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INNOVATIVE CONCEPTUAL MODELS FOR KNOWLEDGE MANAGEMENT IN THE ITALIAN AIR FORCE

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Esiste una forza, nella vita di ognuno, che risulta determinante in ogni contesto: la passione. Che si tratti di un lavoro, di un progetto, di una relazione interpersonale o, nel caso di un militare, di servizio per la comunità, la passione fa la differenza e spinge sempre il cuore oltre gli ostacoli trovati lungo il percorso.

A Giulia, ai nostri figli,
alla donna e all'uomo che diventeranno

Acknowledgments

At the end of this exhilarating yet challenging journey, it feels only right to express my gratitude to those who have made this experience particularly special, helping me balance professional, academic, and family responsibilities in the best possible way.

First and foremost, I extend my thanks to the Commanders I have had at the *Reparto per la Formazione Didattica e Manageriale*, of the *Istituto di Scienze Militari Aeronautiche*, Col. Luca Mazzini, Col. Alessandro Castellan and Col. Gennaro Di Napoli, who understood the importance of this challenge and ensured their support, enabling me to harmonize my duties with the research activities required for this PhD. Their commitment allowed me to bring valuable know-how and substantial added value back to the Department. I would also like to thank my direct supervisors: Lt. Col. Luca Fontana, a partner in innovative and demanding projects and my example of "empowering leadership" and Lt. Col. Giancarlo Maruca, with whom I explored the managerial approaches of the Air Force.

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Finally, my deepest gratitude goes to my family: to my wife Giulia, for all the times she managed our household on her own, and to our little ones, Isabella and Leonardo. Perhaps my strongest motivation has been to set a good example of dedication and determination for them. As I've learned as an Officer in the Italian Air Force, setting a positive example is one of the most powerful tools of leadership.

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Premise

This work is based on a fundamental assumption guiding all the approaches used in the research: the elements of an organization, as well as those of the complex life of humans, cannot be considered separately nor acting in isolation. Each element is related to the others, and the emergent effect of this relationship is almost never the linear combination of the effects of the individual elements. It is not possible to separate the pragmatic level of tools, applications, and software from the theoretical level of the field in which we operate, and vice versa. It is not possible to think of human resources merely as a repository of knowledge and expertise capable of covering a specific role, as the effect of "the right person in the right place" is also determined by the quality of the relationships established within the reference system. Reducing in schemes looses some grip on reality. This is a limit of this study, but I believe it is a limit of any study that analyzes organizational phenomena, and still the quest for great the value of more effective collective action is worth the enterprise

Introduction

In the context of the contemporary world, characterized by rapid and continuous evolution, the complexity of social, economic, and technological dynamics is constantly increasing. To remain competitive and resilient in an *infinitive game*[1] (using Sinek's words) organizations must adapt to increasingly frequent and unpredictable changes. This scenario requires an innovative and flexible approach to managing internal resources, among which knowledge plays a central role.

Knowledge represents a fundamental asset and a strategic resource for every organization. It is not just a set of information and data, but a vital element that directly influences the ability to innovate, make informed decisions, and respond effectively to market challenges. The ability to acquire, preserve, share, and apply knowledge efficiently can determine the success or failure of an organization.

In this context, Knowledge Management (KM) emerges as an essential discipline for managing the complexity of the modern world while pursuing the strategic aims of the organization. KM is not limited to managing explicit information but also includes the valorization of tacit knowledge, that experience and intuition that often remain unformalized but are crucial for organizational functioning and innovation. The main challenge lies in making this tacit knowledge usable, integrating it into decision-making and operational processes.

Military organizations, such as the Italian Air Force, are also playing an *infinitive game*, facing particularly significant challenges in this area. The dynamic and adversarial nature of military operations requires a KM system that can support rapid and informed decisions at all levels, ensure the continuity of strategic competencies, and facilitate continuous personnel training. Therefore, knowledge management becomes a critical factor for the success of missions and the maintenance of national security.

Through the analysis of current practices and the introduction of innovative models, the research aims to equip the Italian Air Force with necessary tools to navigate the complexities of the contemporary operational context. The objective is not only to preserve existing

[1] In his discussion of finite and infinite games, Sinek (2019) explains that while finite games have fixed rules, clear objectives, and definite endpoints, infinite games, such as business, are characterized by continuous play without a clear finish line. In an infinite game, the goal is to perpetuate the game rather than to "win."

strategic skills and human capital but also to enhance them, ensuring that the organization remains at the forefront of its field.

Context, significance and objectives of the research project

After approximately six years as an Officer in the IAF, focusing on digital technologies and learning methodologies, and having contributed to several key projects aimed at innovating learning processes within the Defense sector, I was driven by the desire to combine an academic approach to research with the practical implementation of innovative solutions for the organizational development of my operational environment. I have dedicated my doctoral studies to topics related to knowledge management, which I believe are highly relevant to the IAF, an organization where I am proud to contribute to serving my Country. This research seeks to address the urgent need for a structured approach to managing and leveraging knowledge assets within the organization. The motivation behind this research is threefold, reflecting the critical challenges and opportunities in KM within the military context.

Firstly, the impending retirement of the "baby boomer" generation poses a significant threat to organizational knowledge retention. This demographic shift is expected to lead to a substantial loss of expertise within the Air Force, highlighting the importance of capturing tacit knowledge before it exits the organization. Secondly, the need for just-in-time training capabilities underscores the requirement for a KM system that can swiftly equip personnel with the right skills at the right moment, especially in emergency situations or rapidly evolving operational contexts. Lastly, the dynamic nature of military operations, characterized by volatility, uncertainty, complexity, and ambiguity, demands a KM system that supports decision-making through efficient information flow and analysis.

Addressing these challenges requires more than the mere implementation of technological solutions; it necessitates a methodological overhaul of how technologies are integrated within organizational culture and processes. This thesis aims to explore theoretical and practical solutions in KM and propose new models to foster a culture of continuous learning and knowledge sharing within the IAF.

This research has been guided by the following questions:

- What are the most relevant aspects of Knowledge Management for organizations, particularly for an organization like the IAF?
- Which KM approach is the most effective for the IAF?
- What are the main KM processes, and how are they managed within the IAF?

- What are the primary KM tools used in the IAF, and how can their utilization be improved, considering the specific characteristics of the organization?
- What models and practical solutions can be suggested to the IAF's Knowledge Managers to enhance KM processes?

The following diagram summarizes the key aspects that define the context and objectives of this research project.

Figure 1: Context, significance and objectives of the research project

Research topic: New KM Models for IAF

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Research Problem: The impending retirement of the "baby boomer" generation in the Air Force poses a critical risk to organizational knowledge retention, particularly the loss of tacit expertise. This challenge is compounded by the need for a just-in-time training system that can rapidly equip personnel with essential skills, especially in emergency or fast-evolving operational contexts. Additionally, the inherent volatility, uncertainty, complexity, and ambiguity of military operations demand a Knowledge Management (KM) system that facilitates efficient information flow and supports decision-making.

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Purpose Statement: To propose new models tailored to the organizational context of the IAF to assist Knowledge Managers in effectively facilitating knowledge management and promoting a culture of continuous learning and knowledge sharing.

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Research Questions:

- What are the most relevant aspects of Knowledge Management (KM) for organizations, particularly for an organization like the IAF?
- Which KM approach is the most effective for the IAF?
- What are the main KM processes, and how are they managed within the IAF?
- What are the primary KM tools used in the IAF, and how can their utilization be improved, considering the specific characteristics of the organization?
- What models and practical solutions can be suggested to the IAF's Knowledge Managers to enhance KM processes?

Methodological approach

The research adopts a comprehensive and multi-faceted methodological approach, using both qualitative and quantitative methods to analyze public literature and internal organizational sources. This methodology is designed to explore various elements leading to the identification of innovative Knowledge Management (KM) models within the defense sector, particularly in the context of the Italian Air Force (IAF).

To begin, I conducted an in-depth review of both scientific and non-scientific literature on the fundamentals of KM, addressing key concepts such as definitions, the evolution of KM as a discipline, and its strategic role within organizations. I also examined KM processes and the most established theoretical models in the field, providing the conceptual framework for the subsequent phases of the project.

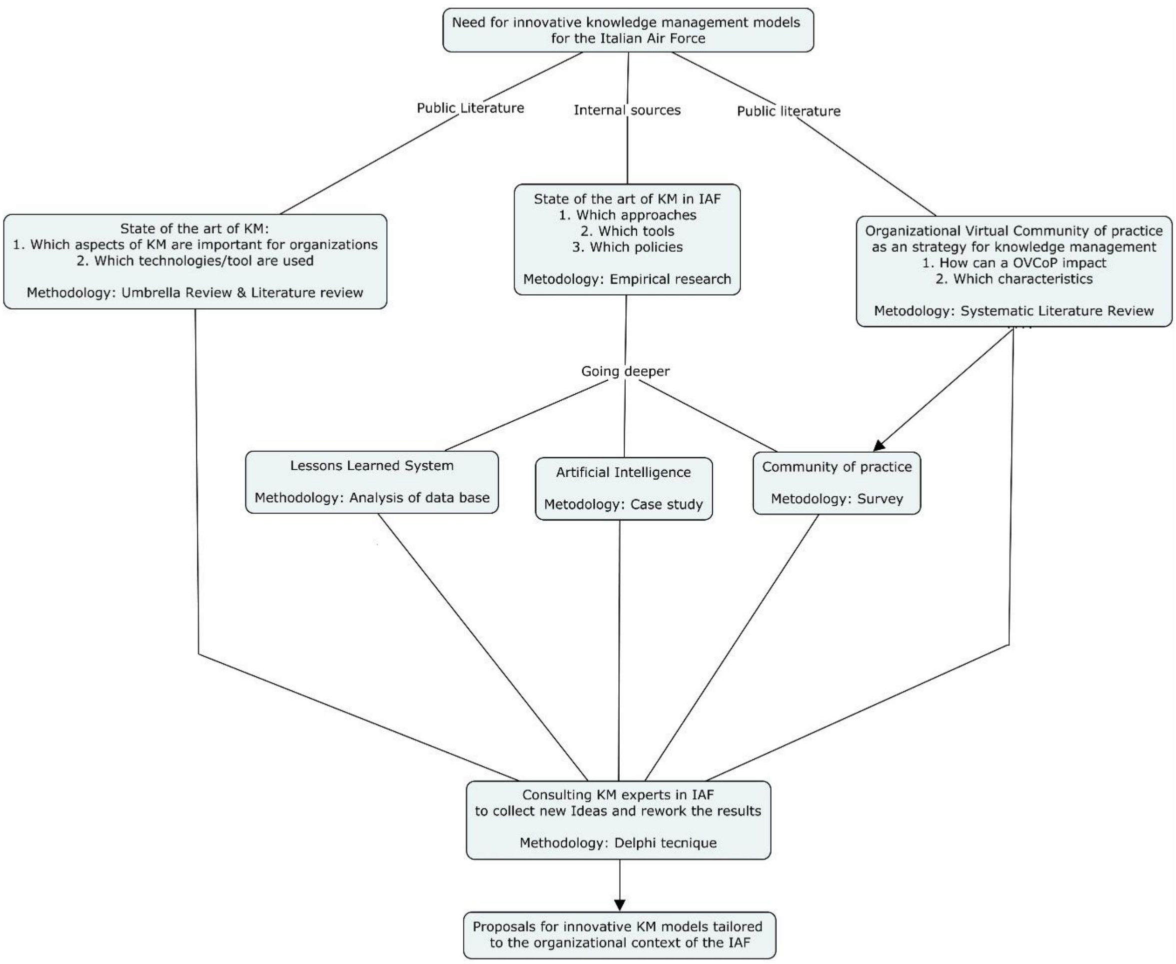
Following this, I performed an umbrella review of systematic literature reviews from the last five years, offering a comprehensive overview of recent research on KM in organizations. This review focused on two key research questions: which aspects of KM are most relevant to organizations, and which KM tools are most commonly used. The findings provided valuable insights into current trends and practical guidance for my research. A specific systematic literature review was also conducted on Organizational Virtual Communities of Practice (OVCoPs), a KM strategy already in use by the IAF. Based on the results of this review, a survey was developed and administered to an active CoP within the IAF.

Additionally, internal sources within the IAF, such as directives, approaches, and KM reference tools, were analyzed to assess the current state of KM in the organization. This analysis revealed that some approaches found in the literature, such as the application of AI algorithms in training, the implementation of digital CoPs, and the use of a Lessons Learned system, had already been adopted by the IAF. To further explore these areas, I conducted three case studies to assess the strengths and weaknesses of these KM practices in the IAF. One of the case studies involved a detailed analysis of the IAF's Lessons Learned system, another relates to the use of AI for enhancing lifelong learning among Defense personnel, and another focuses on the analysis of an operational Virtual Community of Practice (VCoP) within the IAF.

Finally, I employed the Delphi technique, a structured inquiry method conducted over two rounds with KM experts within the IAF. This technique aimed to gather expert opinions and reach a consensus on tailored solutions to meet the organization's specific KM needs.

By combining these methodological approaches, I was able to deeply investigate KM dynamics within organizations. This comprehensive analysis, along with a focus on the unique characteristics of the Air Force's organizational context, led to the development of KM models tailored specifically for the IAF. The research structure and methodologies used are summarized in Figure 2.

Figure 2: Conceptual map of the research structure and methodologies adopted



Thesis structure

This thesis is structured into four main parts, each addressing key aspects of Knowledge Management (KM) and its application within the Italian Air Force (IAF).

Part I and II correspond to the first level of the conceptual map in figure 2.

Part I provides a comprehensive introduction to KM. Chapter 1 discusses fundamental concepts, definitions, and the evolution of KM as a discipline, focusing on its role as an intangible asset in organizations. Chapter 2 explores essential KM processes such as knowledge creation, acquisition, storage/retrivial, transfer, sharing and application. Chapter 3 presents key theoretical models, including the Meyer and Zack model, the Bukowitz and Williams framework, and the SECI model, which provide a foundation for understanding KM in organizational contexts.

Part II focuses on systematic reviews of existing KM literature. Chapter 4 conducts a detailed umbrella review, analyzing key findings, trends, and tools commonly used in KM. Chapter 5 investigates Organizational Virtual Communities of Practice (OVCoP) and their relationship with KM, identifying gaps in the literature and refining the research focus.

Part III corresponds to the last level of the conceptual map.

It shifts to the practical application of KM within the IAF, beginning with an overview of the organization in Chapter 6. Three case studies follow. Chapter 7 presents a study on an OVCoP within the IAF, based on a questionnaire administered to the institutional Moodle administrators. Chapter 8 examines the Lessons Learned System through data analysis, focusing on how specific organizational factors influence the identification and dissemination of lessons learned. Chapter 9 explores an intelligent content recommendation system for lifelong learning in the Defense sector, highlighting the integration of machine learning technologies and their educational benefits.

Finally, Part IV offers solutions for improving KM systems within the IAF. Chapter 10 aims to highlight the main findings gathered in the previous chapters and to introduce Part IV, the innovative core of the thesis. Chapter 11 presents the results of a Delphi method survey, gathering insights from KM experts within the IAF. Chapter 12 synthesizes the findings of the thesis, introducing innovative models aimed at enhancing KM in the IAF. Specifically, this chapter proposes a taxonomy of knowledge types, a reference model for selecting KM processes to strengthen or implement, a framework to guide knowledge managers in implementing KM systems and selecting appropriate tools for their specific context, and a set of principles and guidelines for developing effective Virtual Communities of Practice tailored to the IAF environment. Chapter 13 concludes the thesis by outlining the research limitations and offering suggestions for future development and research directions.

Each part begins with aphorisms shared by distinguished scholars in organizational development, gathered from conferences I attended during my doctoral journey. These aphorisms are included to offer readers a reflective and engaging reading experience as they explore the research—an endeavor driven by my curiosity throughout this journey.

PART I
INTRODUCTION TO KNOWLEDGE MANAGEMENT

Organizational effectiveness does not lie in that narrow minded concept called rationality. It lies in the blend of clearheaded logic and powerful intuition.

Henry Mintzberg

Conference on February 12, 2024 at SDA Bocconi School of Management: *A chat with Henry Mintzberg*.

Chapter 1- Foundations of Knowledge Management

Among the many definitions of Knowledge Management (KM), there is one that describes it as the process of identifying, capturing, sharing, and utilizing an organization's collective knowledge to enhance its competitive advantage (Alavi & Leidner, 2001). This definition, like others, captures only one facet of the complex world of KM. However, what does "knowledge management" truly mean? How has it evolved over time? Why should organizations prioritize it, and what should be taken into consideration for its proper implementation? This chapter seeks to address these questions by examining the evidence from existing literature, offering insights into the concept of knowledge management and its significance in organizational contexts.

1.1 Definitions

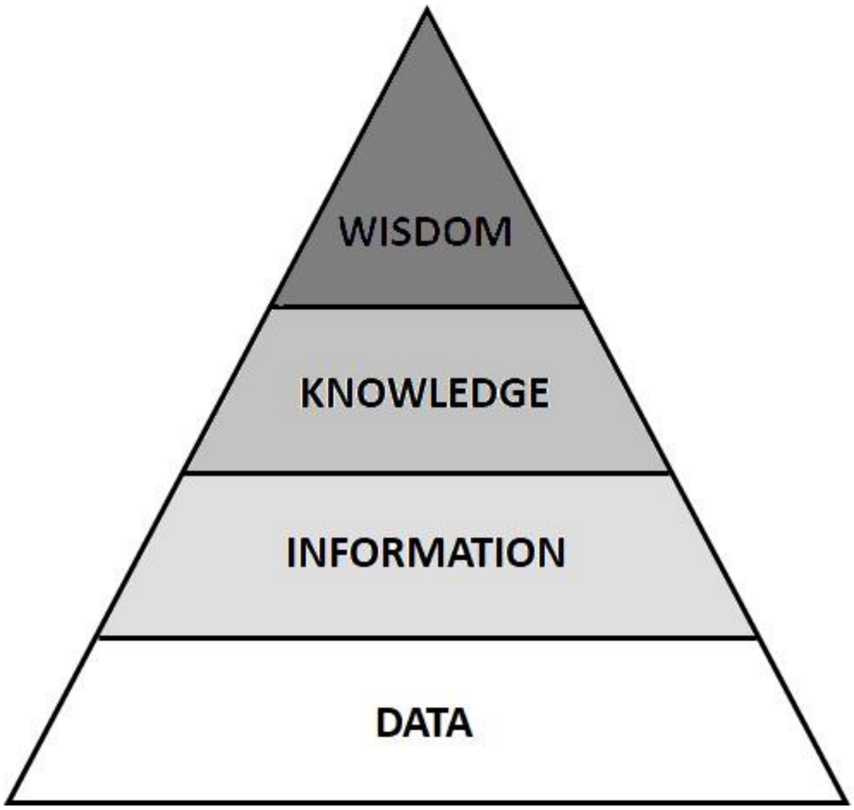
It is essential to clearly differentiate between information and knowledge. Information is structured and understandable data, organized to serve as a useful input for knowledge creation, as mentioned by Child and Hsieh (2014). Knowledge, however, encompasses a broader spectrum of definitions in the literature, each relevant under specific conditions. For instance, Davenport and Prusak (1997) describe knowledge as the highest-value information, making it the most challenging to manage. This value arises because individuals have contemplated the knowledge, infused their own insights, and considered its broader consequences. Similarly, Fahey and Prusak (1998) argue that knowledge does not exist in isolation from the knower; it is influenced by one's needs and pre-existing knowledge base. Therefore, managing information fundamentally differs from managing knowledge.

