-scale infrastructure projects worldwide. Innovation drives its growth through advanced technology, sustainable practices, and digital solutions to improve efficiency and environmental impact. The company plays a key role in building resilient maritime infrastructure and supporting the transition to greener energy sources.

B4. Gonggong specializes in designing, building, and maintaining a wide range of vessels for maritime industries worldwide. It emphasizes modular construction, which enables fast delivery and customization.

B5. Orcus specializes in forwarding, transport, storage, and distribution primarily for the food, beverage, and retail sectors. It integrates multiple transport modes such as road, sea, air, and inland waterways to offer seamless supply chain solutions. It now focuses on digital tools for real-time tracking, waste and to reduce emissions.

B6. Sedna specializes in temperature-controlled transport and logistics for food products across Europe. It offers a range of services including storage at varying temperatures, order preparation, and multi-modal transport to ensure product quality and safety. Innovation is central to its strategy through the use of advanced IT systems for real-time tracking, warehouse automation, and data analytics to optimize supply chains.

B7. RUAS

C1. Data Survey: SME characteristics in the HRM Business (1)

C1. Salacia specializes in end-to-end logistics solutions in automotive and cargo sectors. Innovation focuses on digital tracking systems, blockchain technology for supply chain transparency, and sustainable practices like electric vehicle fleets and carbon footprint reduction.

C.2. TrES-4b specializes in distribution and transport of parcels, length goods, and pallets throughout the Benelux region. It offers a range of services, including route transport, network distribution, special transport, dedicated logistics, container transport, and warehousing. The company combines the agility of a family business with the scale advantages of a larger network

C.3. WASP-76b is a specialist in temperature-controlled transport, primarily servicing routes to France, Belgium, and Sweden. A family-owned business with a focus on fresh and perishable products, the company operates a fleet supported by advanced logistics systems like real-time tracking and temperature monitoring. Innovation is reflected in its commitment to sustainability, using solar panels on storage facilities and vehicles, participation in green certification programs, and investment in digital solutions to optimize transport flows and guarantee product quality.

C.4. TOI-6894 b focuses on delivering efficient, reliable, and technologically advanced port and logistics services, integrating automation, AI, and digitization to optimize operations. Its innovation strategy incorporates cloud computing, blockchain, machine learning, and automated equipment, enabling enhanced productivity, sustainability, and supply chain transparency.

C.5. HD 209458 b specializes in the safe and professional transport of liquid food products. The company operates a modern, well-maintained with high-standard tank cleaning services tailored to customer requirements. HD 209458 b focuses on continuous driver training for efficiency and safety.

C.6. Kepler-10b is a specialized international tank transport company, active primarily in the transport of fuels, lubricants, LPG, industrial gases, chemicals, and liquid fertilizers across major European industrial regions. Innovation is embedded in safety culture, continuous learning, and leveraging digital technologies for fleet management and route optimization.

C.7. Proxima Centauri b develops web-based management software designed to provide organizations full control and real-time insight into processes and information security management by combining deep domain expertise with agile software development.

C.8. KELT-9b is a logistics and distribution company specializing in rapid delivery services across sectors like retail and e-commerce. KELT-9b combines traditional expertise with modern technology, including automated warehouse systems and data analytics, to maintain flexible and customer-focused supply chains.

C.9. 55 Cancri e is a family-owned company with around 200 employees, specialized in maintenance projects. This includes dredging and replenishment, constructive water engineering, survey work, and the detection and removal of unexploded ordnance.

C.10. GJ 1214 b specializes in delivering advanced, web-based rental management software specifically designed for construction and transport equipment rental companies. GJ 1214 b equips rental and logistics businesses with actionable insights and automation.

C.11.Tyche is a global leader in tailored bakery products that help industrial bakers improve the baking process, manage operations, and increase sales. Tyche actively collaborates with customers to develop inventive solutions that meet local tastes and evolving market demands.

C.12.Theia specializes in organizing and managing container transport between major seaports such as Rotterdam and Antwerp, and the European hinterland. The company optimizes traffic flows by leveraging high transport volumes across a network of terminals connected via inland waterways, rail, and road.

C.13. Nemesis is a global leader in contract logistics, specializing in customized, integrated supply chain solutions for diverse industries including life sciences, healthcare, retail, and technology. Innovation is embedded in its digital transformation efforts, IoT-enabled smart warehouses and advanced data analytics.

C.14. Planet Nine is a logistics and supply chain service provider in shipping and fleet management. Their activities focus on combining technological integration with customized services to enhance supply chain efficiency, leveraging digital platforms and data-driven decision-making.

C.15. Oberon offers a range of services including contract transport, internal transportation solutions, commercial vehicle services, warehousing, and truck parking. They combine traditional reliability with digital tools and data-driven management to optimize routes.

C.16.Titan specializes transport of liquid foodstuffs across Europe. Innovation is demonstrated through their investment in advanced, state-of-the-art tank cleaning stations that reduce water and energy use, sustainable fuel-efficient driving programs for their drivers, and efforts to optimize logistics planning to minimize empty runs and lower CO_2 emissions.

C.17.Kepler-22b is a healthcare organization that offers services in hospital care, nursing home care, home care, rehabilitation, youth health services, and day activities. The organization centers on delivering tailored, person-centered care that supports independence, well-being, and quality of life for clients of all ages. They utilize digital tools for coordinated care management, remote monitoring, enhancing accessibility and responsiveness.

C2b HRM (Business) codes comparisons with Logistics (engineering) code

C.2.1 Zythera Prime is a logistics-focused organization. It operates primarily in the recruitment and HRM sector tailored for the logistics industry. Zythera Prime plays a role in innovation by facilitating access to skilled individuals who can contribute to digitalization, process improvements, and modern workforce solutions within logistics organizations. The general education level within the company is relatively high, with the founder holding a master’s degree in strategic HR Management and industry-specific certifications.

C.2.2. Veltrax IV is a global company operates worldwide with production sites in multiple countries including Germany, Mexico, India, and China. The company is deeply engaged with innovation, continually investing in research and development to create new and improved products and technologies.

C.2.3. Orinex Alpha operates primarily as a wholesaler specializing in hygiene, safety, and healthcare products. In terms of innovation, Orinex Alpha integrates digital tools and streamlined logistics to enhance customer experience and supply chain efficiency. The company employs a workforce generally including professionals trained in logistics, business, and healthcare product management.

C.2.4. Kyronis Major is a multinational logistics company that specializes in industrial and automotive logistics solutions. Kyronis Major focuses on integrating digital tracking systems, data analytics, and sustainable logistics practices to enhance efficiency.

C.2.5. Eryndor Beta has expanded into a supply chain and transport service provider, offering solutions that span road, air, sea, and rail freight, along with contract logistics and supply chain optimization. Innovation focuses on process automation, real-time tracking, and green logistics solutions to stay competitive and address evolving market demands.

C.2.6. Quorath Expanse activities include manufacturing, supply chain management, and distribution primarily within the textile and home furnishings sectors. Quorath Expanse adapted to market changes by introducing new product lines, improving quality control through technology, and enhancing operational efficiency.

C.2.7. Pyralis Nine specializes in international sea and air freight services, offering a comprehensive portfolio that includes ocean freight, air freight, warehousing, multi-modal transport, and sector-specific logistics such as perishable goods and project logistics. Innovation is linked to the adoption of digital tools that enhance shipment tracking, process efficiency, and communication across its global offices.

C.2.8. Xandora Prime specializes in temperature-controlled logistics and transport, primarily serving the food industry across several European countries, including the Netherlands.

Innovation revolves around integrating advanced tracking and data analytics to optimize transport routes and reduce carbon emissions.

C.2.9. Verlina VII is a family-owned logistics service provider in transportation, customs formalities, warehousing, and supply chain management.

Innovation is central for warehouse management and digital customs processing. Verlina VII utilize robotic technologies for order picking and emphasize continuous process improvement and sustainability.

D.1 Data In-depth Interviews (volatility & disruptions)

D1.1. Euphrosyne is a major food producer that focuses on retail, food service, and industrial markets across Europe. Operations center on fermentation expertise, continual quality improvement, and the adaptation of products to different consumer needs. The organization collaborates closely with research institutions, to innovate in areas like reducing salt content in foods.

*The company has existed since 1917 but has had a location in the Netherlands since 1997.

D1.2. Cybele is a company specializing in circular supply chain solutions, focusing primarily on reversing electronic waste through repair, refurbishment, and recycling of electronic products. The organization aims to create sustainable value by enabling their clients across industries such as telecommunications, e-mobility, healthcare, and consumer electronics to transition from traditional linear models to circular business models. Their innovative activities include customized reverse logistics, component recovery, and digital integration of supply chain processes.

D1.3. Hermione is a family-owned company established specializing in the collection, sorting, and processing of waste materials such as paper, cardboard, plastics, and foils across Europe. Their operations transform waste into high-quality raw materials that are resold to certified end users worldwide. Hermione integrates both manual and automated sorting techniques to preserve or enhance material value.

D1.4. Davida is a highly specialized organization that produces labels for the safe transportation, storage, and handling of dangerous goods across all transportation modes including road, sea, rail, and air. The organization provides expert knowledge and advice tailored to regulatory requirements for hazardous substances.

D1.5. Eunomia is specialized on supplying high-quality electrotechnical equipment and lighting solutions tailored for the maritime sector. Innovation is reflected in their commitment to energy-efficient LED lighting and customized solutions that meet the stringent requirements of maritime safety and operational standards.

D1.6. Gliese 581g specializes in distributing and marketing a wide range of products such as lighting products and batteries. Gliese 581g emphasizes sustainability by focusing on eco-friendly and energy-efficient product offerings.

D1.7. Camilla is a retail chain focused primarily in the northern regions of the Netherlands. Innovation at is Camilla reflected in its efforts to implement digital self-checkout systems, and enhance online shopping capabilities to meet evolving customer preferences.

D1.8. WASP-49b is a leading company specializing in tire management solutions for both private motorists and professional transport sectors, including transport companies. Innovation at WASP-49b is in their focus on retreading technologies, smart digital tools and data-driven approaches.

D1.9. Tau Ceti specializes in the collection, sorting, and processing of various waste streams for businesses, including construction and demolition waste. They provide container rental, waste transport, and waste management services. Innovation is highlighted by the use of IoT-enabled sensors to track container locations and measure fill levels in real time.