To this day, despite the remarkable capabilities of artificial intelligence, it is ultimately humans who are entrusted with decision-making. While they can rely on input from advanced information collection and processing systems, it is their own knowledge, value system, and inherent biases that ultimately shape the decisions they make. So, the critical element distinguishing knowledge from information is the human aspect. As Ruggles (1998) pointed out, if people issues do not arise, the initiative is likely not about knowledge management. Information is digital and easily transferable, while true knowledge assets thrive within the intellect of individuals and are integral to an intelligent system. These knowledge assets fundamentally reside within the people of an organization, rather than the organizational structure itself.

Data, information, knowledge, and occasionally a further level identified as intelligence, form a continuum characterized by a progressive increase in quality and value, alongside a reduction in quantity (Ponjuán-Dante, 1998).

A similar concept is represented by Ackoff (1989) in his DIKW pyramid[2], which illustrates the hierarchical relationship between data, information, knowledge, and wisdom.

Figure 3 Ackoff's DIKW pyramid model



[2] Referred to in this thesis as a taxonomy rather than a model.

The development of the DIKW (Data-Information-Knowledge-Wisdom) hierarchy can be traced back to references from poet T. S. Eliot, as well as to the research conducted by Harland Cleveland and systems theorists such as Adler, Zeleny, and, notably, Ackoff (Frické, 2019).

Ackoff (1989) explains that data represent symbols that describe the properties of objects, events, and their environments. These are products of observation, which means they are the result of sensory perception. Therefore, data consist of raw, unprocessed facts that hold little intrinsic value until they are processed or interpreted.

Information is obtained by answering specific questions about the data, such as "who," "what," "where," or "how many" (Ackoff, 1989). For example, individual temperature measurements at various locations in the atmosphere represent data, while the identification of a regional temperature trend, such as the warming of a specific atmospheric layer over time, becomes information, as it requires calculation or inference from the raw data.

Knowledge is often understood as the practical application of information, closely related to the ability to use it effectively, frequently associated with skill or expertise. Ackoff (1989) defines knowledge as what enables the transformation of information into instructions, facilitating the control of systems and their efficient functioning. Knowledge empowers individuals to act on information in a meaningful way.

At the top of the hierarchy is wisdom, that, according to Ackoff (1989), involves the application of judgment to integrate ethical and aesthetic values into decisions, distinguishing it from the lower levels of the hierarchy. Ackoff also stresses that wisdom cannot be fully automated or replicated by machines, as it inherently requires human agency.

An other interesting classification concerning the object and content of knowledge is reported by Scarso and Bolisani (2004), distinguishing between the following types:

- Declarative/Descriptive Knowledge (know-about): This is the ability to recognize and classify concepts, elements, events, situations, and so on. This type of knowledge primarily concerns objects and facts, making it easily explicit (i.e., translated into information) and, consequently, simple to transfer.
- Procedural Knowledge (know-how): These are fundamentally practical skills required to perform specific tasks or complete particular assignments. These skills

often derive from experience accumulated over the years and can be acquired only by observing those who possess them and/or participating in their activities.

- Causal/Rational Knowledge (know-why): This is the ability to understand the causes of events. It mainly refers to "scientific" laws and principles. This knowledge is generally codified and can be transmitted in textual form through formulas, diagrams, figures, and so on.
- Knowledge of Sources (know-who): This is knowing where to find useful information and knowledge on a certain topic. It means being aware of who possesses expertise in a particular field. This type of knowledge concerns not only the content but also, and perhaps more importantly, the quality and reliability of the sources.
- Relational Knowledge (know-with): This involves understanding the relationships between the different types of knowledge mentioned above. In many cases, the production of new knowledge occurs through processes of reworking and recombining available knowledge rather than generating completely new knowledge.

Another important distinction to highlight in this thesis was proposed by Polanyi in his work *The Tacit Dimension* (1966), where he differentiates between tacit and explicit knowledge. Tacit knowledge refers to experiential or practical knowledge that is difficult to formalize and communicate. In contrast, explicit knowledge is objective and rational, codifiable, and expressible through systematic and formal language. Nonaka and Takeuchi (1995) further developed this distinction between tacit and explicit knowledge, proposing a model for the externalization of tacit knowledge and the internalization of shared explicit knowledge within an organization. The model is discussed in more detail in section 3.6.

In the military context, explicit knowledge is commonly defined as information that can be clearly articulated, codified, and stored in various media formats. This includes resources such as Doctrine and Tactics, Techniques, and Procedures (Nohuddin et al., 2010).

To conclude this paragraph, it is essential to emphasize that, nowadays, the creation and diffusion of knowledge are key to competitiveness, with knowledge increasingly being seen as a valuable commodity, integral to high-technology products and the tacit knowledge of mobile employees. However, knowledge possesses paradoxical characteristics distinct from other commodities: it does not deplete upon use, its transfer does not equate to loss, and while abundant, the capacity to utilize it is rare.

1.2 Knowledge as an intangible asset

The value placed on knowledge over traditional physical or tangible assets has increased markedly. In the realm of air power, for instance, the effectiveness of an air force was once primarily assessed by the size and capabilities of its fleet; today, however, its most valuable assets are often advanced intelligence, surveillance, and reconnaissance (ISR) systems. These digital systems gather and analyze vast amounts of data in real time, enabling pilots to make the best possible decisions and enhancing strategic decision-making and mission success. This shift underscores the rising importance of non-physical assets, where knowledge management, data analysis, and digital systems are essential to maximizing operational efficiency and effectiveness in modern air operations.

Similarly, in manufacturing, emphasis has moved toward valuing non-physical assets such as just-in-time (JIT) inventory systems, now recognized for their significant contributions to overall value.

In the tech industry, the expertise and creativity of software engineers, data scientists, and other highly skilled employees are indispensable for innovation and competitive edge. This human capital drives product development, addresses complex challenges, and sustains continuous growth, positioning it as one of the most valuable intangible assets in modern organizations. However, these intangible assets, which include an organization's documented information and human expertise, are often prone to inefficiencies in storage and at risk of being lost, especially in large, geographically dispersed organizations (Stewart, 1991).

In 1994, Drucker posited that knowledge has become the most critical economic resource and the primary source of comparative advantage in the global economy, surpassing traditional factors such as land, labor, capital, and organizational structure. In this context, we live in a knowledge society, characterized by organizations that are predominantly driven by sophisticated management practices and specialized knowledge bases.

Dalkir (2013) highlights that intellectual assets span strategic, tactical, and operational levels within an organization. Intellectual capital encompasses:

- **Competence:** The skills required for high-level performance.
- **Capability:** Strategic skills for integrating and applying competencies.
- **Technologies:** Tools and methods necessary for producing specific outcomes.

The relationship between an organization's vulnerability and the uniqueness and scarcity of certain capabilities among employees is significant; the departure of key employees can pose substantial risks. This complex interplay between competencies, capabilities, and technologies underscores the importance of knowledge management in leveraging intellectual capital for competitive advantage, as explored in business management literature (e.g., Hamel and Prahalad, 1990).

David Teece and his colleagues coined the term "dynamic capabilities" to describe a firm's ability to integrate, develop, and reconfigure both internal and external competencies in response to rapidly changing environments (Teece et al. 1997). These capabilities are crucial for an organization seeking to remain competitive in its industry and are likely also the responsibility of KM.

In 1993, Wiig delineated knowledge management within organizations through three distinct lenses, each offering unique objectives and scopes:

- **Business Perspective:** This angle prioritizes understanding the rationale behind, the areas in which, and the extent to which an organization needs to invest in or leverage knowledge. It suggests that decisions regarding strategies, products, services, partnerships, acquisitions, or divestitures should be evaluated with knowledge as a central factor.
- **Management Perspective:** This viewpoint is concerned with the identification, organization, leadership, facilitation, and supervision of knowledge-centric practices and activities essential for realizing the organization's strategic goals and objectives.
- **Hands-On Perspective:** Concentrates on the practical application of expertise to execute specific knowledge-related tasks and activities.

Given the critical importance and impact of knowledge as a strategic asset within an organization, both at tactical and strategic levels, it is evident that effective knowledge management is essential for maintaining a competitive edge. This holds particularly true in the military sector, where the ability to manage and leverage intellectual assets can significantly influence the outcomes of rival organizations.

1.3 Knowledge Management: evolution of a pragmatic discipline

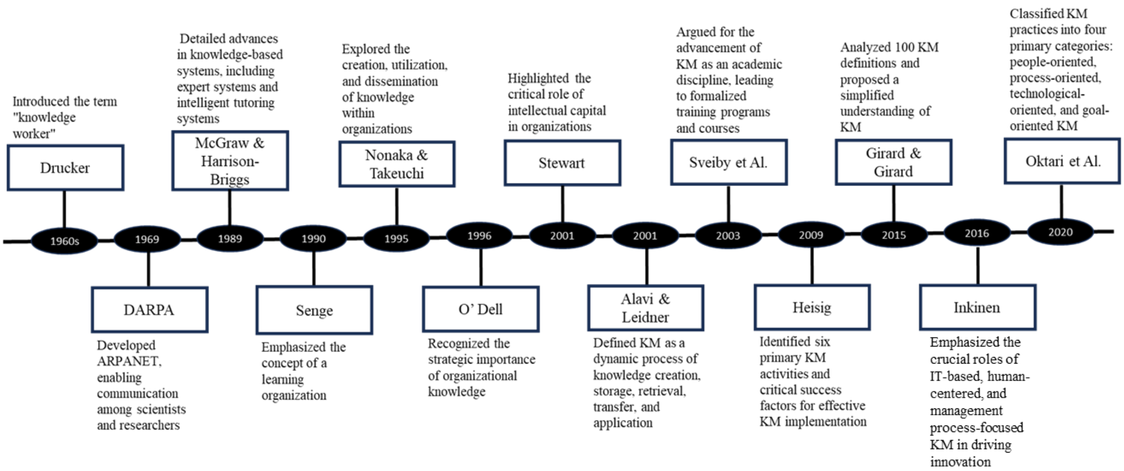
For the purposes of the Chapter 1, it is essential to trace the evolution of KM both as an academic discipline and as a managerial practice, outlining the development that has shaped the most established theories today. Dalkir (2013) addresses this progression in his work, identifying key phases that have expanded KM's scope and complexity.

Beginning with industrialization in the 1800s, the focus transitioned to transportation technologies by 1850, communications by 1900, and then to computerization in the 1950s, leading to the transformative advent of the Internet in 1969. The 1980s marked a shift toward virtualization, with the 2000s focusing on technologies capable of delivering highly personalized services. These stages reflect the growing sophistication and reach of KM practices over time.

KM formally emerged as a recognized scientific field in the early 1990s, notably with Leif Edvinsson’s appointment as the world’s first Chief Knowledge Officer at Skandia in Sweden. Before this milestone, individuals like Hubert Saint-Onge were already exploring KM principles in their work environments. Edvinsson’s role aimed at enhancing the value of organizational intangible assets, signaling a growing interest in both practical and theoretical KM applications, which contributed to the establishment of KM as a distinct research field (Dalkir, 2013).

Figure 4 below highlights the key contributions that have shaped KM’s evolution. In the following section, these contributions will be examined in depth to provide readers with a richer and more comprehensive understanding of the discipline’s development.

Figure 4: Key aspects of the evolution of KM - graphical representation by the author



As can be easily inferred from figure 4, it can be stated that the history of KM reflects its diverse and evolving nature, characterized by several distinct phases.

The term "knowledge worker" was first introduced by Drucker in the early 1960s, setting the stage for future explorations into the role of knowledge in organizational contexts (Drucker, 2018). The inception of ARPANET[3] in 1969 marked a pivotal moment in communication among scientists and researchers, laying the groundwork for the Internet and World Wide Web. Advances in communication technology have enabled virtual simulations of direct knowledge interactions, facilitating the integration and management of an organization's intellectual assets around shared interests, languages, and cooperative goals.

In 1989, McGraw and Harrison-Briggs detailed significant advances in the creation of knowledge-based systems, including expert systems, intelligent tutoring systems, and the application of artificial intelligence to encapsulate expert knowledge. In 1990, Peter Senge further expanded on these ideas by emphasizing the concept of a learning organization capable of leveraging experiences stored in corporate memory systems (Senge, 1990).

Scholars like Ikujiro Nonaka and Hirotaka Takeuchi (1995) further contributed to the KM field in 1995 by exploring the creation, utilization, and dissemination of knowledge within organizations, highlighting its role in fostering innovation. Their work set a foundation for others to build upon.

The strategic importance of organizational knowledge as a competitive asset was recognized by several thinkers, including those involved in a benchmarking study led by APQC's Carla O'Dell (1996). This study identified critical areas of KM, such as its role as a business strategy and the facilitation of innovation and knowledge creation.

In 2001, Thomas A. Stewart underscored the critical role of intellectual capital in organizations through his work in *Fortune* magazine and later in the *Harvard Business Review*, further emphasizing KM's relevance. In the same year, Alavi and Leidner (2001) defined KM as a dynamic process encompassing the creation, storage and retrieval,

[3] ARPANET (an acronym for "Advanced Research Projects Agency Network") was a computer network developed in 1969 by DARPA, the agency of the United States Department of Defense responsible for the development of new military technologies. From this network, the modern Internet began to emerge in 1983.

distribution, and application of knowledge. This view underscores KM's multifaceted nature within organizations, highlighting its role across various functional domains.

In January 2003, at the 24th World Congress on Intellectual Capital Management, prominent figures such as Karl Sveiby, Leif Edvinsson, Debra Amidon, Hubert Saint-Onge, and Verna Allee argued for the advancement of KM as an academic discipline, leading to the establishment of formalized training programs and courses in knowledge management at over a hundred universities worldwide (Petrides and Nodine, 2003).

Heisig (2009) detailed the specific activities most commonly associated with effective KM practices, identifying six primary KM activities: knowledge sharing, creation, application, storage, identification, and acquisition. He also highlighted critical success factors essential for effective KM implementation, including human-oriented factors, organizational processes and structure, technology infrastructure, and management processes.

Girard & Girard (2015) analyzed 100 KM definitions from various sources, proposing a simplified understanding of KM as "the process of creating, sharing, using, and managing the knowledge and information of an organization."

Inkinen (2016) emphasized the multifaceted nature of KM, where IT-based KM, human-oriented KM, and management process-focused KM play crucial roles in innovation and in disseminating organizational knowledge.

This evolution of KM is further contextualized by the progression through different eras, from the industrial age focusing on transportation and communication technologies, to the advent of computerization, virtualization, and the recent emphasis on personalization and profiling technologies, highlighting the dynamic nature of knowledge management throughout history.

With the dawn of the information or computer age, KM has evolved to focus on the systematic optimization of knowledge assets, enabling the preservation and wide dissemination of valuable knowledge through organizational learning and corporate memory systems. This shift parallels the transition from a retail to a personalization model, achieving real-time alignment of user needs and services.

Based on recent studies (Oktari et al., 2020), the practices of Knowledge Management (KM) can be classified into four primary categories:

- **People-oriented KM**: This category emphasizes the human factors in KM, highlighting the critical role of interpersonal interactions and social networks in enabling effective knowledge sharing and collaboration. This approach recognizes the importance of fostering strong relationships and a supportive culture to facilitate the exchange of knowledge.
- **Process-oriented KM**: This aspect focuses on the methodologies and procedures utilized to capture, process, and utilize knowledge within an organization. It involves the systematic management of knowledge flows and the seamless integration of KM into everyday business operations, ensuring that knowledge is efficiently handled and applied.
- **Technological-oriented KM**: This component pertains to the technological tools and systems that underpin KM practices. It encompasses the design and implementation of IT systems that facilitate the storage, retrieval, and dissemination of knowledge, supporting the infrastructure needed for effective knowledge management.
- **Goal-oriented KM**: This approach directly ties KM activities to the strategic goals of the organization. It aims to achieve specific outcomes by leveraging knowledge effectively, ensuring that KM initiatives are aligned with and contribute to the organization's overarching objectives.

Together, these four categories illustrate the multifaceted approach required for successful implementation of KM practices. Each element plays a unique and vital role in enhancing the overall effectiveness of KM strategies within organizations (Oktari et al., 2020).

1.4 Principal aspects of KM in organizations

Nowadays, when considering KM in organizations, it is crucial to adopt a systematic approach focused on enhancing the quality and productivity of knowledge. This involves strategically managing knowledge to optimize its effectiveness and impact, ensuring that organizations can maintain their competitive edge in an increasingly knowledge-driven world.

According to Becerra-Fernandez and Sabherwal (2014) knowledge management can have significant impacts on various areas of an organization. Below are the main areas and specific aspects that can be influenced by KM:

People

- **Employee Learning**: KM facilitates continuous learning for employees, enhancing their ability to acquire new skills and knowledge.
- **Employee Adaptability**: Employees become more adaptable to organizational changes due to constant exposure to new ideas and practices.
- **Employee Job Satisfaction**: KM can increase job satisfaction by improving employees' ability to solve problems and learn effective solutions.

Processes

- **Process Effectiveness**: KM helps the organization select and implement the most appropriate processes, improving operational effectiveness.
- **Process Efficiency**: By effectively managing knowledge, organizations can perform processes more quickly and at lower costs.
- **Process Innovativeness**: KM promotes innovation in organizational processes, allowing for the introduction of creative and improved solutions.

Products

- **Value-added Products**: KM enables the development of new products or the improvement of existing ones, offering significant additional value compared to previous versions.
- **Knowledge-based Products**: In sectors such as consulting and software development, KM is essential for creating products based on in-depth and updated knowledge.

Organizational Performance

- **Direct Impact**: KM can directly influence organizational performance by increasing revenue and reducing costs, aligning the knowledge management strategy with the business strategy.
- **Indirect Impact**: KM can enhance intellectual leadership within the industry, increasing customer loyalty and the organization's competitive position.
- **Economies of Scale and Scope**: KM can help reduce production costs and develop new market opportunities by sharing knowledge and expertise across different business units.
- **Sustainable Competitive Advantage:** KM can provide a sustainable competitive advantage due to the difficulty for competitors to imitate the specific and contextual knowledge developed internally by the organization.

Ferreira et al. (2022) assert that KM is underpinned by three critical elements: processes, technology, and people. Each of these elements plays a pivotal role in the effective management of organizational knowledge.

Processes: This aspect involves the systematic handling of knowledge, which includes its creation, acquisition, sharing, storage, utilization, and protection. Processes are the frameworks through which knowledge flows within the organization and are essential for maintaining the lifecycle of knowledge.

Technology: Technology encompasses the software and hardware resources required to support the KM processes. It provides the necessary tools for storing, retrieving, and sharing knowledge, thereby facilitating seamless knowledge flows across the organization.

People: The human element is central to KM. It includes employees, the organizational culture, and the roles and attitudes of individuals within the company. People are not only users of the KM system but also contribute to its design and operation, ensuring that the KM processes align with organizational needs and culture.

The interplay among these elements is dynamic and cyclical. People use technology to enhance their work efficiency, while technology, in turn, supports people by simplifying and enabling knowledge processes. Furthermore, people are instrumental in designing and operating these processes, which in turn dictate the knowledge roles required by the organization. This cyclical relationship ensures that the technological needs are met, and that technology enhances the capability of the KM processes (Curado et al., 2011; Edwards, 2008). This interconnectedness highlights the synergy necessary among processes, technology, and people for effective knowledge management within organizations.

Young (2010) delineated four distinct levels at which KM can be effectively implemented, each encompassing a progressively broader scope:

Individual Level: at this most granular level, KM focuses on the personal knowledge, capabilities, experiences, competences, and development of individuals. Individuals manage their own knowledge using various tools such as mobile devices, wireless technologies, and web-based applications. This self-directed approach allows employees to enhance their personal expertise and skills in line with their professional needs and career goals.

Team Level: KM at the team level involves collaboration among team members to generate new knowledge and transfer existing knowledge. This is facilitated through models based on sharing or pulling knowledge within the team context. Effective team KM relies on cooperative efforts and the synergistic use of collective knowledge to achieve common objectives.

Organizational Level: This level involves the strategic implementation of KM across an entire organization. It includes the development and deployment of a KM strategy and the provision of necessary infrastructure to support KM processes. Organizational KM is typically driven by a top-down approach, where senior management initiates and guides the KM practices to ensure alignment with the organization's goals.

Inter-Organizational Level: At this level, KM extends beyond the boundaries of the individual organization to include knowledge exchanges with external entities such as co-partners, customers, suppliers, and even competitors. This level of KM leverages external knowledge to enhance competitiveness and innovation.

According to Young (2010), leadership styles and roles are crucial in either facilitating or inhibiting the successful implementation of KM activities across various levels. Subsequently, Al Amiri et al. (2020) systematically reviewed previous quantitative research to evaluate the impact of different leadership styles and roles on KM capabilities within business organizations.

The review found that transformational leadership was the most frequently examined style, with more than half of the studies confirming its strong, positive influence on KM capabilities, particularly in enhancing knowledge sharing. Transformational leadership also positively impacted knowledge acquisition, knowledge transfer, and strategic knowledge variables such as knowledge slack, absorptive capacity, and tacitness, though these were less frequently studied.

Despite these findings, other leadership styles' effects on KM were less documented, with limited studies providing mixed results. The study concluded that transformational, transactional, knowledge-based, top executive, and strategic leadership styles consistently positively influence KM activities to varying degrees. This highlights the importance of effective leadership in fostering robust KM practices within organizations.

Leoni et al. (2022) explore the relationships between Artificial Intelligence (AI), Knowledge Management Processes (KMP), Supply Chain Resilience (SCR), and Manufacturing Firm Performance (MFP), highlighting the critical mediating role of KMP in the relationship between AI and SCR, as well as AI and MFP.

The growing prevalence of AI in KM processes for organizational decision-making is widely recognized by scholars, including Leoni et al. (2024). AI is increasingly used to enhance decision-making accuracy and efficiency by processing large datasets and providing actionable insights. However, its successful implementation depends on overcoming challenges related to human-AI interaction, adoption barriers, and business strategy impact.

AI reliance influences decision accuracy; both over-reliance and under-reliance can lead to errors. Cognitive models help understand human-AI collaboration to improve decision-making. Social, regulatory, and ethical challenges affect trust and transparency, requiring strategies to address resistance. AI enhances efficiency, innovation, and performance, but concerns like data privacy and human oversight must be managed to ensure responsible adoption. While AI transforms decision-making, balancing technological advancements with human oversight and ethical considerations is crucial for effective and responsible integration (Leoni et al. 2024).

1.5 Conclusions

This chapter established a foundational understanding of knowledge and its distinction from information, emphasizing the role of human interpretation and contextualization in knowledge creation. The DIKW hierarchy (Ackoff, 1989) illustrates how data transforms into information, then knowledge, and ultimately wisdom, where ethical and strategic considerations influence decision-making. By defining KM principles, knowledge classifications (Scarso & Bolisani, 2004), and tacit vs. explicit knowledge (Polanyi, 1966), the chapter aligns with the research objective of identifying key aspects of KM for the IAF and establishing a theoretical framework for its application. Additionally, it highlights knowledge as a strategic asset, surpassing traditional physical resources in value, with direct implications for decision-making, innovation, and operational efficiency in military, manufacturing, and technology sectors. The chapter also traces KM’s evolution as a discipline, from its industrial roots to people-, process-, technology-, and goal-oriented KM approaches (Young, 2010), emphasizing the need for a structured yet adaptable framework. The role of Artificial Intelligence (AI) in KM is explored, stressing the importance of balancing technological advancements with human oversight (Leoni et al., 2024). Ultimately, this chapter provides a conceptual foundation for the subsequent analysis of KM models, processes, and frameworks, supporting the development of tailored KM solutions for the IAF.

Chapter 2 - Key KM Processes

According to a document of MIT (https://web.mit.edu/ecom/www/Project98/G4/Sections/section1b.html[4]) *"The primary role of KM is to connect to "knowledge nodes" both the knowledge providers and the knowledge seekers. The knowledge of the mind of one provider may thus be ultimately transferred to the mind of someone who seeks that knowledge, so that a new decision can be made or situation handled. KM provides a means of capturing and storing knowledge and brokering it to the appropriate individual"*

In this chapter and its paragraphs, it is described what the literature considers to be the main KM processes. In particular:

1. **Knowledge Creation (KC)**: The ability to develop new and useful ideas. It can be achieved through internal research, external benchmarking, and collaborative efforts. KC is promoted by employee skills and intellectual agility.
2. **Knowledge Acquisition (KA)**: The process of obtaining knowledge from external sources such as customers, suppliers, and competitors. KA is crucial for organizational innovation.
3. **Knowledge Storage/retrieval (KSTR)**: Archiving and structuring data to build an organizational memory, which is essential for preserving valuable knowledge assets.
4. **Knowledge Transfer (KT)**: Consists of a period, of varying length, during which experts impart key skills to integrate the "newcomers" into a project or a job.
5. **Knowledge Sharing (KS)**: The share of knowledge among individuals and groups, facilitated by trust and social interactions within the organization.
6. **Knowledge Application (KAP)**: Applying knowledge to practical actions, which involves integrating new knowledge into business processes to improve performance.

2.1 Knowledge creation

Nonaka and Toyama (2002) described knowledge creation as a dialectical process, synthesizing various contradictions through dynamic interactions among individuals, organizations and the environment, in other words, they describe KC as a dynamic process that involves transforming individual knowledge into accessible organizational assets.

[4] Accessed on September 20, 2024.

Digitally supported communication plays a key role by providing a space to consider multiple viewpoints, construct and share beliefs, and express new ideas (Alavi & Leidner 2001).

KC involves an organization's ability to develop new and useful ideas and solutions across various domains, including products, technological processes, and management practices (Andreeva & Kianto, 2011; Nonaka & Takeuchi, 1995). This process entails making individual-created knowledge accessible by amplifying it in social contexts and connecting it with existing organizational knowledge (Nonaka & von Krogh, 2009). Organizations can generate knowledge through internal research and development or by leveraging external sources like benchmarking, networks, imitation practices, and outsourcing (Lyles, 2014; Zaim, 2006). Human resource practices play a crucial role in fostering KC (Collins, 2000).

Kimmerle et al. (2010) examined how interactions via social media platforms within organizations can lead to new knowledge. They highlighted the crucial exchange between the collective knowledge enabled by shared digital artifacts and the cognitive systems of individuals as foundational for developing new knowledge. Sumbal et al. (2017) explored how big data facilitates knowledge creation, showing that knowledge emerges from merging predictive analytics with individuals' tacit knowledge, which includes their insights and opinions critical to decision-making processes.

KC can occur deliberately through structured methods and clear objectives or spontaneously through "enlightened moments" that introduce new ideas into the existing knowledge base (Brix, 2014; Kao et al., 2011). Once new knowledge is recognized, it can be codified and developed, making it more structured and less uncertain (von Krogh et al., 2012; Brix, 2017).

Moreover, KC can manifest in various forms: it may occur through the synthesis of existing knowledge, the transformation of tacit knowledge into explicit forms (such as formalizing practices), or the conversion of explicit knowledge into tacit knowledge, exemplified by individuals internalizing information from written sources (Nonaka, 1994).

2.2 Knowledge acquisition

KA involves obtaining knowledge from external sources, such as following market trends or addressing customer issues (Monteiro, 2016). It encompasses the appropriation of knowledge from outside the organization, including insights from customers, suppliers, and competitors (Andreeva & Kianto, 2011). KA is not just about gaining access to external knowledge but about strategically leveraging this knowledge to achieve competitive advantage and drive organizational growth.

According to Ferreira et al. (2022), KA is a critical organizational process through which knowledge is gathered from various sources.

Empirical research suggests that KA is strongly associated with positive organizational outcomes, particularly in fostering innovation (Andreeva & Kianto, 2011; Monteiro, 2016). By effectively acquiring and utilizing external knowledge, organizations can enhance their innovativeness, adapt more swiftly to changes in the market, and address customer problems more effectively.

2.3 Knowledge storage/retrieval

While organizations generate knowledge, they also maintain an "organizational memory" which can both store and "forget" knowledge, as highlighted by Argote et al. (1990).

The concepts of storing and retrieving knowledge, or organizational memory, were further defined by Walsh and Ungson (1991) as central components of effective knowledge management (KM), according to Alavi and Leidner (2001). Stein and Zwass (1995: 85) describe organizational memory as "the means by which knowledge from the past, experience, and events influence present organizational activities."

Knowledge storage involves archiving and structuring data and information to conserve knowledge systematically (Donate & Sánchez de Pablo, 2015). This practice ensures that knowledge is selectively stored in well-indexed and interconnected repositories, allowing organizations to build valuable knowledge assets over time (Ranjbarfard et al., 2014).

The stored knowledge forms an organizational memory, which can be captured in various formats such as written documents, electronic databases, coding systems, organizational processes, and the minds of individuals (Andreeva & Kianto, 2011). Without accessible and adequately managed storage, organizations risk losing their innovation capability, creativity, and competitive advantage (Andreeva & Kianto, 2011). This diverse repository ensures that critical information is preserved and can be accessed when needed, supporting ongoing organizational functions and strategic initiatives.

However, if knowledge is not stored effectively or if the storage systems do not allow easy access, the organization could suffer from diminished innovation capacity, creativity, and competitive advantage. Thus, the type of knowledge storage employed is not merely about retention but about enhancing the utility and accessibility of information, which in turn supports the organization's overall performance and adaptability in a competitive landscape. (Andreeva & Kianto 2011)

Content management now plays a critical role in organizing and describing content to ensure it is discoverable, accessible, and usable. Key aspects include the use of metadata, content structuring, content management systems, and the development of knowledge taxonomies. The guiding principle is that knowledge must be actively utilized for the benefit of individuals and the organization, emphasizing "taxonomy before technology" (Kohenig, 2002) to ensure effective knowledge application.

Furthermore, lessons learned are often stored in varied formats across different systems, making them hard to locate and reuse due to poor organization (Wan et al. 2018).

2.4 Knowledge transfer

Given its distributed nature, knowledge often needs to be moved to a new location before it can be applied effectively, a process described by Alavi and Leidner (2001). The success of knowledge transfer hinges on several factors, including the motivational disposition of both the sender and the receiver—specifically, their willingness to share and acquire knowledge, respectively—as well as the availability of effective transmission channels, as identified by Gupta and Govindarajan (2000). Knowledge transfer can occur across various levels, including individual, group, and organizational levels. Communication channels that support this transfer include formal methods such as training sessions, informal interactions like coffee-break conversations, personal approaches such as apprenticeships, and impersonal means like knowledge repositories, further detailed by Alavi and Leidner (2001). The effectiveness of these transfer mechanisms also varies depending on the type of knowledge being transferred and the entities involved[5], as noted by Inkpen and Dinur (1998).

From the studies by Andreasian & Andreasian (2013), it emerges that KT focuses on the acquisition and effective absorption of knowledge to enhance operational efficiency and

[5] E.g. Communities of Practice or On the job training

effectiveness. This differentiates it from Knowledge Sharing (KS), which instead aims at the dissemination of knowledge among individuals or teams, promoting mutual learning and skill improvement through spontaneous sharing.

This process is particularly important when there is a need to transfer know-how from an experienced professional to a newcomer entering the profession.

2.5 Knowledge sharing

KS occurs when individuals exchange or acquire knowledge, either within an organization or between different organizations (Chen & Hung 2010).

KS involves the distribution of stored knowledge among individuals, groups, and organizations in various ways (Wang & Ko, 2012; Navimipour & Charband, 2016). It is a strategically important process that enables access to necessary knowledge for improving performance (Wang & Ko, 2012). KS facilitates knowledge exchange, allowing recipients to apply or adapt it in new contexts. Its success relies on the values, interests, and motivations of employees.

Environments with high levels of trust, social interaction, proximity, and frequent communication enhance KS and the flow of intangible and cognitive resources (Wee & Chua, 2013). Fundamentally, KS is based on the belief that knowledge should continuously circulate within the organization, fostering interactions that enable its accumulation, reuse, and recombination.

Organizational culture comprises a framework of norms and values that influence how employees interpret and understand their environment, as outlined by Zheng, Yang, and Mclean (2010). Additionally, several scholars, including Mojibi, Hosseinzadeh, and Khojasteh (2017), emphasize the significance of fostering a culture that actively supports and values knowledge sharing.

Alternative methods, including video, virtual reality, augmented reality, and sensor technology, are being explored to more effectively capture and convey embedded knowledge. De Carvalho et al. (2018) and Hoffmann et al. (2019) recommend leveraging cyber-physical system technology to document and integrate embodied knowledge with formal content, facilitating its comprehension and sharing in industrial environments.

2.6 Knowledge application

Knowledge application involves utilizing knowledge to gain a competitive edge by enhancing organizational capabilities. In the literature, the application of knowledge is often intertwined with other knowledge management processes rather than being the sole focus of investigation. Specifically, it is frequently linked with knowledge storage, facilitating access to necessary knowledge, and with knowledge sharing, which broadens individual networks and fosters collaboration. This integration helps in applying organizational knowledge effectively across various contexts and over time.

Grant (1996) emphasizes that effective knowledge application within an organization typically requires clear directives, such as established rules and procedures, which are supported by well-defined routines. These routines, developed from coordination patterns and protocols, serve as crucial mechanisms for applying knowledge. They enable individuals to integrate and utilize their knowledge efficiently without necessarily having to communicate this knowledge explicitly to others, as noted by Alavi and Leidner (2001). Essentially, without a systematic approach to apply knowledge, merely possessing it provides little to no value to the organization. This underscores the importance of structured processes in leveraging the full potential of knowledge within a firm.

2.7 Conclusions

This chapter has provided a comprehensive analysis of the key Knowledge Management processes, laying the groundwork for understanding how knowledge is created, acquired, stored, transferred, shared, and applied within organizations. By exploring these fundamental processes, the chapter contributes directly to the research objectives by:

Defining the Core Components of KM – The six processes outlined—Knowledge Creation (KC), Knowledge Acquisition (KA), Knowledge Storage/Retrieval (KSTR), Knowledge Transfer (KT), Knowledge Sharing (KS), and Knowledge Application (KAP)—offer a structured framework for examining KM in organizational settings, including the IAF. This directly addresses the research question concerning the most relevant aspects of KM for organizations.

In conclusion, this chapter provides the theoretical foundations for KM implementation by examining key processes essential for developing a tailored KM model for the IAF, bridging theory and application through real-world challenges and practical insights. These foundational principles will guide the evaluation of current KM practices within the IAF and support the design of innovative KM frameworks adapted to the complexity of military operations.

Chapter 3 - Key Theoretical Models

A KM model could be considered as a cycle that systematically includes one or more processes of creation, acquisition, storage, sharing, transfer, retrieval, and utilization of both explicit and implicit forms of knowledge at individual, group, organizational, and community levels. This cycle leverages people, processes, and technology to enhance organizational performance and create value (Davenport & Prusak, 1997; Alavi & Leidner, 2001; Rašula et al., 2012).