D1.10. Hektor is a supplier in steel, stainless steel, and aluminum semi-finished products, serving various industrial sectors in the southern Netherlands. Innovation is reflected in their Quick Response Supply concept, designed to optimize ordering and delivery processes, helping clients streamline their operations.

D1.11. Vulcan is specialized in the treatment and handling of hazardous materials, particularly polychlorinated biphenyls (PCBs) and other halogenated compounds. The company focuses on environmentally responsible decontamination processes.

D1.12. Europa is a training institute specializing in business intelligence, data science, and performance management education designed to help organizations become more data-driven and intelligent. Their programs combine theoretical knowledge with real-world application, equipping professionals to leverage data analytics for better decision-making and innovation.

D.2 Data Interviews: Characteristics of the environments / SMEs / In-depth Interviews/ Future Skills/ Social Ontologies/ Learning Communities UASs SMEs

D2.1. Tatooine is logistics and transport company serving key sectors such as retail, hospitality/food service, pallet distribution, and pharmaceutical transport. Innovation at Tatooine is seen in their embrace of digital transformation, including the implementation of advanced transport management systems and data-driven decision-making tools that enhance operational efficiency and customer service.

D2.2. Naboo specializes in the supply of electrical materials, lighting, tools, sanitary, heating, and climate technology products. Innovation focuses on energy-efficient products delivery services tailored for complex construction site needs.

D2.3. Coruscant specializes in the storage, handling, and transshipment of food products, particularly nuts, dried fruits, and seeds, requiring specialized storage conditions. Innovation plays a role through the adoption of in-house customs services.

D2.4. LV-426 is a consultancy firm specializing in providing tailored solutions for both private and public sector clients. LV-426 offers procurement advisory, contract management, strategic sourcing, and recruitment of procurement professionals.

D2.5./2.6./D2.7. Altair IV is a global logistics company specializing in air, sea, and land freight forwarding, warehousing, and supply chain management. Altair IV offers advanced logistics services including temperature-controlled storage for pharmaceuticals and handling of semiconductor-related cargo. Innovation is demonstrated through eco-friendly warehouse facilities equipped with solar panels, automated handling systems, and real-time monitoring technologies that enhance efficiency and sustainability.

D2.8. Pandora is a construction and development company. The company emphasizes sustainable building practices, smart urban development, and social cohesion in its projects. Innovation focuses on investments in electrification of equipment, industrialized housing production, integration of digital technologies, and advanced safety measures like emergency brake assistance on construction machinery.

D2.9. Arrakis is a logistics service provider specializing in the transport and storage of large products, fresh produce such as vegetables, fruit, flowers, and plants. Innovation at Arrakis is evident in their investment in building a new state-of-the-art logistics center designed for sustainability, featuring solar panels.

D2.10. Arda is a logistics company that focuses on chemical, petrochemical, gas, polymer, and bulk logistics. The company operates 27 countries with a large fleet of specialized equipment. Arda emphasizes innovation in safety, efficiency, and sustainability.

D2.11./D2.12. Windesheim University Applied Sciences

D3 Data Survey: Characteristics of the environments / SMEs: case Learning culture / Focus groups The survey was sent to 18 SMEs n = 312

D3.1. Euphoria operates in power supply and energy, offering systems and services that help organizations safeguard critical operations. Euphoria contributes by integrating new technologies for energy efficiency, monitoring, and system reliability, supporting clients in adapting to evolving demands for sustainable power solutions.

D3.2. Entea focuses on the surface treatment of metal products, providing a range of electroplating services such as chrome, nickel, zinc, and silver plating. Their operations serve diverse industries including mechanical engineering, automotive, yacht building, and healthcare. In terms of innovation, Entea integrates advanced technologies for quality control, environmental management, and process automation.

D3.3. Super-Ego supports IT service providers and IT departments in recruitment capabilities. In relation to innovation, Super-Ego adopts tailored strategies, marketing, and content creation, which empowers clients to regain control over their talent acquisition processes and adapt to changing labor market demands.

D3.4. Thanagar specializes in dental care to children. Innovation at Thanagar is reflected in their use of scientifically based prevention methods, and services such as school-based dental check-ups with transportation support for children, enhancing accessibility and efficiency of care.

D3.5.Xorr is a software company specializing in solutions for the temporary employment sector. Innovation at Xorr is driven by the integration of AI and automation technologies in their software, improving operational efficiency and user experience.

D3.6. Klyntar is a company specializing in the supply, maintenance, and servicing of maritime engines and energy solutions primarily for inland shipping, offshore, and seagoing vessels. Innovation at Klyntar focuses on hybrid and emission-reducing engine solutions.

D3.7.Magrathea operates in the production and trade of construction and civil engineering materials, including various types of sand, foundation materials, and soil products used in road construction and landscaping. In relation to innovation, Magrathea uses sustainable production processes powered by solar power and the adoption of environmentally friendly fuels for its machinery fleet.

D3.8.Caprica is involved primarily in the cultivation and breeding of ornamental plants. In terms of innovation, Caprica engages in selective breeding and cultivation techniques to develop new plant varieties with desirable traits, improving quality and resilience.

D3.9. Mogo is a company that designs, engineers, and manufactures integrated mooring, berthing, towing, and ship-to-shore systems for the marine and offshore industries. Innovation at Mogo is reflected in continuous development of advanced safety systems, remote control technologies, and sustainable solutions.

D3.10.Krypton manufactures, and supplies industrial cleaning and handling systems for the food and non-food industries. Innovation at Krypton focuses on optimizing cleaning processes by precisely controlling factors such as time, temperature, detergent use, and mechanical force to achieve optimal hygiene results while minimizing water and energy consumption.

D3.11. Rann is a biotechnology company on drug development through artificial intelligence. Their innovative approach supports partnerships with pharmaceutical firms to bring breakthrough precision medicines to patients with urgent unmet needs more quickly.

D3.12.New Genesis is a company active in the production and supply of concrete products and construction materials. Innovation is reflected in continuous adoption of advancements in concrete technology.

D3.13. Tamaran is a company specializing in high-quality short line and feeder rail services. Innovation at Tamaran is demonstrated through its integration of advanced rail technology and optimizing logistics and rail connections.

D.314. Korugar is a company specializing in the design and manufacture of high-quality scale truck models primarily for collectors and promotional purposes. Innovation at Korugar is in its use of advanced design techniques like 3D modeling and precision injection molding to produce intricate and durable miniature truck replicas.

D3.15. Illa is a logistics and transport company providing comprehensive storage and transportation services. Innovation at Illa focuses on combining traditional reliability with technological solutions to enhance flexibility.

D3.16. Worlorn is a company specializing primarily in the trade, processing, and logistics of agricultural products. Innovation at Worlorn is driven by development of sustainable transportation logistics and flexible operational practices.

D3.17. Oa specializes in developing and implementing comprehensive e-commerce solutions for manufacturers, wholesalers, and retailers. Innovation at Oa is demonstrated through its use of data analytics and marketing automation.

D3.18. Gallifrey is an international company specializing in innovative and customer-specific ingredient solutions food industries. Innovation at Gallifrey is in its continuous development of healthier and environmentally friendly products, and the use of advanced knowledge in bakery processes.

Appendix: C Questionnaire Sobek Study 1 (before)

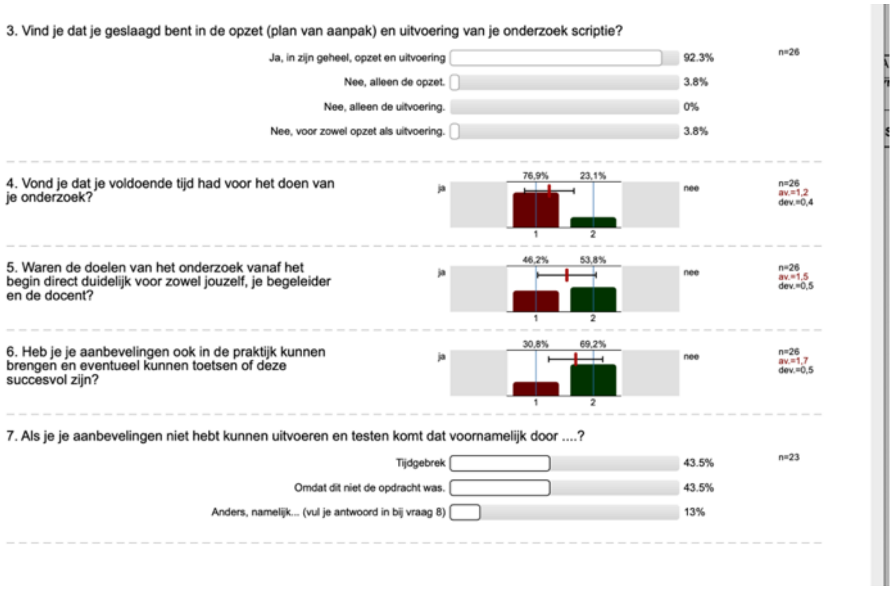

Figure 35. Example perception of students

Below a translation of the questions (made by researcher)

3. Do you think you succeeded in setting up (plan of approach) and carrying out your research thesis?

Yes, entirely – both setup and execution: 92.3%

No, only the setup: 3.8%

No, only the execution: 0%

No, neither setup nor execution: 3.8%

n=26

4. Did you have enough time to conduct your research?

Yes: 76.9%

No: 23.1%

n=26 | average = 1.2 | deviation = 0.4

5. Were the research objectives clear from the start for you, your supervisor, and your lecturer?

Yes: 46.2%

4.I had enough time to both Did you have enough time to conduct your research?

5.Were the goals of the research clear from the start to you, your supervisor, and your lecturer?

6.Were you able to implement your recommendations in practice and, if applicable, test whether they were successful?

11.Because of the good guidance from my workplace supervisor.

12.Because the problem was clear and well-defined.

13.Because I could devote all my time to the research.

14.Mainly because of the product or service they provide.

15.The organization was located close to my home.

32.Communication between the university and the internship organization contributed positively to a good result.

33.The role of the workplace supervisor contributed positively to the quality of my thesis.

34.The culture of the organization.

35.The opportunity to experiment within my research contributed positively to my result.

36.There is a safe and empathetic atmosphere.