A KM model typically uses visual representations of processes (often complex), eliminates ambiguity in managing organizational knowledge, introduces order into knowledge management, and systematizes the KM process.

Many KM models are discussed in the literature. Based on two authoritative texts on KM (De Toni & Fornasier, 2012 and Dalkir, 2013), it is possible to identify criteria that a KM model should satisfy:

- Implemented and validated in real-world contexts.
- Comprehensive regarding the various types of stages found in KM literature.
- Detailed descriptions of the KM processes involved in each stage.

Based on the aforementioned criteria and a literature review, the most recognized models in the literature to date (De Toni & Fornasier, 2012; Mohajan, 2016; Ahmadani et al., 2023; Dalkir, 2023) are as follows:

- Meyer and Zack KM Cycle model
- Bukowitz and Williams KM Cycle
- Wiig KM Cycle
- Boisot's I-Space Model
- ICAS Model
- SECI Model

3.1 Meyer and Zack model

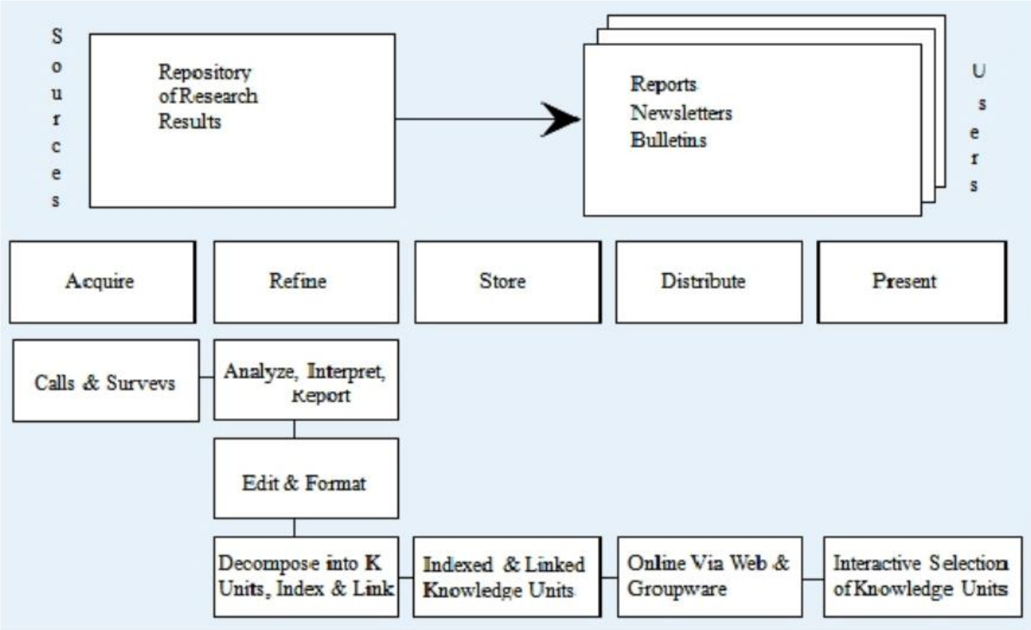
The Meyer and Zack model, developed in 1996, is one of the most comprehensive descriptions of the key elements involved in knowledge management. This approach, based on the design and development of information products, applies the principles of physical product management to knowledge assets. The model places greater emphasis on the distribution of knowledge, primarily through technological means, rather than merely collecting or aggregating content.

The Meyer and Zack KM Cycle model includes both knowledge content and information, envisioning the circulation of information both internally and externally, in electronic or printed format.

The model includes five steps, which are outlined below (Dalkir, 2013):

1. **Data or Information Acquisition**: This phase refers to the collection of information and the quality control of data. The data source must be of high quality to maintain integrity throughout the lifecycle. Acquisition involves aspects such as the origin of raw materials, scope, depth, credibility, accuracy, timeliness, relevance, cost, control, and exclusivity.
2. **Refinement**: Refinement involves adding value, reorganizing, labeling, and indexing. This phase is the main source of added value, both in physical form (translating information across various media) and in logical form (restructuring, labeling, indexing, and integration). Refinement standardizes primary data by removing irrelevant materials.
3. **Storage/Retrieval**: Storage is a vital phase because it links the first two phases (acquisition and refinement) that feed the repository to the subsequent product generation phases. Storage can be either physical (printed documents) or digital (databases, knowledge management software).
4. **Distribution**: Distribution involves delivering information to users through various media (print, phone, radio, television, email, fax, letters), considering not only the delivery medium but also its timing, frequency, form, language, etc. This phase highlights the interrelationship between medium and content. The process delivers the product to end users.
5. **Presentation**: This is the cumulative effect of each phase of the model. It establishes the value of information through its usage context. If it succeeds in creating value, the KM cycle model has been successful; otherwise, it has failed to provide value to the individual and the organization.

Figure 5: Diagram[6] of the Meyer and Zack model



3.2 Bukowitz and Williams Model

Bukowitz and Williams (2000) present a KM framework that outlines how organizations can generate, maintain, and utilize a strategically aligned stock of knowledge to create value. The Bukowitz and Williams KM model is designed to help organizations manage their knowledge processes to achieve strategic goals.

In their book "The Knowledge Management Fieldbook" (2000), Bukowitz and Williams provide a practical guide for organizations in the knowledge management process, presenting the KM cycle divided into seven phases: Get, Use, Learn, Contribute, Assess, Build/Sustain, and Divest.

- **Get**: This phase emphasizes the collection of knowledge from various sources, both internal and external to the organization. The challenge is not merely finding information but effectively managing the vast volume of available information, identifying valuable knowledge, and managing it efficiently.
- **Use**: After acquiring knowledge, the use phase applies the acquired knowledge to maximize organizational performance. The focus is primarily on individuals and groups, encouraging creativity and out-of-the-box thinking.

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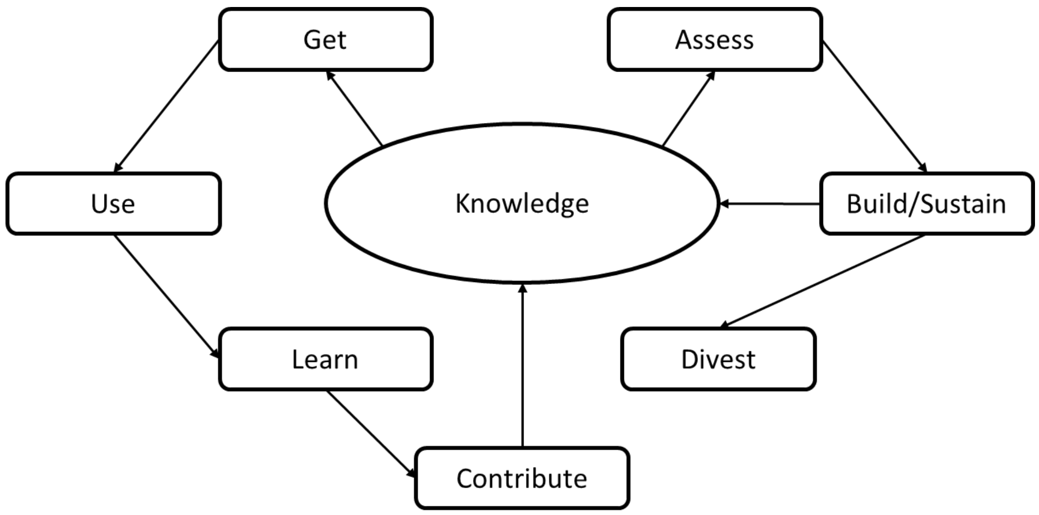
[6] Source: https://www.researchgate.net/figure/Cycle-of-Meyer-and-Zack-1996-see-online-version-for-colours_fig1_333106083

- **Learn**: This phase involves understanding and learning from the acquired knowledge. It may include formal or informal training and learning, as well as knowledge sharing through communities of practice or social networks. An organizational memory is created, allowing for organizational learning from both successes (best practices) and failures (lessons learned).
- **Contribute**: This phase focuses on sharing the acquired knowledge from individuals or teams with other members of the organization, making individual knowledge visible and available to the entire organization.
- **Assess**: In this phase, an evaluation is conducted to determine the relevance and effectiveness of existing knowledge. This process includes identifying relevant and useful knowledge, as well as knowledge that might be obsolete or irrelevant. It also includes identifying new forms of capital such as human capital, customer capital, and organizational capital.
- **Build/Sustain**: This phase focuses on building and maintaining the infrastructure and culture that support knowledge management. It ensures that the organization's future intellectual capital will keep the company competitive. Resources must be allocated for the growth and maintenance of knowledge, creating new knowledge and strengthening existing knowledge.
- **Divest**: Finally, the divest phase involves the removal or ignoring of knowledge that is no longer relevant or useful to the organization. Some knowledge may be more valuable if transferred outside the organization. This strategic decision-making process involves analyzing the opportunity cost of maintaining certain parts of knowledge.

Figure 6: Diagram of the Bukowitz and Williams model



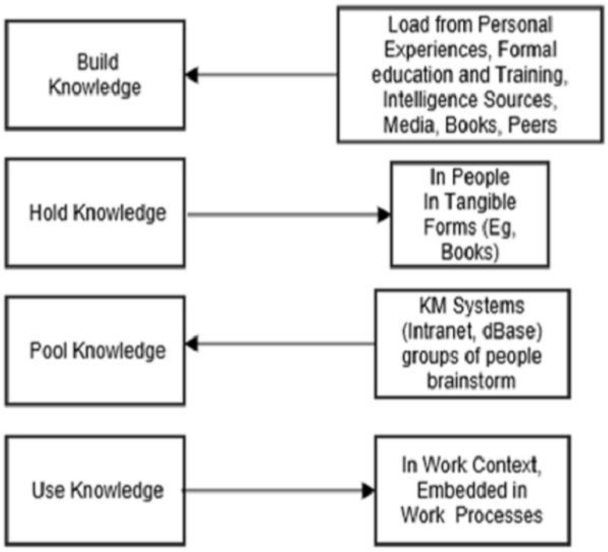
3.3 Wiig's model

The KM model developed by Karl M. Wiig (1993) was designed to describe a series of phases in knowledge management. The purpose of this model is to ensure that knowledge management within an organization can be carried out effectively and sustainably. The Wiig KM cycle consists of four main steps, which, although presented in sequence, often occur in parallel or with iterations for refinement:

1. **Build Knowledge**: This encompasses a wide range of activities aimed at acquiring and improving knowledge, including market research, competitive intelligence, and data analysis. Key activities in this phase include obtaining, analyzing, reconstructing, codifying, and organizing knowledge. This process facilitates the generation of new knowledge through various means, such as R&D, hiring new talent, and observing real-world applications.
2. **Hold Knowledge**: This step involves preserving and managing knowledge in both individuals and organizational repositories. Methods include incorporating knowledge into business procedures, creating databases for easy retrieval, and archiving obsolete or irrelevant knowledge. Companies maintain knowledge in various forms, including intellectual property rights, documented reports, and tacit knowledge that can be captured and shared.
3. **Pool Knowledge**: Coordinating, assembling, and accessing knowledge are key components here. By forming collaborative teams and establishing a network of "who knows what," organizations can simplify knowledge access and retrieval. This pooling is crucial for consulting experts, obtaining second opinions, and discussing complex cases among peers.
4. **Apply Knowledge**: The final step involves the practical use of knowledge in various contexts, from routine tasks to solving unique problems. Application strategies can include using established knowledge for standard operations, analyzing and synthesizing solutions for complex problems, and deciding on and implementing chosen alternatives.

Wiig's cycle also details the processes of analysis, synthesis, and codification of knowledge, emphasizing the transformation of knowledge into applicable formats that can be readily used throughout the organization. This approach not only facilitates individual and organizational learning but also ensures that knowledge effectively contributes to the organization's objectives.

Figure 7: Diagram[7] of the Wiig's model



3.4 Boisot's I-Space KM model

Boisot's KM model revolves around the key concept of an "information good," distinguishing it from a physical good. Boisot differentiates between information and data, emphasizing that information is what an observer extracts from data based on their expectations or prior knowledge. The effective movement of information goods heavily depends on whether senders and receivers share the same coding scheme or language. A "knowledge good" is a concept that also includes a context within which it can be interpreted. Effective knowledge sharing requires that both the sender and receiver share the context and the coding scheme.

Boisot (1998) proposes two key points:

1. The easier it is to structure data and convert it into information, the more diffusible it becomes.
2. The less structured data requires a shared context for its dissemination, the more diffusible it becomes.

Together, these points support a simple conceptual framework, the information space or I-Space KM model. Data is structured and understood through the processes of codification and abstraction. Codification refers to creating content categories: the fewer the categories,

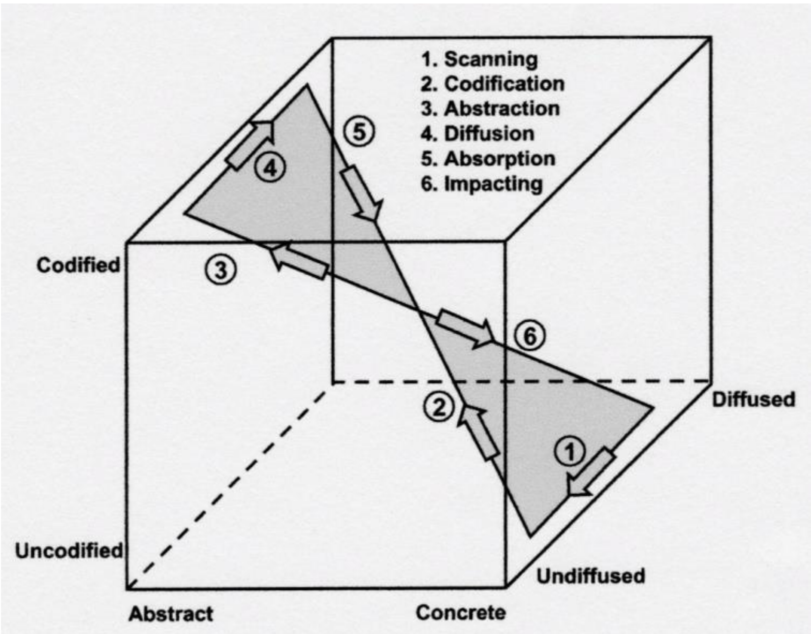
[7] Source: https://coderlessons.com/tutorials/upravlenie/nauchitsia-upravleniiu-znaniiami/modeli-km-tsikl

the more abstract the coding scheme. The assumption is that well-codified and abstract content is much easier to understand and apply compared to highly contextualized content. Boisot's KM model also addresses tacit knowledge, noting that in many situations, the loss of context due to codification can result in the loss of valuable content. This content requires a shared context for interpretation, implying face-to-face interaction and spatial proximity.

The I-Space model can be visualized as a three-dimensional cube with the following dimensions:

- Codified - Uncodified
- Abstract - Concrete
- Diffused – Undiffused

Figure 8: Graphical representation[8] of Boisot's I-Space KM model



The activities of codifying, abstracting, diffusing, absorbing, impacting, and scanning all contribute to learning. When they occur in sequence, they collectively constitute the six phases of a social learning cycle (SLC) in the model:

[8] Source: https://www.researchgate.net/figure/Figura-7-O-modelo-de-Gestao-do-Conhecimento-I-Space-de-Boisot_fig1_320720372

1. **Scanning**: Identifying threats and opportunities in generally available but often unclear content. Scanning for patterns as unique or idiosyncratic insights that then become the property of individuals or small groups. Scanning can be very rapid when data is well-codified and abstract, and very slow and random when data is uncodified and context-specific.
2. **Codification**: Structuring and cohering those insights, i.e., codifying them. In this phase, they take on a defined form, and much of the initial uncertainty associated with them is eliminated. Problem-solving initiated in the uncodified region of I-Space is often risky and contentious.
3. **Abstraction**: Generalizing the application of the newly codified insights to a broader range of situations, reducing them to their essential characteristics, i.e., conceptualizing them. Problem-solving and abstracting often work in tandem.
4. **Diffusion**: Sharing the newly created insights with a target population. The diffusion of well-codified and abstract content to a large population is technically less problematic compared to uncodified and context-specific content. Only shared context between sender and receiver can speed up the diffusion of uncodified data.
5. **Absorption**: Applying the newly codified insights to various situations in a "learning by doing" or "learning by using" manner. Over time, these codified insights acquire a halo of uncodified knowledge that helps guide their application in particular circumstances.
6. **Impacting**: Incorporating abstract knowledge into concrete practices. Incorporation can occur in artifacts, technical or organizational rules, or behavioral practices. Absorption and impacting often work in tandem.

3.5 ICAS KM model

The Intelligent Complex Adaptive Systems (ICAS) theory of knowledge management views the organization as a living complex system. Bennet and Bennet (2004) strongly believe that traditional bureaucracies or popular matrix and flat organizations are insufficient to provide the cohesion, complexity, and selective pressures that ensure an organization's survival. They propose a model in which the organization is seen as a system in a symbiotic relationship with its environment, in other words, as a complex adaptive system (De Toni & Fornasier, 2012). Complex adaptive systems are organizations composed of a large number of self-organizing components, each seeking to maximize its specific objectives while operating according to the rules and context of relationships with other components and the external world.

In this model, the intelligent components consist of people who are authorized to self-organize, but who remain part of the overall corporate hierarchy. The challenge is to leverage people's strengths by ensuring they collaborate to utilize knowledge and maintain a sense of unified purpose (Dalkir, 2023). Organizations take inputs from the environment, transform these inputs into higher-value outputs, and deliver them to customers and stakeholders. Organizational intelligence becomes a form of competitive intelligence that helps facilitate innovation, learning, adaptation, and rapid responses to unforeseen situations. From this perspective, knowledge becomes a valuable resource because it is essential for taking effective actions in a variety of uncertain situations.