37.The level of the graduation project matches what I learned during my studies.

38.I had sufficient research skills to bring the research to a successful conclusion complete my internship and conduct the research.

39.I had enough time to both do an internship and conduct research.

40. The assessment criteria.

41.The research method I used matched the company’s assignment well.

42.The assignment was challenging for a student.

43.The way of working and thinking at the internship organization aligns with what I’m used to at the university.

44.The graduation projects produce concrete professional products that are used in practice.

45.The graduation projects are innovative and therefore important for the HRM professional field.

Table 45. Example evaluation based on Sobek Study (in Dutch).

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Based on our framework (Sobek, 2004; Bendixen, 2016; Spiro, et al., 1988) of Learners with more superficial epistemic beliefs tend to engage in surface-level processing, which affects their ability to make statements on complex, multidimensional problems. A focus on surface content or oversimplified problem-solving steps, does not develop the coherent, well-structured knowledge frameworks or adaptive epistemic beliefs essential for higher-level understanding and success in complex tasks

Appendix D: Themes collecting based on scenarios (A1-A10)

Themes	Connection with inspiration sessions / digital survey
Next Economy	
1. Next Design Lab	A8 It is a typical port area. Eventually, there must be housing, but until 2030, there will be companies. RvO - comparable with MHVH Rotterdam, opportunity to start with hotspots, incubators, pop-up café? Survey: Everyone says: more collaboration with other companies, new products and services, and markets (diversification) and focus on automation. For example, Q41: collaboration via cobots is also important. Therefore, the opportunities lie much more in high-quality products and/or more complex products. Do you agree or disagree? Almost all respondents agree. A5: Our company is still unknown. We lose out against other companies. The supply is there, but the quality is lacking. Maybe it also plays a role that we are located in Schiedam. Schiedam is not attractive. Making a region like Schiedam attractive for employees is a challenge. A2: Our company has undergone a transition from a truly Schiedam company to an international one. There is some local connection. But when it comes down to it, we do not principally choose Schiedam. Area development, keeping the area attractive. That can be done together. Whatever happens, you need education and an eco-innovation system. Living environment, schools, and innovation promotion have priority.
2. automatic driving system in taxis	A10: joint research projects in an eco-innovation system

Themes	Connection with inspiration sessions / digital survey
Next Professional	
3. Propeller Program	A6: Joining the innovation ecosystem Maritime Cluster, the area remains vital due to promising opportunities in high-quality manufacturing industry, active participation in innovation ecosystem development, collaboration with other companies and educational institutions, initially focusing on education.A8. How do we motivate the 45+ age group to take the final step? We as a company want to, but people lack motivation. Society is not ready for it.A5: We have a step ahead program: what did you want to be before, what are you doing now? In five years, no one will be doing the same. We only reach the motivated group. How do you reach the other group? Their conclusion is: you want to fire me. A5: here I see a real challenge for us is how to approach people who are worn out. I expect other companies also struggle with this. A labor pool might be possible. A2: That second career line? We have too many of certain specialists. How can we get them to switch to another career? We tried, but they were not enthusiastic. How can we do it differently? A10: It is difficult to keep the existing pool of people who have already worked here for 40 years. Now it's like, what shall we do with "Piet."
4. Innovation Spaces	Survey: Collaboration both within and outside the sector in the field of service development is the most important. This aligns with the service scenario. Here, personnel policy (Human Resources) is seen as the most important, along with labor market policy. Collaborating with other companies, new products and services, and markets (diversification), and focusing on automation. Collaboration is desired but fails due to personnel policy and competition. Personal skills (personal leadership) and technical skills are important, which can be explained by changing job functions. Everyone finds collaboration important in the Triple Helix. This corresponds with question 20; 66% believe this is related to personnel policy, innovation methods, and labor market policy. All respondents also see regional collaboration as beneficial for their organization: mainly because the development of HRM is specifically mentioned here as important. In this area, cross-overs must arise in the field of functions (knowledge management). This aligns with earlier questions that this is (a) important but also still insufficiently occurring (namely development of new functions).

Themes	Connection with inspiration sessions / digital survey
5. Mentoring and Monitoring	-All HRM themes are regarded as important: talent, training, task analysis, organizational development. -Lifelong learning is becoming important, especially through additional training and retraining, which is still insufficiently addressed. - 66% believe that this is related to personnel policy, the way of innovating, and labor market policy. - However, on the other hand, exchange with other companies to possibly address staff shortages or to gain more knowledge. -Here, personnel policy (Human Resources) is seen as the most important, together with labor market policy. This may correspond with the question of whether collaborating in pools (which is seen as less important) has an effect. - A10: Interested in other contract forms.
Next Education	
6. Hybrid Teacher	- At Stream, people teach without a formal certificate. These are skilled craftsmen. When a boat comes in, a tension arises. Expertise takes precedence over teaching. We could solve this, for example, by exchanging instructors between A10 and A8. If you don't teach here but at Pluto (A10), you avoid this issue. - You need to ensure that the knowledge of 'older skilled workers' is preserved. - Becoming a teacher from within the company is a great advantage for education. But then the company must be able to arrange it—funds for training, making time available. - A5: We have some mechanics who are being trained as trainers at the school of the future.
7. 21st Century e-Skills.	A7. The younger generation, where we mainly have issues, is the control technology, electrical and process control, you can teach that very well practically.A6: We invest in our people in the hope that they stay.A5. Digital skills are insufficient in many people. We are much more dependent on digital skills. The role on board is also changing. Soft skills and digital skills are the most important.A2: We do not yet do anything specifically to increase the digital skills of employees

Themes	Connection with inspiration sessions / digital survey
Conclusion Robotization and Automatization (R&A)	R&A is seen as a threat. It has an impact on the development of job functions. It affects the number of job openings and the disappearance of jobs, but according to respondents, it does not create an hourglass model. Opinions are divided on the disappearance of routine work at MBO2 level, which may relate to which tasks respondents consider here. More job openings at HBO level. And, new craftsmanship arises with different skills, more cobots, and the related "crossing of craftsmanship," which corresponds with skills. Skills Respondents are divided on whether R&A will lead to a skills mismatch. There is a mismatch in many areas, indicating that other skills need to be developed and existing skills adapted. social and communication skills are especially important.

Table 46. Higher-order themes, based on survey and focus groups

Appendix E: analysis archetypical epistemic quadrants/ using the modal cube

Participation in skill in Human Capital in logistics

We used modal knowledge us to formally represent and reason about uncertainty, beliefs, or varying states of knowledge in practical environments, complementing the topology for different conceptual and pragmatic spaces under uncertainty (see below). It explains why knowledge or skill descriptions or expression vary across roles or contexts. Different sets allow a richer analysis based different circumstances and helps to explain that knowledge is not absolute, but rather modal and intensional under epistemic uncertainty

Kripke Semantics in System (S4): understanding the belief systems of a given world.

However, in $S4$, the accessibility relation is transitive, so if an object $O(x)$ holds in one world, $C(x)$ must hold in all worlds accessible from that world and all worlds accessible from those worlds, and so on. Here we know that $\Box A \rightarrow \Box\ A$ means transitivity: if something is true it remains necessarily true in all accessible worlds, both transitive and reflexive.

Transitivity is essential for a hierarchy, for example in statements. If something is true in a statement, the consequences of that statements are also true.

Choices in modal operator for transitivity

In practical sense for our research this emphasizes the consequences of descriptions of functionalities in the application of knowledge. For this condition we must <u>use a single modality</u> and preferably <u>one statement</u> and know the when a statement is true that this will hold in the world that are accessible form that world.

If we use the example of only modal semantics for framing states a more distinct description of necessity can be made:

Logical Distinctions: contingency modelling of SME strategies

Type A:	Type D:
□(P↔Q)□(P↔Q)	□(P↔Q)□(P↔Q)
Type B:	**Type C:**
□(P↔Q)□(P↔Q)	□(P↔Q)□(P↔Q)

Type A:	Type D:
◊(P↔Q) ◊(P↔Q)	◊(P↔Q) ◊(P↔Q)
Type B:	**Type C:**
◊(P↔Q) ◊(P↔Q)	◊(P↔Q) ◊(P↔Q)

(source data analysis stage III)

Figure 36. Logical distinctions based on different situations

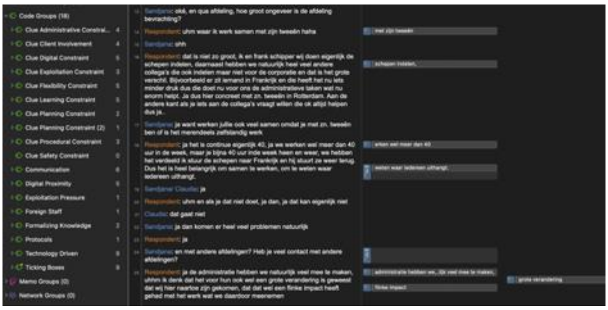
Type A example shows ineffective use multiple statements (indistinctions)

In this position, it is necessary (□) that organizations' boundary spanning takes place through experts. These actors necessarily (□) span boundaries by conducting research and connecting science with policy. It is possible (◇) that spanners in this position have sufficient resources and facilities. However, it is also possible (◇) that the impact of spanning capacity might be low because actors encounter pragmatic boundaries. The capacity of spanners is influenced by long-term and complex processes in order to necessarily (□) contribute to sustainable solutions. Skills in this position are more likely (◇) to deal with negotiating scientific knowledge.

Appendix F: Analysis of meta codes

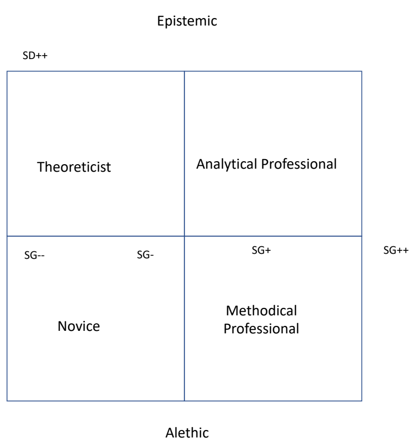
Based on the analysis of semantic gravity (SG) and semantic density (SD) levels and the associated scores, the student tries in this case can be concluded to be at a practitioner level of expertise. This is because the analysis shows a mix between horizontal and vertical codes, which requires more abstract thinking but is still closely related to the context, matching the description of Analysis Prosaic with scores such as (SG+, SD-) indicating more context-related but simpler meanings typical of a practitioner’s understanding.