The five key processes in the ICAS KM model can be summarized as:

1. Understanding
2. Generating New Ideas
3. Problem Solving
4. Decision Making
5. Actions to Achieve Desired Outcomes

Since only individuals can make decisions and take action, this model emphasizes the individual knowledge worker and their competence, capability, learning, etc. These are leveraged through multiple networks (e.g., communities of practice) to make available the knowledge, experience, and insights of others. This type of tacit knowledge, exploited through dynamic networks, creates a broader "highway" for connecting data, information, and people through virtual communities and knowledge repositories.

To survive and compete successfully, an organization will also require eight emergent characteristics:

1. Organizational Intelligence
2. Shared Purpose
3. Selectivity
4. Optimal Complexity
5. Permeable Boundaries
6. Knowledge Centrality

7. Flow
8. Multidimensionality

An emergent characteristic is the result of non-linear interactions, synergistic interactions, and self-organizing systems (De Toni & De Zan, 2015). The ICAS KM model follows the lines of other approaches as it is connectionist and holistic in nature. The emergent characteristics of ICAS are outlined in the following figure. These emergent properties equip the organization with the internal capability to face future unforeseen environments.

3.6 SECI Model

The SECI model, proposed by Ikujiro Nonaka and Hirotaka Takeuchi, is one of the most well-known knowledge management models. SECI stands for the four phases of the knowledge management cycle: Socialization, Externalization, Combination, and Internalization. This model can be applied in organizations to improve knowledge management. The phases are detailed as follows:

1. **Socialization**: In this phase, tacit knowledge, which is based on personal experience, is shared among individuals. This can occur through discussions, storytelling, shared experiences, or direct observation.
2. **Externalization**: This process converts tacit knowledge into explicit knowledge. Explicit knowledge can be written, shared, and understood by others. Examples include writing work procedures, creating flowcharts, or documenting processes.
3. **Combination**: This phase involves combining various elements of explicit knowledge to create new knowledge. For instance, merging data from different sources to create a new report or combining various studies to form a new theory.
4. **Internalization**: In this phase, explicit knowledge is reconverted into tacit knowledge by individuals. An example is learning from a book or documentation and then applying it in the workplace, making it part of an individual's tacit knowledge.

The SECI model emphasizes a continuous cycle between tacit and explicit knowledge, allowing knowledge to grow and develop within organizations. It is important for the organization to ensure that the principles in line with the organization are truly integrated and well understood.

An essential concept in facilitating Knowledge Creation (KC) is "Ba," described by Nonaka et al. (2000) as a "place" or "enabling context" that provides the necessary physical setting for creation. Nonaka and colleagues identify four types of Ba, created through combinations of two types of interaction—individual or collective—and two modes of interaction—face-to-face or virtual. These environments support the transformation processes of tacit and explicit knowledge, enhancing the dynamics of the knowledge creation spiral.

Nonaka et al. (2000) categorize knowledge assets into four distinct groups:

1. **Experiential**: Includes tacit knowledge shared through common experiences.
2. **Conceptual**: Where knowledge is articulated through images, symbols, and language.
3. **Systemic**: Consists of systematized, organized, and standardized knowledge documented in formats such as manuals, databases, and specifications.
4. **Routine**: Encompasses tacit knowledge that has become integrated into organizational actions and practices.

By integrating the concepts of Ba, the SECI model, and knowledge assets, Nonaka and colleagues present a comprehensive model illustrating how these elements collectively foster a dynamic process through which organizations create, maintain, and utilize knowledge.

3.7 Limitations and Challenges of Applying KM Models to the IAF

Despite their theoretical robustness, the direct application of these KM models within the Italian Air Force presents several challenges:

1. Limited Adaptation to Military-Specific Needs

- These models were not explicitly designed for military organizations, which operate under strict hierarchies, security constraints, and mission-critical objectives that differ significantly from commercial or academic environments.
- Military knowledge is often highly sensitive, requiring secure, restricted, and controlled access mechanisms.
- To be effectively applied, these models would need customization to align with the IAF’s command structure, operational workflows, and classified knowledge-sharing protocols.

2. Dependence on Technology and Infrastructure Constraints

- Most KM models assume the availability of digital platforms, databases, and automated tools, which may not always be accessible in operational environments, combat zones, or remote deployments.
- A high reliance on digital systems increases vulnerability to cyber threats, data breaches, and system failures, making cybersecurity a critical issue.
- The IAF must ensure that KM solutions are resilient, secure, and adaptable, even in highly constrained or compromised environments.

3. Sustainability and Resource Constraints

- Effective KM implementation requires continuous updates, dedicated personnel, and long-term financial investment, all of which must be carefully assessed against the IAF's available resources.
- If not properly maintained, KM initiatives risk becoming outdated and ineffective, leading to fragmentation, redundancies, and a loss of institutional knowledge.

4. Balancing Standardization and Flexibility

- While structured KM frameworks provide consistency and reliability, military operations require adaptability and responsiveness to unpredictable situations.
- A rigid KM system may hinder real-time decision-making and knowledge accessibility in dynamic operational contexts.
- The IAF's KM approach must find a balance between standardized knowledge management processes and flexible, mission-driven knowledge-sharing mechanisms.

3.8 Conclusions

Chapter 3 has provided a non-exhaustive analysis of the most frequently cited Knowledge Management (KM) models in the academic literature. The selection of models was based on key criteria identified by authoritative sources (De Toni & Fornasier, 2012; Dalkir, 2013).

Among the models reviewed in this chapter are:

- Meyer and Zack KM Cycle
- Bukowitz and Williams KM Cycle

- Wiig KM Cycle
- Boisot's I-Space Model
- ICAS Model
- SECI Model

While these models provide valuable theoretical foundations, they do not offer practical guidance on selecting specific tools and methodologies based on the challenges encountered in knowledge management processes. This limitation is particularly significant in the military sector, where secure, structured, and efficient knowledge-sharing mechanisms are essential for operational effectiveness.

The following table highlights the strengths and weaknesses of each model in relation to its applicability within the IAF context.

Table 1: Comparison between KM models

Model	Strengths	Weaknesses
Meyer and Zack	- Focus on value-added processes - Effective in managing product evolution - Clear distinction between knowledge management and document management - Can be linked to the Lesson Learned (LL) process	- Limited applicability in operational units - Requires ongoing maintenance and repository updates - Primarily focuses on information management, with no clear guidance on tacit knowledge management - More aligned with Information Management than KM in a broader sense
Bukowitz and Williams	- Integrates both tacit and explicit knowledge - Strong emphasis on learning and evaluation - Holistic approach to knowledge management - Encourages innovation and proactive knowledge acquisition - Supports Lesson Learned (LL) acquisition	- Requires a strong organizational culture of knowledge sharing - Not designed for operational contexts - Primarily business-oriented, focusing on corporate competitiveness
Wiig	- Detailed articulation of organizational memory - Strong emphasis on continuous knowledge creation - Incorporates learning processes	- Requires strong cultural support for implementation - Does not provide specific guidance on tool selection
Boisot I-Space	- Emphasizes social learning - Establishes a connection between content management and knowledge management	- Complex to understand and implement - Less widely tested and known compared to other models
ICAS	- Holistic and adaptive approach - Strong focus on organizational intelligence and self-organization - Enhances innovation and adaptability	- Complexity in managing non-linear interactions - Requires a strong organizational culture and adaptive leadership
SECI	- Effectively captures the dynamics between tacit and explicit knowledge	- Strongly oriented toward knowledge creation and innovation, rather than operational efficiency

Model	Strengths	Weaknesses
	- Emphasizes socialization and interaction - Well-structured and widely recognized model	- Does not provide practical tools for implementation - Not suited for operational contexts - Overlooks aspects related to information management

This consideration serves as a starting point for the next stages of this research. The following sections of the thesis will delve into both conceptual and practical aspects of KM that may be more relevant to the IAF's specific organizational context. Moreover, the analysis of the models discussed in this chapter will be further developed in Part IV of this thesis, particularly in Chapter 12 – "Beyond the Gaps: Rethinking Knowledge Management for the Italian Air Force." This final discussion will integrate insights from the literature reviews in Part II and the case studies presented in Part III, ultimately paving the way for a KM approach better aligned with the needs and challenges of the IAF.

PART II

SYSTEMATIC REVIEWS

Non si può parlare di Knowledge Management senza parlare di apprendimento.

Carlo Odoardi

Conference on June 3, 2024 at Palazzo dell'Aeronautica: *Dal patrimonio conoscitivo al knowledge management: esperienze, modelli e strumenti per l'Aeronautica Militare*.

Chapter 4 - Knowledge management: an umbrella review

This Chapter reports an overview on recent studies and trends about KM in organizations. An umbrella literature review was conducted focusing on two critical topics: aspects of KM relevant for organizations, and KM tools utilized within these entities. Following the methodology prescribed by Aromataris et al (2015), the purpose of this narrative is to synthesize and compare existing systematic reviews examining the interactions between these domains.

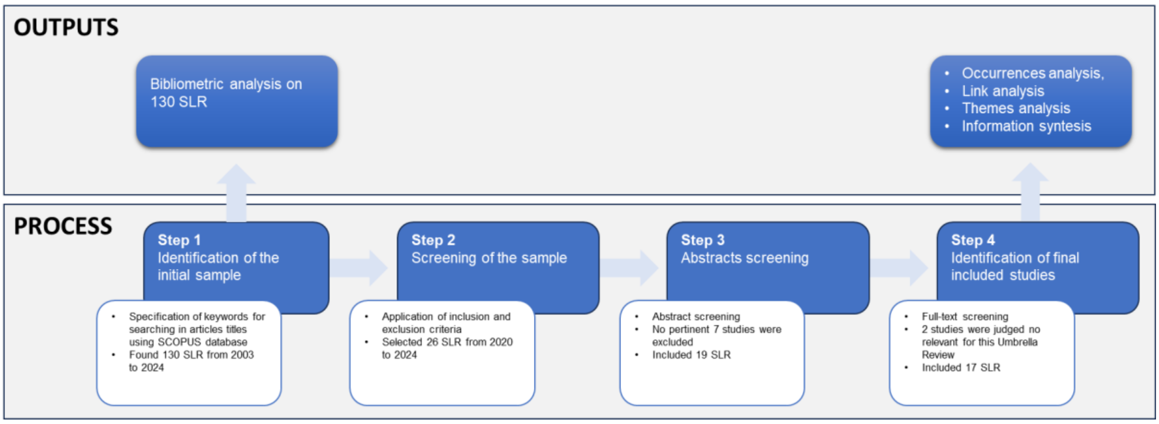
4.1 Materials and methods

A meticulous search strategy is employed to ensure exhaustive coverage of pertinent literature. This strategy captures the breadth of the research and enables a deeper understanding and interpretation of the underlying themes and contexts through the integration of qualitative content analysis.

By methodically analyzing and contrasting the findings from diverse studies, the chapter aims to provide comprehensive responses to the research questions posed. Ultimately, it seeks to elucidate the significant interplay between effective KM practices and the utilization of KM tools in organizations, highlighting how these elements collectively enhance organizational performance and innovation.

The following figure outlines the steps followed for the selection of the systematic reviews considered for this umbrella review and highlights the outputs reported in this study.

Figure 9: Followed steps in this umbrella review

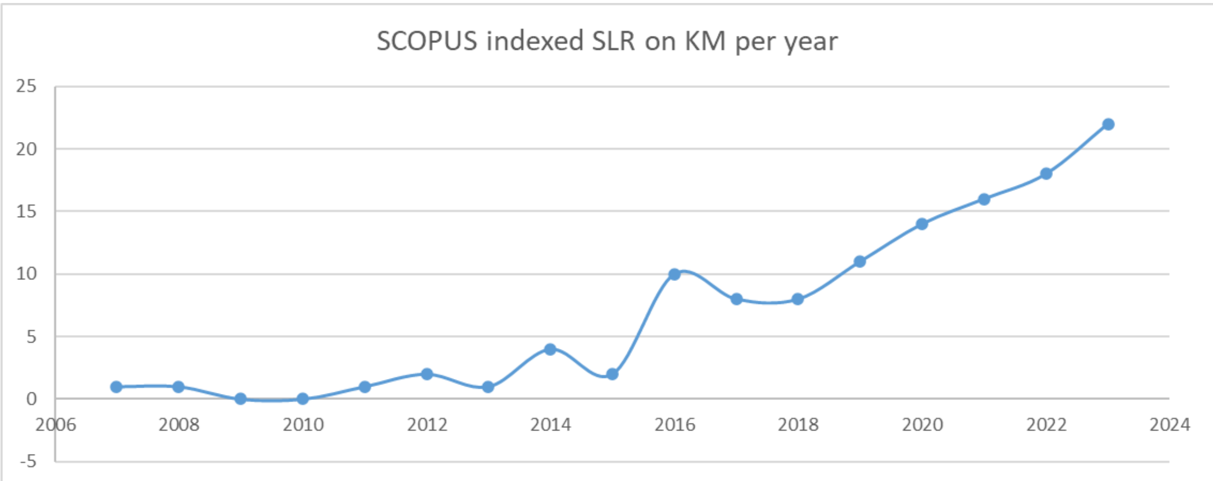


The umbrella review was structured using the SCOPUS database as the primary reference source. The search was conducted with the keywords "Knowledge AND Management AND Systematic AND Review" within the titles of the documents. Filters were applied to limit the search to peer-reviewed journal articles written in English. This initial search yielded 130 documents.

4.2 Bibliometric analysis

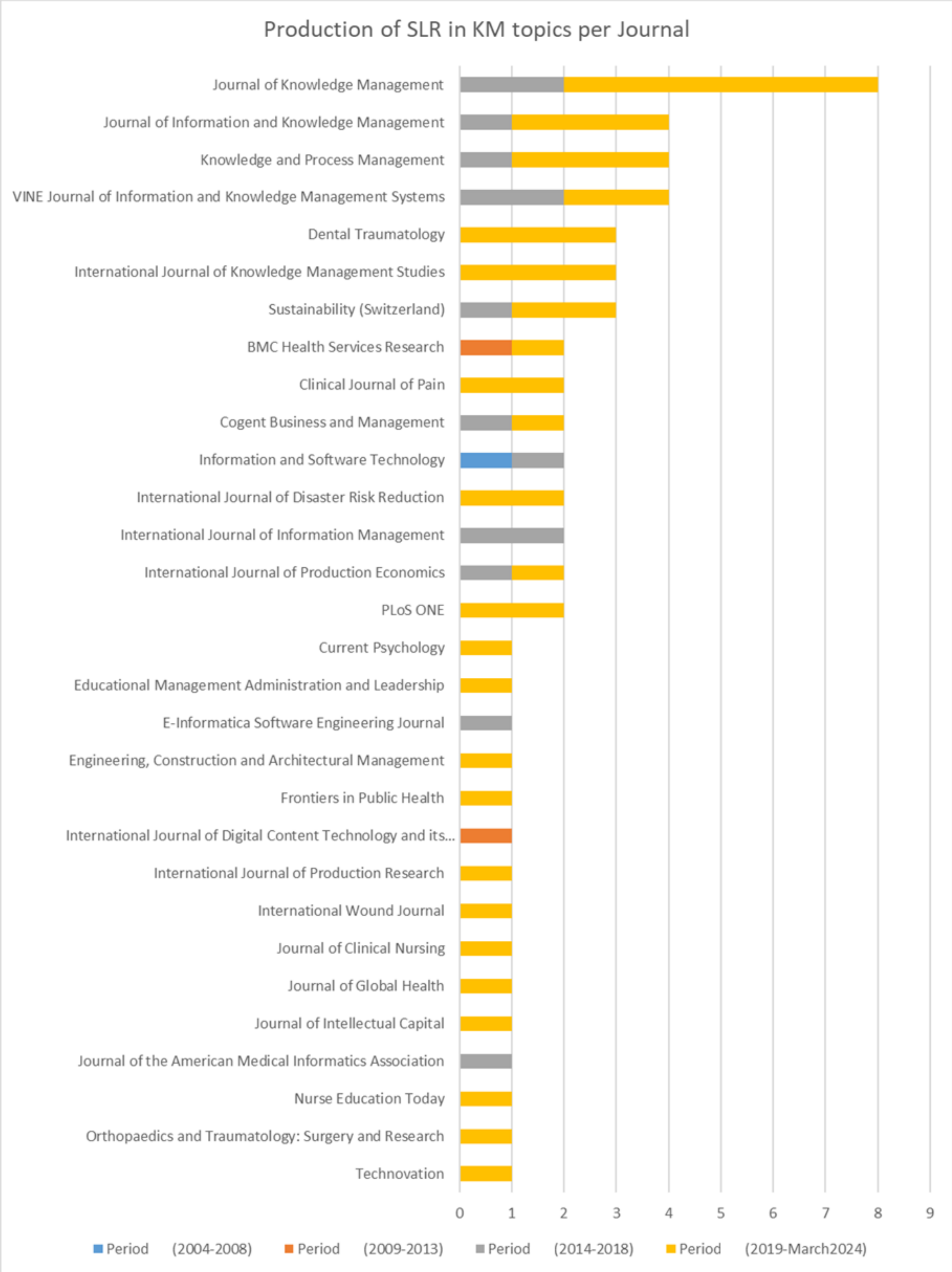
At this point, it was interesting to conduct an initial bibliometric analysis to highlight some information regarding the trends in scientific literature on the topic of KM. The analysis revealed a growing trend over time in the production of Systematic Literature Reviews (as shown in Graph 1).

Graph 1: Trend in scientific literature on the topic of KM



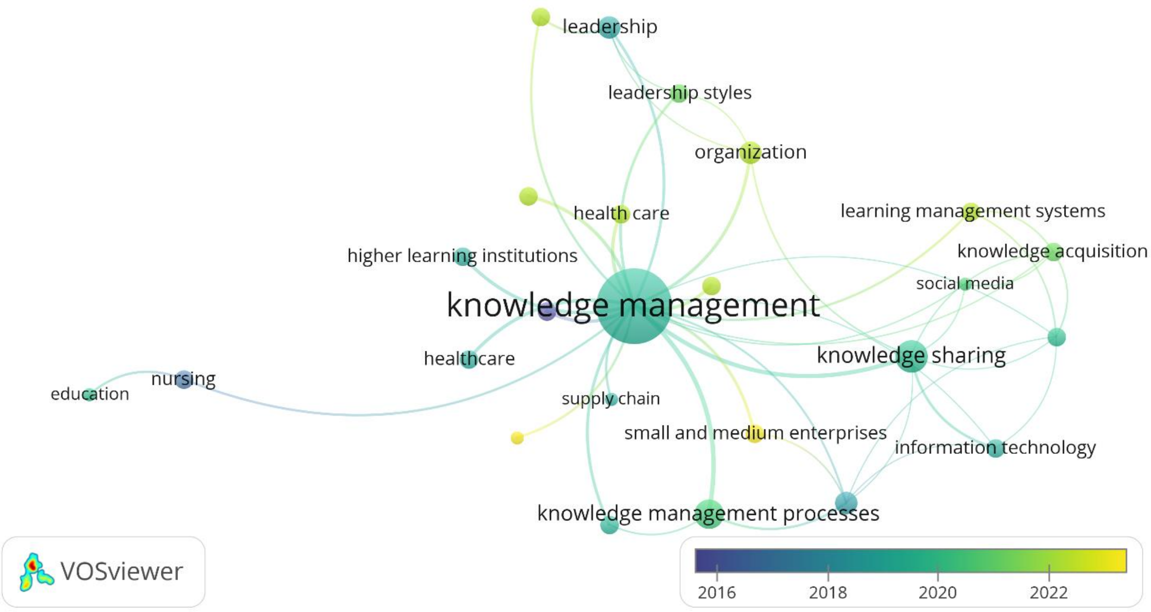
Specifically, Graph 2 highlights the 30 journals that have published the most SRs identified in the sample of 130 SRs. The graph shows that in the last decade, journals from areas not strictly managerial have also shown interest in the topic. In particular, journals in the healthcare field (BMC Health Services Research, Clinical Journal of Pain, Frontiers in Public Health, Journal of Clinical Nursing, Journal of Global Health, Journal of the American Medical Informatics Association, Nurse Education Today, Orthopaedics and Traumatology: Surgery and Research), the psychological field (Current Psychology), and the disaster management field (International Journal of Disaster Risk Reduction) have shown increased interest.

Graph 2: Top 30 Journals Publishing the Most Systematic Reviews (SRs)



This trend is also highlighted by the following figure, which represents the co-occurrences of the most relevant terms within the 130 papers. The figure shows that items such as healthcare, supply chain, small and medium enterprises, education, nursing, and learning management systems have begun to be correlated with KM and studied in SLRs in more recent times.

Figure 10: Co-occurrences of the most relevant terms within the 130 papers



4.3 Selection of the reference sample

Exclusion criteria were then applied to narrow down the selection to only those systematic reviews that were international, recently published (up to March 2024), and had a certain number of citations. Specifically, articles were excluded if they were not in English, were not systematic reviews, were published before 2020, had fewer than 2 average citations per year if published between 2020 and 2023, had irrelevant titles, or were not accessible online.

Table 2: Summary of the study's structure

Research questions	RQ1 According to recent literature reviews, which aspects of knowledge management are most relevant in an organization? RQ2 Which KM tools are most commonly used in organizations?
Database	*Scopus*
Filter criteria	*Publication date:* 2020–2024 (March) *Language:* Only English-language publications *Citations:* no less than 2 *Type of source:* peer-reviewed journals
Data synthesis	*Qualitative synthesis:* Articles are briefly presented with a focus on themes that emerged from the co-occurrence analysis and are discussed in relation to the research questions.

After applying the exclusion criteria, 26 documents were selected for abstract analysis. From this analysis, 19 documents were chosen for further review, and after a thorough full-text evaluation, 2 reviews were excluded due to the lack of relevant information for this study.

As a result, the review included 17 systematic reviews, which are detailed in the following table.

Table 3: Systematic reviews considered for the umbrella review

Authors	Journal	Topic Focus	Included studies	Publication Range	Information sources
Ton & Hammerl 2021	Knowledge and Performance Management	Knowledge management in the environment of cross-functional team coopetition	25	2010-2021	Emerald, Elsevier, Google Scholar, JSTOR, SpringerLink, Web of Science
Caccamo et al. 2023	Technovation	the role of boundary objects in achieving effective knowledge integration among diverse actors	87	2002-2022	Google Scholar
Pai et al. 2022	Economic Research-Ekonomska Istraživanja	the extent to which AI can assist companies in effectively handling information and managing knowledge	9	1990-2022	Emerald Insight, Scopus, Springer LINK, JSTOR, Sage, ScienceDirect (Elsevier), SSRN, EBSCO
Asiedu et al. 2022	Cogent Business & Management	the examination of knowledge management strategies within higher learning institutions	40	1999-2022	Google Scholar, core.ac.uk and eric.ed.gov, Emerald Insight database, Wiley online
Nappi & Kelly 2021	International Journal of Knowledge Management Studies	the use of performance indicators (PIs) in the field of knowledge management (KM) to measure and manage the innovation process.	23	1995-2019	Web of Science, Scopus, cross-reference
Yao et al. 2023	IEEE transactions on knowledge and data engineering	the impact of digital technologies on knowledge management in the engineering sector	27	2021-2022	ACM Digital Library, IEEE e x-plore, ProQuest, Scopus, Web of Science
Di Vaio et al. 2021	Journal of Business Research	the role of digital innovation in knowledge management systems (KMS) and its impact on business governance	46	1990-2020	Web of Science, Google Scholar
Ferreira et al. 2022	Journal of the knowledge economy	the interrelation between knowledge management (KM) and human resource management (HRM), specifically how KM contributes to human resource development (HRD)	47	2000-2019	Online Knowledge Library (B-ON)
Sartori et al. 2022	Knowledge and Process Management	the potential of Organizational Knowledge Management (OKM) to contribute to companies and nations, particularly within the complex context of Supply Chain 4.0	249	1999-2019	Web of Science, EBSCO
Kosklin et al. 2023	Knowledge Management Research & Practice	the impact of knowledge management (KM) on organizational goals and performance in the healthcare sector	16	2008-2018	Cinahl, PubMed, Scopus, Web of Science, ABI/Inform data bases, Business Source Complete
Shahzad et al. 2022	Sustainability	exploring the relationship between IT self-efficacy and personal knowledge and information management (PKIM) practices	50	2000-2022	Summon, LISA, LISTA, Scopus,Web of Science, EBSCO Host, Google Scholar, Pro Quest, Emerald, Wiley Inter Science, Taylor & Francis, and Wiley Inter-Science Databases
Al Amiri et al. 2019	Business and Economic Horizons	how business organizations can achieve competitive advantage and sustainability by identifying, enhancing, and	27	2014-2019	Emerald, ScienceDirect, Springer, Ebsco, Google Scholar

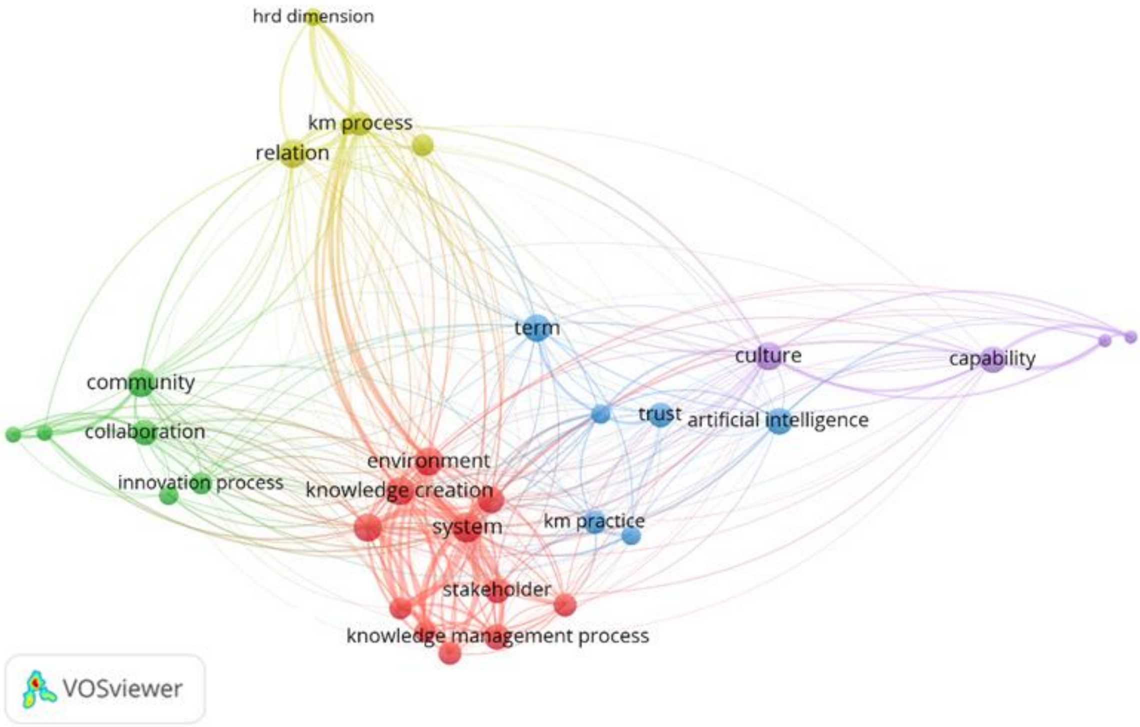
		directing their resources towards building capabilities			
Sartori et al. 2020	International Journal of Business Excellence	the obstacles small and medium-sized enterprises (SMEs) face in implementing knowledge management (KM) despite its well-documented positive impacts on organizations	6	2012-2017	Not specified
Durst et al. 2024	Management Review Quarterly	the importance of knowledge management (KM) for small and medium-sized enterprises (SMEs)	180	2012-2022	Web of Science
Oktari et al. 2020	International Journal of Disaster Risk Reduction	the application of knowledge management (KM) practices within the context of disaster management.	72	2005-2020	Scopus
Pflugfelder 2021	Journal of Intellectual Capital	how Knowledge Management (KM) and Intellectual Capital (IC) can enhance the organizational performance of ambulatory healthcare providers and how this performance can be effectively assessed	31	before 2020	ACM Digital Library, Cochrane Library, DARE, EBSCOHost, Medline, ProQuest, PubMed, ScienceDirect, Scopus, Web of Science

Among the selected 16 papers, 8 systematic reviews can be primarily used to investigate RQ1, 4 SLRs are more oriented towards the themes of RQ2, while 4 SLRs contain useful insights for both RQs. The following section presents the results related to RQ1.

4.4 Results

In this context, it is useful to present the results of a co-occurrence analysis performed using the VOSviewer software (version 1.6.20). The following map shows the co-occurrences of items present within the 16 selected papers. The analysis was based on the text from the abstracts, discussion sections, and conclusions of each paper. To improve the clarity of the graphical representation, terms not relevant to this study were excluded. The graphical result is shown in the following figure.

Figure 11: Co-occurrences of items present within the selected papers



The following table presents the clustering breakdown provided by the software. For each item, the table shows the values of occurrences within the texts, the links between the words, and a value that accounts for the combination of both parameters.

Table 4: Clustering analysis generated by the software

	items	weight <Occurrences>	weight <Links>	weight <Total link strength>
Cluster 1				
	digital technology	16	17	1771
	environment	23	26	1938
	integration	11	24	1018
	knowledge creation	19	27	1761
	knowledge management process	8	22	729
	knowledge management system	11	18	570
	knowledge process	8	18	909
	knowledge sharing	25	27	1690
	knowledge storage	11	15	1216
	stakeholder	13	21	853
	system	83	31	4672
Cluster 2				

	cognitive perspective	7	9	280
	collaboration	11	22	355
	community	18	27	527
	innovation manager	9	13	214
	innovation process	13	17	301
	knowledge integration	11	9	396
Cluster 3				
	artificial intelligence	8	23	205
	km practice	17	18	224
	kms	14	13	188
	supply chain	29	13	580
	term	15	25	382
	trust	7	20	195
Cluster 4				
	hrd	48	11	2688
	hrd dimension	7	11	679
	human capital	7	16	169
	km process	32	19	2236
	relation	13	26	837
Cluster 5				
	capability	28	23	658
	culture	16	27	575
	knowledge management capability	11	6	374
	organizational resource	8	6	296

In Cluster 1 (defined by the author as “integrated digital system”), are gathered the themes of digital technology, system integration, environments contributing to KM, and stakeholders.

In Cluster 2 (defined by the author as “innovation”), the themes of innovation, knowledge integration through communities, and collaboration emerge.

In Cluster 3 (defined by the author as “artificial intelligence”), the importance of artificial intelligence for KM practices, enhancing KM systems, and functions such as supply chain management emerge.

Cluster 4 (defined by the author as “human resource development”), is decidedly focused on human capital, human resource development, and relationships.

Cluster 5 (defined by the author as “organizational capabilities”), encompasses themes of culture, resources, and organizational capabilities.

Now we will analyze how these items are addressed in the sample of systematic reviews under consideration.

Table 5: Relevant points for RQs

RQ	Authors	Title	Relevant points
RQ1	Ton & Hammerl 2021	Knowledge management in the environment of cross-functional team coopetition: A systematic literature review	*Knowledge management capability:* Knowledge evaluated as a crucial resource for strategic competitiveness of the organization. *Knowledge sharing*: Facilitation of knowledge sharing alone is insufficient. *Innovation*: Innovation as a direct consequence of knowledge management, fostered by cross-functional team coopetition (considered as a combination of competition and cooperation). *Collaboration*: Coordinated efforts and common understanding of knowledge practices for basic cooperation. *Relation*: Communication and social interactions as key factors, creating deeply connecting informal networks. *Integration*: Organizational and cultural learning structures to maintain organizational cohesion and support cross-functional teams. *Human capital:* High competence of team leaders and prior experience among team members significantly influence success. *Knowledge management capability:* Need for distinct and individualized knowledge management strategies for long-term profitability.
RQ1	Nappi & Kelly 2021	Measuring knowledge management in the innovation process: a systematic literature review	*Innovation process*: Integrating KM into the innovation process, focusing on performance indicators for managing knowledge repositories and aiding CoPs in knowledge sharing. *Knowledge creation*: Metrics for generating new ideas and fostering innovation, including the rate of generated ideas and the training of team leaders in creativity techniques. *Knowledge management capability:* Emphasis on using patent data as a measure of innovation, including the average age of company patents. *Knowledge sharing*: Indicators for assessing the diversity of knowledge sources, such as the technical and industrial experience of staff. *Culture*: Evaluating the organizational environment that supports innovation, including external recognition, published works, and rewards for employees sharing and using knowledge. *Knowledge management capability*: Identified deficiencies in metrics for tacit knowledge and quality of knowledge sharing in external collaborations.
RQ1+RQ2	Di Vaio et al. 2021	The role of digital innovation in knowledge management systems: A systematic literature review	*Capability*: Fostering the development of strategic capabilities across business sectors through open and innovative systems. *Culture*: Aligning business strategies with sustainable practices through digital innovation, facilitating eco-friendly transformations. *Capability:* Developing integrated strategic capabilities by sharing and exchanging diverse expertise and insights.
RQ1	Ferreira et al. 2022	The contribution of knowledge management to human resource development: A systematic and integrative literature review	*Human Resources Development*: Intersection of HRD dimensions with KM processes. *Professional Development:* Equipping employees with necessary skills for optimal performance, influenced by KM. *Human capital*: Cultivating personal and intrinsic skills unique to each employee, influenced by experiences, education, and social environment. *Capability*: Strategies for aligning structures, processes, and people with strategic objectives, emphasizing knowledge creation. *Environment*: Integrating sustainable practices within HRD frameworks to address ecological needs. *HRD dimension*: Improving quality of life and access to development opportunities, emphasizing knowledge sharing. *Integration*: Integrating various knowledge sources to achieve specific goals, highlighting the role of technology in KM. *Knowledge creation*: A pivotal KM process fostering innovation and supporting sustainable growth. *Knowledge sharing*: Enhancing community and organizational practices through effective knowledge exchange.

RQ1+RQ2	Sartori et al. 2022	Organizational knowledge management in the context of supply chain 4.0: A systematic literature review and conceptual model proposal	*KM process*: Represents the essence of Supply Chain 4.0, integrating interorganizational knowledge and technological elements of the fourth industrial revolution. *Integration*: an interorganizational knowledge development is central to collaborative knowledge creation and sharing among supply chain members. *Capability*: Consideration of the different challenges faced by small and medium businesses compared to large enterprises in KM processes. *Knowledge sharing*: Focus on sharing and appropriation of knowledge in supply chains 4.0. *Collaboration:* More developed theme in new product development within supply chains. *Integration:* Higher levels anticipated in industry 4.0, requiring deeper investigation into KM implications. *Innovation process*: Personalization of KMS, adapting knowledge management systems to the specific needs of organizations within the industry 4.0 context.
RQ1	Kosklin et al. 2023	Knowledge management effects and performance in health care: a systematic literature review	*KM capability*: Enhances management activities, operational efficiency, and financial outcomes within healthcare organizations. *HRD dimention:* Transformational leadership can be supported by KM to improve quality management and organizational operations. *Organizational resource:* Financial performance are positively influenced by effective KM practices. *KM process*: KM is crucial for clinical work, patient safety, and quality improvement. *KM process:* Operational procedure improvements enhanced by integrating diverse healthcare professionals' knowledge. *HRD dimension:* Employee satisfaction is positively influenced by KM, supporting organizational learning. *Culture*: Influenced by KM, improving responsiveness and learning. *Decision-Making:* Improved by KM, leading to better clinical operations efficiency.
RQ1+RQ2	Shahzad et al. 2022	Relationship between IT Self-Efficacy and Personal Knowledge and Information Management for Sustainable Lifelong Learning and Organizational Performance: A Systematic Review from 2000 to 2022	*Integration:* Sustainable learning and innovative work performance enhanced by overcoming traditional mindsets, financial limitations, and technical support barriers. *KM process:* Positive correlation with Personal Knowledge and Information Management (PKIM), enhancing learning and job performance. KM Process: PKIM (Personal Knowledge and Information Management) practices are crucial for personal and professional growth, supported by IT expertise in navigating, searching, storing, and utilizing information. *HRD dimension: Psychological ownership* motivates individuals to organize knowledge and information effectively, fostering innovation and enhancing performance. *Digital technologies*: Semantic tools and e-learning forums are key for organizing personal information systematically and achieving academic and professional milestones.
RQ1+RQ2	Al Amiri et al. 2019	The organizational resources and knowledge management capability: A systematic review	*Culture*: Elements such as cooperation, innovation, consistency, and effectiveness positively influence knowledge management capability. *Culture:* Clan, adhocracy, hierarchy, and result-oriented cultures facilitate knowledge creation, exchange, and application. *Collaboration*: Beneficial for knowledge acquisition, conversion, application, and protection. *HRD dimension*: Top management support fosters an environment conducive to knowledge donation and collection. *Organizational capability*: Commitment-based HR strategies and entrepreneurial orientation positively impact knowledge management capabilities. *Culture*: Traditional management styles, non-cooperative attitudes, and financial constraints hinder effective KM. *Organizational resources:* Firm size, age, and industry specifics affect KM capabilities. *Organizational capabilities*: Quality management, environmental management, market-sensing capability, service entrepreneurship, episodic learning capability, and client-focused learning. *Culture:* Data-Driven Decision-Making culture is essential for integrating Industry 4.0 technologies.