This indicates the person has moved beyond novice or simple context-independent knowledge (SG-, SD-) but may not yet have fully reached the professional level that handles highly condensed and context-dependent knowledge (SG+, SD+).



When examples are given on how labor markets change with regard to skills and knowledge (Code C.2 OrgC2.1.IO/AS/ 4:164) there are no questions on what this means for the organization.

Meta code5: how do organizations deal with fast changing demands for new skills. Pragmatics and more theoretical analyses of the problems must be combined to get ideas on the solutions.



Many organizations are shifting to use of different, sustainable methods of transportations.

Metacode6: use of social media in organizations is difficult for more traditional organizations.

From the questionnaire we sometimes see clear relationships between demographics, environmental changes and statements on ambiguity in terms of HR strategies. We see these that these relations are not addressed as constraints by students.

Sometime there is a mix between horizontal and vertical codes which creates difficulties (Here clearly this is a pragmatic problem which involves more abstract analysis (C.2 OrgC2.1.IAZ/5:33)).

Analysis; context independent and low complexity (SG-, SD-)/novice

Score: (SG-= -1; SG--= -2; SD-= -1; SD--= -2)

Analysis Prosaic: more related to context and simpler meaning (SG+,SD-)/practitioner

Score: (SG+=1; SG++=2; SD-= -1; SD--= -2)

Analysis Worldly: context-dependent legitimacy and related to other meanings condense and meaningful (SG+, SD+)/ Professional

Score: (SG+=1; SG++=2; SD+ = +1; SD++ = +2)

Appendix G: Samenwerken13

Samenwerken[13]

Onderstaande vragen gaan over het samenwerken bij uw organisatie. In hoeverre herkent u zich in de onderstaande stellingen?

		Helemaal mee oneens	Oneens	Neutraal	Mee eens	Helemaal mee eens
SWI1	In deze organisatie werken teams/afdelingen samen om meer te leren over wat ons werk inhoudt.					
SWI2	In deze organisatie kijken we regelmatig terug op werk dat is gedaan.					
SWI3	In deze organisatie delen we regelmatig kennis en inzichten met elkaar.					
SWI4	Door met elkaar te praten over de inhoud van ons werk, kan iedereen doen waar hij of zij goed in is.					
SWI5	In deze organisatie praten we veel over de manier waarop we samenwerken.					
SWI6	Wanneer iemand in onze organisatie suggesties doet om de kwaliteit van het werk te verbeteren, wordt dit serieus genomen					
SWI8	In deze organisatie passen we de werkprocessen aan als deze niet langer effectief blijken te zijn					
SWI10	In deze organisatie weten we van elkaar wie waar goed in is					

Code	Statement (translation made by researcher)
SWI1	In this organization, teams/departments work together to learn more about what our work involves.
SWI2	In this organization, we regularly reflect on the work that has been done.
SWI3	In this organization, we regularly share knowledge and insights with one another.
SWI4	By talking with each other about the content of our work, everyone can do what they are good at.
SWI5	In this organization, we talk a lot about how we collaborate.
SWI6	When someone in our organization makes suggestions to improve the quality of work, these suggestions are taken seriously.
SWI8	In this organization, we adjust work processes when they are no longer effective.
SWI10	In this organization, we know each other's strengths.

Table 47. Example question from Survey in D3

Appendix H: Case observation criteria

Dimensions of epistemic spaces.	**Mono-tonicity (0)**	**Non-Mono-tonicity (1)**	**Short description of the analysis. Further details and descriptions can be found in previous chapters on theoretical framework.**
	From zero to 1 (0-1) on each item		(set of outcomes)
A. Boundaries: Analysis Semantic vs Pragmatic	Fuzzy when **both (1)** boundaries take place to define functionalities if not **(0)**		**Define specific boundary that is involved:** What are differences in interoperability or interpretation (semantic) vs specific constraints and necessary adaptations (pragmatic)? Are agents familiar with the situation? Does the situation require semantic or pragmatic knowledge that corresponds with earlier experiences?
B. Boundary: Functionality Weak vs Strong	Do the boundaries affect existing boundaries? (strong 0)		What are procedures, rules or other type or arrangements that affect the situation? (compare judgmental: based on incomplete claim. Non-absolutists. Weak boundaries require more reasoning
C. Prerequisite codification or previous knowledge Strong EP/ ST	Strong: codes already exist: makes it easier to make knowledge representations **(0)** Weak codes (non- pertinent barriers between vertical distributions) require modal choices **(1)**		What is the dominant discourse and how does this affect the inquiry method and or reasoning. e.g.: strong tacit is experience not codified, repetitive, existing critical processes.
D. Codification direction Vertical or Horizontal	Strong horizontal codification (ether pragmatic or semantic, such as in procedures) limits non-monotonicity **(0)**		Horizontal and strong explicit is for example a type of method or procedure. Also it can indicate domain knowledge from specific users or customers
E. Density – Gravity	High Density (conceptual and abstract) require more instantiations in reason and justifications **(1).**		Do students have retrieve instantiations from the situational space and or do they respond on the presence or absence.