RQ1	Sartori et al. 2020	Specificities of SMEs relevant to knowledge management: a systematic literature review	*Organizational resource*: Family-run vs. professionally run SMEs, affecting trust levels and knowledge management practices. *Organizational resource*: Specific characteristics vary across strategic, tactical, and operational levels. *Organizational resource*: Critical area requiring attention, with a call for government support for KM initiatives in SMEs. *Stakeholder:* Cross-Company knowledge sharing encouraging knowledge sharing among competitors as partners.
RQ1	Durst et al. 2024	A systematic literature review on knowledge management	*Capabilities*: Essential for SMEs to leverage knowledge management effectively. *Innovation*: Role of KM in fostering innovation within SMEs. *Culture*: KM's contribution to sustainable business practices addresses long-term viability and environmental considerations. *Capability*: KM's impact on organizational adaptability, eables SMEs to respond swiftly to market changes.
RQ1	Oktari et al. 2020	Knowledge management practices in disaster management: systematic review	*Integration :* Need for integrating theoretical frameworks from both Knowledge Management and Disaster Management fields. *Culture*: Enhancing disaster resilience through improved KM practices. *KM process:* Importance of a comprehensive architecture supporting all KM processes.
RQ1	Pflugfelder 2021	Knowledge management as a driver of performance in ambulatory healthcare – a systematic literature review through an intellectual capital lens	*Innovation*: Combination of technological and human-centered initiatives. *Relation*: Strengthened by CoPs through the+B2:D14 creation of social-professional networks. *Human capital*: Increased by training interventions. *Integration*: Importance of integrating KM technology with human-centered initiatives. Ensures comprehensive enhancement of intellectual capital. *Integration*: KM's role in integrating care processes to improve healthcare delivery. *Collaboration*: Social-Professional networks strengthening through Communities of Practice.

4.5 Discussing on RQ1 “According to recent literature reviews, which aspects of knowledge management are most relevant in an organization?”

Cluster 1: integrated digital system

The findings from the systematic literature reviews provide a comprehensive understanding of the multifaceted role of Knowledge Management (KM) in various organizational contexts.

According to Ton (2021), organizations can maintain cohesion and align cross-functional teams with predefined goals by leveraging a unique organizational and cultural learning structure. This approach ensures that entities within the same ecosystem can benefit from each other, enhancing overall organizational performance.

Pai et al. (2022) highlight the importance of integrating human and machine interactions to create sustainable implementations. This integration is crucial for optimizing the interaction between human knowledge bearers and technological systems.

Asiedu et al. (2022) identify two main strategies for managing knowledge: codification and personalization. These methods are effective in handling explicit and tacit knowledge, respectively. The study suggests that combining these approaches, known as the "integrative approach," can provide a robust framework for KM in both business and educational settings.

Yao et al. (2023) highlight the potential of virtual reality platforms in enhancing real-time interaction and configuration of virtual prototypes. They emphasize the use of 3D simulations, virtual reality, and advanced user interfaces in the nuclear industry, demonstrating the benefits of presenting data in real environments to improve visual perception and understanding.

The concept of Cyber-Physical Systems is explored by Lee and Seshia (2016), who highlight the seamless interaction between physical processes and computational elements. Augmented reality is particularly noted for its potential to enhance knowledge sharing in complex industrial settings.

Sartori (2020) examines the specific challenges faced by small and medium-sized enterprises in implementing KM. The study reveals that resource constraints, such as financial, human, and technological capacities, often lead to undervalued KM initiatives. However, the inherent flexibility and close-knit nature of SMEs present unique opportunities for effective KM practices.

Drust (2022) emphasizes the evolution of theoretical foundations in SME research, advocating for theoretical pluralism. The integration of classical and emerging theories can enrich the analytical depth of KM studies, capturing the complex nature of KM within SMEs.

Octari et al. (2020) point out the lack of integration between KM and Disaster Management theoretical frameworks. They call for robust theoretical support to enhance KM's practical implementation in disaster scenarios. Future research should explore comprehensive KM practices using balanced strategies focused on people, processes, technology, and goals.

Finally, Pflugfelder (2020) categorizes KM interventions and their impact on Intellectual Capital (IC). The study identifies six main types of KM interventions, including technology-focused and human-centered approaches. Multi-faceted interventions that combine these approaches are found to enhance human, structural, and relational capital, ultimately improving process performance and healthcare outcomes.

In summary, the integration of KM practices, leveraging both human and technological resources, is essential for enhancing organizational performance across various contexts.

Future research should continue to explore these integrations, focusing on the unique challenges and opportunities within different organizational settings.

Cluster 2: innovation

The findings from the systematic literature reviews underscore the critical role of innovation in enhancing organizational performance and addressing complex challenges.

Ton (2021) emphasizes that maintaining organizational cohesion through a unique organizational and cultural learning structure is crucial. This approach ensures that cross-functional teams adhere to predefined goals and leverage insights from other organizational entities, fostering an ecosystem that supports innovation.

Caccamo et al. (2023) highlight the importance of boundary objects[9] (i.e. project documents, roadmaps in product development, virtual communities of practice, prototypes, drawings, sketches and designs, simulation models, databases, and software platforms) in innovation, particularly in addressing grand challenges such as the Covid-19 pandemic. The complexity of collaboration in these scenarios requires systemic action involving numerous stakeholders. This perspective opens new avenues for studying and managing innovation in complex, unpredictable environments.

According to Pai et al. (2022), a collective approach to knowledge management using big data analytics is essential for decision-making in unpredictable environments. The fluidity of social and business configurations challenges traditional managerial approaches and business models. Integrating big data and artificial intelligence helps organizations make better business decisions, enhancing their ability to innovate.

Nappi and Kelly (2021) discuss the integration of KM within the innovation process, a concept that gained traction in scholarly discussions around the mid-2000s. They focus on the use of Performance Indicators for managing knowledge repositories and aiding Communities of Practice in knowledge sharing, which are vital for fostering innovation.

[9] In their systematic review, Caccamo et al. report these definition of boundary objects: […] *artifacts and concepts allowing diverse individuals to span the boundaries of their specializations and integrate knowledge (Bechky, 2003; Carlile, 2002; Majchrzak et al., 2012; Nicolini et al., 2012). Star and Griesemer (1989) define boundary objects as "objects which are both plastic enough to adapt to local needs and constraints of the several parties employing them, yet robust enough to maintain a common identity across sites" (Star and Griesemer, 1989: 393)* [...]

Di Vaio et al. (2021) report that the adoption of Information Technology and Big Data significantly benefits organizational performance. Open, innovative systems foster integrated strategic capabilities across various business sectors by facilitating the sharing and exchange of multidisciplinary knowledge. This integration enhances strategic functions and operational efficiency, driving innovation.

Shahzad et al. (2022) find a significant positive correlation between IT self-efficacy and Personal Knowledge and Information Management (PKIM) across various domains. Different facets of IT self-efficacy, including web, computer, virtual media, digital, e-learning, and social media, are linked to effective PKIM practices. These practices are crucial for sustainable learning and job performance, contributing to innovation in both personal and professional contexts.

In conclusion, the integration of KM practices with advanced technological tools and approaches is essential for fostering innovation. Future research should focus on exploring these integrations further, particularly in the context of Industry 4.0, to enhance organizational resilience and performance in an increasingly complex and dynamic environment.

Cluster 3: Artificial intelligence

The findings from the systematic literature reviews underscore the pivotal role of artificial intelligence (AI) in enhancing knowledge management and organizational efficiency.

Pai et al. (2022) emphasize that AI-based IT support systems have become essential for organizations aiming to achieve innovation, efficiency, and effectiveness. While the comprehensive task analysis and automation required for these systems can be demanding, they are invaluable for high-value applications. Organizations that invest in AI technologies for knowledge management—such as information sorting, extraction, intelligent search, end-user profiling, and content forwarding—can achieve substantial returns, particularly when these technologies are applied wisely.

Sartori et al. (2021) propose a "tech-powered shared context" model that integrates advanced Industry 4.0 technologies, such as communications, e-learning, virtual reality, and real-time connections, into knowledge management. This virtual context contrasts with the traditional physical space, introducing challenges in collaboration, trust, and openness. The model emphasizes that AI and big data tools are essential for modern organizational functioning, though human behavior challenges persist.

Al Amiri et al. (2019) note a gap in research on the impact of Industry 4.0 resources—such as IoT, big data, AI, cloud computing, and real-time data processing—on knowledge management capabilities. Addressing this gap is essential for understanding how these technologies can enhance KM practices and drive innovation.

Shahzad et al. (2022) report that technological advancements in artificial intelligence, big data analytics, and the Internet of Things are pivotal in developing robust PKIM systems, further driving innovation in learning and work.

In conclusion, AI plays a crucial role in modernizing and optimizing knowledge management systems. By leveraging AI technologies, organizations can enhance their information processing capabilities, improve decision-making, and foster a more interconnected and efficient work environment. Future research should continue to explore the integration of AI within knowledge management frameworks to address the dynamic needs of Industry 4.0 and beyond.

Cluster 4: human resource development

The findings from the systematic literature reviews emphasize the significant role of Human Resource Management (HRM) in enhancing organizational performance and development.

According to Ton (2021), communication and social interactions are crucial, particularly through previously untapped channels that create deeply connecting informal networks. The competence of team leaders and the prior experience of team members are also significant factors influencing the success of team projects.

Ferreira et al. (2022) identify seven key dimensions of Human Resource Development (HRD): individual (ID), professional (PD), organizational (OD), economic (EcoD), social (SD), environmental (EnvD), and technological developments (TD). These dimensions are intricately linked to various KM processes. PD is critical for equipping employees with necessary skills, heavily influenced by KM processes. ID focuses on personal skills unique to each employee, influenced by experiences, education, and social environment. OD involves strategies aligning structures, processes, and people with strategic objectives, with knowledge creation as a pivotal KM process. EcoD enhances efficiency and effectiveness in economic activities. EnvD integrates sustainable practices within HRD frameworks. SD emphasizes knowledge sharing to improve quality of life and development opportunities. TD integrates various knowledge sources to achieve specific goals, despite being less frequently addressed in literature.

Kosklin et al. (2022) highlight that KM is vital across various organizational aspects, enhancing management activities, operational processes, and financial outcomes. KM supports transformational leadership and quality management, leading to improved knowledge acquisition, dissemination, and responsiveness. Continuous improvements and quality enhancements in organizational operations are facilitated by KM, which is also linked to positive financial performance.

In conclusion, the integration of HRM and KM processes is essential for organizational success. Communication, social interactions, and competence development are pivotal for team success. The multifaceted dimensions of HRD, influenced by KM, contribute to sustained competitive advantage and comprehensive organizational development. KM enhances management activities, operational efficiency, and financial performance, supporting transformational leadership and continuous improvement. Future research should continue exploring the interplay between HRM and KM to further enhance organizational outcomes.

Cluster 5: organizational capabilities

The findings from the systematic literature reviews highlight the critical role of organizational capabilities in enhancing performance and achieving long-term profitability.

Ton (2021) underscores that individual management practices must be uniquely tailored to each enterprise's knowledge management strategy to ensure long-term profitability. This customization reflects the necessity for organizations to develop distinct approaches that align with their specific goals and contexts.

Kosklin et al. (2022) categorize the effects and performance of knowledge management (KM) in healthcare into three main categories: KM as an asset, KM as support, and KM as a mediator. They also identify two performance categories: general and practical performance. As an asset, KM enhances management activities, operational efficiency, and financial outcomes by supporting transformational leadership and quality management. As support, KM improves clinical operations, patient safety, and overall quality of care through better knowledge integration among healthcare professionals. As a mediator, KM fosters knowledge sharing and integration, leveraging advanced technologies like electronic medical records to enhance efficiency. The general performance of KM is positively correlated with organizational performance, influencing culture and financial outcomes, while practical performance improvements include enhanced patient care, decision-making, and employee performance.

Al Amiri et al. (2019) identify several influential factors on organizational capabilities:

- Social Factors: Including social resources, inter-organizational structural social capital, social media knowledge management discussion groups, and internal social capital.
- Organizational Knowledge: Factors like knowledge heterogeneity, cognition, and local knowledge flows.
- Organizational Characteristics: Such as firm size, age, and industry specifics.

Pai et al. (2022) propose a four-stage cycle for transforming raw data into awareness, which is essential for effective knowledge management:

- Find: Identifying and retrieving sources and records in a timely manner, organizing them into beneficial categories.
- Filter: Extracting pertinent information using rigorous tests and natural-language processing strategies.
- Format: Standardizing and presenting filtered data through various formats like text, graphics, and multimedia.
- Forward: Delivering the processed information to the appropriate individuals via multiple media channels.

In conclusion, the integration of customized knowledge management practices, social and organizational factors, and efficient data processing methods is crucial for developing robust organizational capabilities. These capabilities enhance overall performance, support strategic objectives, and foster a culture of continuous improvement and innovation within organizations. Future research should continue exploring these integrations to further optimize organizational outcomes.

4.6 Discussing on RQ2 "Which KM tools are most commonly used in organizations?"

Regarding to RQ2, the systematic literature reviews highlight a range of tools and strategies that are crucial for effective KM across various organizational contexts. These tools facilitate the capture, sharing, and utilization of knowledge, contributing to enhanced organizational performance and innovation. They are synthetically reported in the following table:

Table 6: identified KM tools in the review

Authors	KM Tools presented
Caccamo et al. 2023	present a diverse set of tools designed for innovation and knowledge integration. These include: • *Boundary Objects*: Tools for addressing complex problems and fostering innovation, such as during the Covid-19 pandemic. • *Information Systems*: Platforms for interorganizational knowledge sharing and digital artifacts for distributed innovation in open-source software. • *Workspace Tools*: Movable whiteboards, online blogs, and other tools for collaborative work environments. • *Virtual Boards:* For virtual innovation communities and version-controlled documents in IT systems for product development. • *Community of Practice*: Creating metadata for digital libraries and utilizing technical drawings and Excel workbooks for developing new routines.
Pai et al. 2022	focus on integrating artificial intelligence (AI) with KM systems to enhance efficiency and innovation. Their key tools include: • *AI-based IT Support Systems*: For sorting, information extraction, intelligent search, and document forwarding. • *Big Data Analytics:* For decision-making in unpredictable environments. • *Human-Robot Interaction Framework:* For sustainable interactions leveraging explicit KM. • *Hierarchical Blockchain and Federated Learning:* To enhance security and privacy in knowledge sharing. • *Visualization Tools:* Such as InXight and Perspecta for presenting information. • *Groupware-based Tools:* Like Lotus Notes for collaboration.
Asiedu et al. 2022	explore strategies in higher education and corporate settings, emphasizing different KM approaches: • *Soft Approach*: Face-to-face interactions for sharing tacit knowledge. • *Hard Approach:* Information communication technology for sharing explicit knowledge. • *System Strategy:* Technology to codify and transfer explicit knowledge and support tacit knowledge through virtual meetings. • *Communities of Practice*: Formal groups for sharing challenges and experiences. • *Codification and Personalization Approaches:* Documenting explicit knowledge and facilitating direct person-to-person interactions for tacit knowledge.
Yao et al. 2023	discuss the influence of digital technologies on KM in engineering, introducing several innovative tools: • *Content Management Systems:* For building digital collaborations. • *Schema Exploration and Evolving Knowledge Entity Recorder (SEEKER):* Virtual repositories of institutional memory. • *Social Media Platforms*: For collaborative knowledge building and sharing. • *Building Information Modelling (BIM*): For knowledge acquisition and sharing in a 3D CAD environment. • *Visualization Technologies:* Virtual reality and augmented reality for enhancing real-time interaction and understanding. • *Cyber-Physical Systems (CPS):* Integrating physical processes with computational elements for seamless interaction.

Di Vaio et al. 2021	highlight the role of digital innovation tools in reshaping business models and aligning strategies with sustainability. Their focus is on: • *Digital Innovation Tools:* For eco-friendly and efficient business transformations. • *Knowledge Management Systems*: Broader access to information and influencing investment strategies. • *Big Data Management*: Facilitating the exchange of multidisciplinary knowledge for strategic functions.
Sartori et al. 2022	*emphasize the implications of Industry 4.0 on KM with tools such as:* • *Machine-Created Knowledge:* Challenges of knowledge created by machines. • *Tech-Powered Shared Context:* Technologies like communications, e-learning, and real-time connections. • *Artificial Intelligence and Big Data:* Complementing and enriching KM processes. • *Integration and Automation:* Anticipated higher levels in Industry 4.0.
Shahzad et al. 2022	review the relationship between IT self-efficacy and PKIM, identifying several technological tools: • *Technological Tools:* Search engines, databases, digital libraries, citation management software, and cloud storage. • *Artificial Intelligence and Big Data Analytics:* Developing robust PKIM systems. • *Internet of Things (IoT):* Enhancing PKIM systems. • *Social Media Tools*: Platforms like YouTube and Facebook for managing personal knowledge and information.
Al Amiri et al. 2019	explore the impact of Industry 4.0 on KM capabilities, focusing on: • *Industry 4.0 Technologies*: IoT, big data, AI, cloud computing, and real-time data processing. • *IT Technology*: Includes IT resources, information systems, IT-supported operations, and IT relationship management.