F. Maturity spanning High Low	Possible modal choices, either presented or detected by agents involved. More modal choices possible: **(1)**	A more feasible categorization: - Fact - Value - Policy - Concept - Interpretation (Hart, 1998)	A knowledge claim can be formulated on its utility, such as in design. A knowledge claim can be based on a more conceptual or ontological claim that may serve a wider community or a network. These different claims also divided different disciplines. The choices that are made on this can help to understand the domain knowledge, correspondence and information gravity. More interaction between facts and polices require different reasoning- and inquiry methods.
G. Probability Contingency – Necessity	This concerns multiple stakeholders (such as in a Triple Helix) or requirements that exceed different modal claims making in it highly reasonable in terms of contingencies and or direct solutions. (exceed= 1)		Does a specific problem exceed contextual needs (Moerman, 2020)? How can we define the problem is a situation in terms of a necessity vs probability vs contingency. For applications of knowledge this involves the type of requirements and actions that may be needed at the moment or may be in the future.
H. Epistemic Functionality Requirements (eF) Objects	New requirements needed (1)		Does the object or the subject require (new) semantic descriptions that explains the functions on a horizonal knowledge distribution and or on a vertical distribution (concepts)?
Adaptation (A) Identify and Transfer (ITA) Identify and Transform (ITO)	After finishing the project, the designed object has a clear functiona-lity	These relate to the necessary requirements: for example, in SMES the HR or KM maturity. In general, it relates to the object that can be applied in different situations. Properties of the epistemic object: boundary (flexible design) epistemic (conceptual) or experimental (require more testing).	

<table>
<tr><td>I.
Necessary requirements present</td><td colspan="2">In the case of SMEs maturity (HR) in other case other regulated or defined requirements already present (e.g. process outcomes) If so = (0)</td><td colspan="3">Do extra requirements have to be made?</td></tr>
<tr><td>J.
Integration of Knowledge</td><td colspan="5">a) Work of students is (directly) used.
b) Collaborative or individual teamwork is disseminated in the curriculum Explanations/ Examples. A functional design independently of the criteria above is useful when integrated and contributed to knowledge disseminations according to criteria for these disseminations.
If either a or b (1).</td></tr>
<tr><td>Transfer possibilities</td><td colspan="2">Results, design or object can be transferred to other projects or used in courses</td><td colspan="3">Yes/ No:</td></tr>
<tr><td>Level of Implementation
What is the (modal) output/ solution</td><td>1</td><td>2</td><td>3</td><td>4</td><td>5</td></tr>
<tr><td>Description of level</td><td>1= Problem formulated,</td><td>2 = development of a model</td><td>3. developments of a concept</td><td>4. Prototypes or testing</td><td>5. used and implemented</td></tr>
<tr><td colspan="6">Description of level:
Here is a description of actual solutions in relation to the situation. An excellent solution may be found without reasoning requirements using expertise without specific domain knowledge. However, we not only want to know if agents are successful, but if the situation is related to the capability of agents as well if this is a learning opportunity in the sense that it evokes epistemic doubts.</td></tr>
</table>

Table 48. Observation List (translated)

This table shows an observation list for reasoning on decisions and possibilities on non-numerical information. This enables us to analyze whether agents involved used different techniques for semantic disambiguation. By doing so it is our understanding that helps in general to determine the given information in terms of its functionality. This analysis form is a way to give directions to evaluate the capability of agents (epistemic stances) Epistemic stance is both an attitude to knowledge and the capability or knowledge on the interaction and method or tool chosen that relates to the question of knowledge. A non-monotonic space can be, for example, useful in a multidisciplinary environment. These spaces can also create learning environments since they are not corresponding with earlier problem-solving arrangements that are often well-structured.

Appendix I: On the researcher

The researcher was employed as a lecturer at Rotterdam University of Applied Sciences, where he fulfilled multiple roles related to the research. He was affiliated with the research centre Creating010, a collaborative institute within RUAS, and actively contributed to projects at the Centre of Expertise HRTech, TKI Dinalog, and Topsector Logistiek. His involvement extended to consortium-based initiatives such as the TNO Transfer Skills project, as well as engagements with the Research Centre EMI Urban Innovation (Living Lab), the Metropolitan Region Rotterdam The Hague (MRDH), Rotterdam The Hague Innovation Airport, and two field labs.

To support the research objectives, a dedicated design lab named Next Professional Design was established. This lab, among the first of its kind within RUAS, was developed based on insights from preliminary phases and served as a platform for testing specific design interventions. Additionally, the research incorporated collaboration with the Rotterdam University Wicked Problems Plaza, Innovation Quarter, and multiple municipalities including Rotterdam, Schiedam, Delft, and The Hague.

The research engaged students from diverse vocational backgrounds—including logistics, HRM, and the arts—working collaboratively within differentiated groups such as field labs, design labs, solution labs, and living labs.

Case selection for the research was guided by regional policies and challenges within the Metropolitan Region Rotterdam The Hague, TKI/Dinalog, the Rotterdam The Hague Innovation Airport. Cases included public-private partnerships, consortia, branch organizations, and individual student-led projects, ensuring a multifaceted and contextually grounded research scope.