As shown in the previous table, Caccamo et al. (2023) emphasize the importance of boundary objects and workspace tools in fostering innovation and addressing complex problems. These tools facilitate collaboration and knowledge sharing within and between organizations, supporting innovation even in challenging circumstances like the Covid-19 pandemic.

Similarly, Pai et al. (2022) illustrate how artificial intelligence (AI) can revolutionize KM systems. AI-based IT support systems, big data analytics, and human-robot interaction frameworks not only enhance decision-making and efficiency but also ensure sustainable interactions and robust knowledge management practices. The incorporation of hierarchical blockchain and federated learning further secures and privatizes knowledge sharing.

Asiedu et al. (2022) provide a nuanced view of KM strategies by emphasizing both soft (face-to-face) and hard (technology-based) approaches. These strategies ensure that explicit and tacit knowledge are effectively managed through codification and personalization methods, fostering a culture of continuous learning and knowledge sharing within organizations.

In addition, Yao et al. (2023) demonstrate the transformative potential of digital technologies in KM, particularly in engineering. Tools like BIM, virtual and augmented reality, and CPS enable organizations to visualize, share, and apply knowledge in real-time, significantly improving collaboration and understanding in complex industrial settings.

Furthermore, Di Vaio et al. (2021) highlight the role of digital innovation tools in aligning business models with sustainability goals. By integrating digital innovation tools and KM systems, organizations can achieve eco-friendly business transformations and optimize the utilization of their knowledge assets, leading to better strategic decision-making and operational efficiency.

Sartori et al. (2022) discuss the impact of Industry 4.0 on KM, focusing on the integration of AI, big data, and machine-created knowledge. These technologies are anticipated to bring about higher levels of automation and integration, which will require deeper investigation into their implications for KM practices.

Additionally, Shahzad et al. (2022) underscore the importance of technological tools in enhancing personal knowledge and information management (PKIM). Search engines, digital libraries, AI, big data analytics, and IoT are pivotal in developing robust PKIM systems that drive innovation and sustainable learning.

Lastly, Al Amiri et al. (2019) explore the comprehensive impact of Industry 4.0 technologies on KM capabilities, highlighting the importance of IT resources and systems in supporting organizational operations and enhancing relationship management.

Overall, these studies collectively underscore the need for continuous exploration and integration of KM practices to address dynamic organizational challenges. By leveraging a combination of traditional and cutting-edge digital tools, organizations can foster a culture of continuous improvement, innovation, and resilience. Future research should continue to delve into these integrations, focusing on how emerging technologies and collaborative platforms can further optimize KM processes and enhance organizational outcomes in an increasingly complex and fast-paced environment.

Chapter 5 - Organizational Virtual Communities of Practice: a systematic review

The study of Virtual Communities of Practice (VCoPs) has gained increasing relevance in the field of Knowledge Management (KM) as organizations seek to enhance collaboration, innovation, and expertise sharing beyond physical and organizational boundaries. My interest in VCoPs stems from their dual function as a tool for both knowledge sharing and creation and as a strategic instrument for human resource development.

In the context of the Italian Air Force (IAF), VCoPs represent a promising yet underexplored avenue for fostering knowledge exchange, strengthening professional expertise, and supporting continuous learning. Given their potential impact on organizational efficiency and workforce development, I deemed it essential to dedicate two entire chapters (Chapter 5 and Chapter 7) to this subject. This focus aims to explore how VCoPs can be effectively leveraged within the IAF, assessing their applicability, challenges, and best practices. Despite being recognized as one of the KM tools currently in use within the IAF, their full capabilities have yet to be systematically analyzed and optimized for military-specific requirements.

This chapter, therefore, seeks to bridge this gap by offering a comprehensive examination of VCoPs, their role in modern knowledge ecosystems, and their potential in enhancing collaborative learning, decision-making, and professional development within the IAF's organizational framework.

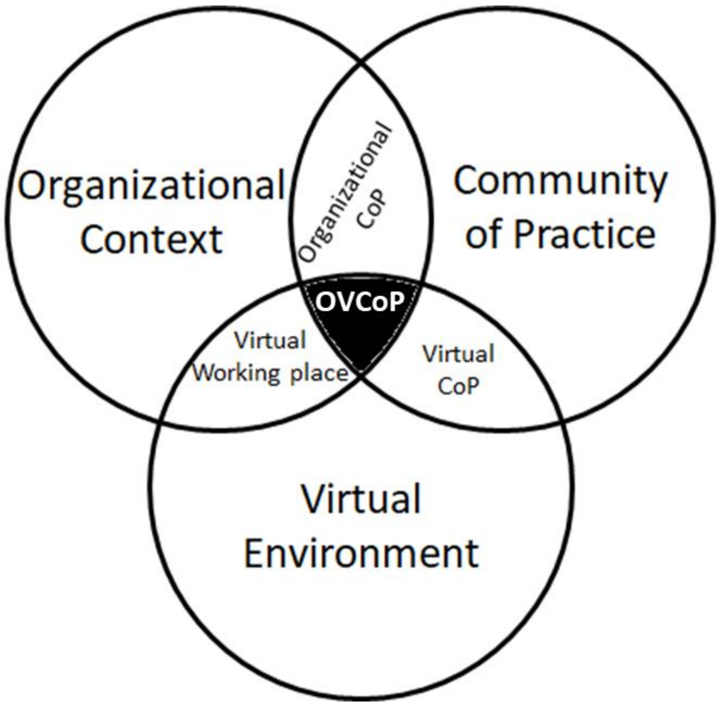
This chapter refers to a systematic literature review conducted between March and September 2023 by Lieutenant General Fernando Giancotti, former president of the Center for Higher Defense Studies as well as the creator of the *Squadra 4.0 Plan*[10], and myself.

In today's complex global landscape, organizations are tasked with making decisions within intricate contexts. Virtual Communities of Practice (VCoPs), when effectively established and managed, stand as pivotal instruments for the aggregation, sharing, transformation, and dissemination of knowledge. This process engenders a virtuous cycle that enriches and

[10] *Piano Squadra 4.0* is a strategic initiative by the Italian Air Force (IAF) aimed at optimizing processes, enhancing knowledge sharing, and fostering innovation through digital tools and collaborative platforms. It supports the continuous development of personnel and operational capabilities to maximize mission effectiveness. A more detailed description of the plan is provided in paragraph 6.2.

enhances organizational performance, positioning VCoPs as invaluable assets for achieving high levels of efficiency and innovation (Giancotti, 2022).

Figure 12: graphical framework of the main research topic



The study investigates the effectiveness and characteristics of Virtual Communities of Practice (VCoPs) in business environments, with a specific focus on Organizational Virtual Communities of Practice (OVCoPs) and their impact on various organizational business areas.

The research employs a systematic literature review, involving an extensive search across three of the most popular databases. A comprehensive review was conducted using a rigorous and standardized procedure following the PRISMA guidelines. From a full-text analysis of 86 papers, 26 case studies were selected as relevant for addressing the research questions and were compiled for in-depth analysis.

The relevance of VCoPs in terms of organizational effectiveness is analyzed, categorizing their impact by business areas. Furthermore, a Pareto analysis identifies the elements that most significantly promote engagement in an OVCoP, and the study examines the most effective modalities for implementing a VCoP.

5.1 Theoretical background

This paragraph provides an overview of the literature on the theoretical principles of CoPs, Virtual Communities of Practice (VCoPs), and Organizational Virtual Communities of Practice (OVCoPs), highlighting the unique features that distinguish each.

Communities of Practice

The term "Community of Practice" (CoP) was coined by Wenger and Lave (Lave, 1991). It refers to groups of individuals who share common goals, interests, and activities, collaborating to enhance their expertise in a specific domain (Wenger, 2008). CoPs have been used across various fields, including social sciences, education, and knowledge management, to study collaborative work and learning processes (Cox, 2005). They synergistically create and share knowledge, and collaboratively make decisions to address shared challenges (Edwards et al., 2021). The domain provides a platform for members to exchange thoughts, expertise, and experiences, defining the group's identity and fostering a sense of affiliation (Wenger et al., 2002). The practice aspect encompasses the collective expertise, techniques, tools, and documents that members develop and maintain (Smith et al., 2017).

Successful CoPs foster varied levels of involvement, categorized into core, active, and peripheral members (Wenger et al., 2002). Core members lead and guide activities, active members participate regularly, and peripheral members primarily observe but absorb and reflect on the discussions.

Wenger (1998) defines a CoP through mutual engagement, joint enterprise, and a shared repertoire. Mutual engagement involves interpersonal connections and social capital (Wenger, 2000), joint enterprise denotes the collective purpose (Snyder et al., 2003), and shared repertoire includes the routines, terminologies, methodologies, and concepts developed over time (Wenger, 1998).

Hierarchical control mechanisms can inhibit knowledge sharing and collaboration, particularly in public sector offices where top-down governance creates silos that hinder effective learning (Thiry, 2007; Duryan, 2019). Studies show CoPs support continuous improvement and knowledge sharing (Bolisani & Scarso, 2014), and they can also enhance disaster resilience in emergency situations (Amaratunga, 2014).

Assigning clear tasks to CoPs and designating formal roles can lead to concrete benefits and managerial attention, integrating CoP ideas into company operations (Yamklin & Igel, 2012). Bolisani et al. (2021) argue for formal recognition of CoP members within organizational governance, including financial support and acknowledgment of their contributions.

Virtual Community of Practice

Professionals sharing knowledge across geographical boundaries often rely on technology-driven digital platforms. Allen, Ure, and Evans (2003) describe these platforms as Virtual Communities of Practice (VCoPs). VCoPs are CoPs enabled by technology, allowing individuals to engage virtually. These communities, supported by electronic platforms like online forums and emails, unite members over shared practices and knowledge (Jan, 2019).

The evolution of the Web transformed CoPs. Early Web 1.0 featured a one-directional information flow, creating passive learning. With Web 2.0, characterized by interactive platforms like blogs, wikis, and social media, learning became collaborative and participatory (Edwards & Hoefer, 2010). This shift transformed CoPs into peer-to-peer learning models, mirrored by the rise of VCoPs for electronic knowledge sharing.

Modern communication channels have significantly reshaped traditional social work practices, integrating cyber communication into administrative and therapeutic tasks (Mishna et al., 2012). Embrett's study (2021) highlights how VCoP frameworks enable rapid, collective responses to challenges, like maintaining productivity during a pandemic. VCoPs optimize cost-effective communication technologies, fostering long-distance collaboration (Embrett et al., 2021).

VCoPs bridge geographically separated groups, facilitating swift knowledge exchange at minimal cost and serving as navigable knowledge banks (Tickle et al., 2011). Effective VCoP activity requires a foundation of trust, often fostered through face-to-face meetings (Nagy, 2006). Key advantages of VCoPs include camaraderie, resource sharing, collaborative problem-solving, and overcoming geographical and hierarchical limitations.

Fang and Chiu (2010) identify three crucial elements for VCoPs: knowledge, individuals, and the social network. Knowledge is fundamental, sustaining the VCoP and motivating participation through mutual exchange.

Organizational Virtual Community of Practice

Woolis et al. (2008) argue that online Communities of Practice (CoPs) enhance organizational productivity by improving time management, optimizing human capital through resource sharing, stimulating dialogue, fostering leadership, advancing practices and policies, and achieving better results. Lesser & Storck (2001) note that Organizational Virtual Communities of Practice (OVCoPs) shorten onboarding processes, enhance customer responsiveness, reduce redundancy, and stimulate innovative ideas for products and services. Kirkman et al. (2013) found that communication tools like email and instant messaging enhance CoP efficiency internationally, but emphasized the importance of in-person meetings and videoconferences for diverse OCoPs.

Kirkman further argues that OCoPs are more effective when responsibilities are distributed among members, highlighting their structured nature compared to traditional CoPs and teams. However, Wolf et al. (2011) suggest that the impact of formally established CoPs on company performance is unclear. Roberts (2006) posits that societies with robust social structures, particularly collectivist cultures, are more conducive to CoPs, enhancing knowledge creation and dissemination. She asserts that Arab work culture aligns more with informal CoPs than formal teams.

Many companies see a decline in CoP participation after initial enthusiasm. Strategies to counter this include minimizing organizational hierarchies to facilitate open interactions and encouraging grassroots CoPs. Engagement, defined by Porter et al. (2011) as voluntary, constructive participation, is crucial. McDermott & Consulting (2004) identify "localism" as a challenge, where the hosting site unduly influences the CoP.

Davenport and Prusak (2000) note that CoPs often form spontaneously among colleagues with shared professional practices. Recognizing the attributes and lifecycle of CoPs is essential. McDermott (2000) argues that business unit support is crucial for CoP sustainability, identifying four managerial challenges: focusing on themes vital to both the business and community, appointing respected community leaders, ensuring member participation, and upholding organizational values.

5.2 OVCoP and Knowledge Management

Knowledge management is pivotal in the process of knowledge creation within organizations, involving an ongoing cycle that transcends conventional boundaries and explores new horizons. This process is likened to "the journey of being," where individual (micro) and broader environment (macro) dimensions interact and shape each other (Nonaka et al., 2000).

Organizations increasingly encourage dialogue and feedback from employees through social and digital communication technologies such as corporate blogs, wikis, discussion forums, and social networking sites. Major U.S. corporations like Intel, Dell, IBM, and Starbucks use social media tools to foster social interaction among employees (Postman, 2009).

Disseminating tacit knowledge, embedded in employees' minds, is a significant challenge for organizations. The SECI model, proposed by Nonaka and Takeuchi (1995), addresses this by outlining a cycle of knowledge creation and sharing through four modes: socialization, externalization, combination, and internalization. This model emphasizes the importance of tacit knowledge, described by Polanyi as "... we know more than we can tell" (Polanyi & Sen, 1983).

Dube et al. (2005) argue that in geographically dispersed organizations with tight schedules, virtual Communities of Practice (CoPs) provide a more efficient communication alternative to in-person meetings. Participation in a CoP allows new members to develop their skills by collaborating with experienced members, akin to an apprenticeship. This communal learning perspective views learning as a journey of shaping practice, defining meaning, and building identity within a practice-based community (Lave & Wenger, 1991).

5.3 Methods

The literature review approach was selected as the most suitable method to gain both quantitative and qualitative insights into the intended field of knowledge. This approach allowed the integration of content from previous studies conducted by a wide range of researchers globally, published in leading academic journals. A systematic literature review is valued for providing insights into existing research, enabling scholars to craft innovative future studies and substantiate their research proposals, rather than merely recapitulating existing literature (Easterby-Smith et al., 2021).

This review method adheres to a structured methodology that supports replicability and facilitates updates, ensuring transparency and consistency (Gray, 2021). The steps undertaken in this study are outlined below, providing a clear framework for replication and future updates. To address the proposed objective, a descriptive-explicative approach using a qualitative strategy was adopted. Qualitative research is well-suited for exploratory studies, essential for understanding phenomena and proposing constructs for quantitative research (Bryman & Bell, 2007).

The systematic review followed the PRISMA guidelines, which include a 27-item checklist and a four-phase flow diagram to ensure transparent reporting. These guidelines assist researchers in documenting a deductive roadmap for their systematic evaluation. The checklist covers various aspects, such as the rationale, protocol, specific objectives, registration, eligibility criteria, information sources, search strategy, study selection, data collection methods, data items, risk of bias assessment in individual studies, summary measures, synthesis of results, and overall risk of bias across studies (Gough & Oliver, 2017).

5.4 Literature gaps

This study reviewed a small collection of recent systematic literature reviews (SLRs) on Virtual Communities of Practice (VCoPs), published between January 2021 and May 2023, and identified two major gaps:

- The literature on VCoPs primarily focuses on the learning process, often applicable in educational contexts.
- The analyzed characteristics of VCoPs cover a broad range of areas, but there is a lack of studies focusing on elements that can be governed by an organization.

Table 7 provides a concise overview of some recent SLRs on VCoPs.

Table 7: overview of some recent SLRs on VCoPs

Author	Year	Reference sector	Purpose of the research	Gaps to fill by this Systematic Review
Hernández-Soto et al.	2021	VCoP in general	To explore factors influencing knowledge sharing in VCOPs across sectors, cultures, and countries, to provide a comprehensive understanding in diverse contexts.	No focus on the context of the organization or on elements governable by the organization.
Abedini et al.	2021	Educational	To give a comprehensive synthesis of online adult learning in virtual CoPs through an analysis of research literature.	Focused on the andragogic aspects and lifelong learning.

Akosen and Asiedu	2023	Industrial	To investigate CoP trends, challenges, and benefits in the telecommunications industry through a systematic research approach.	Limited exclusively to the telecommunications industrial context, with no consideration of organizations..
Beres and Janes	2023	Academic	To investigate employee involvement in VCOPs, digital tools utilized in VCOPs and the factors influencing tool selection. To study the impact of digital tools in COPs	Focus on faculty and Staff in Higher Education.
Geheb	2022	STEM Education	To compare publication trends in K-12 engineering education research between engineering education journals and other educational research journals.	No focus on CoP but on engineering education in K-12 contexts.
Han et al.	2021	STEM Education	To study secondary educators in establishing integrated STEM Communities of Practice with experts and partners to enhance teaching knowledge, skills, and self-efficacy.	focused on teachers' CoP for STEM.

5.5 Research questions

The aim of this research is to offer knowledge managers in large organizations valuable insights for implementing Virtual Communities of Practice (VCoPs) that can add value to the work environment. The central research question is: "What are the elements that make a VCoP effective in an organizational context?"

To address this, the research is guided by two specific questions:

- In which business areas can an OVCoP be effective?
- What characteristics define an effective OVCoP?

Table 8 presents the keywords and synonyms derived from these research questions, which were utilized to search for and identify relevant papers for analysis.

Table 8: Keywords and synonyms identified for the searchTable

KEYWORDS	SYNONYMS
“Communities of practice”	“community of practice”, “learning communities”, “learning community”
Virtual	digital, distance, online
Effective	operative, functioning, “high performance”
Organisation	work

The research examined studies published between 2012 and 2022, indexed in three databases: Crossref, Google Scholar, and Scopus. The search on Crossref was conducted using the software "Harzing's Publish or Perish" (version 8.8), yielding 379 results. A direct search on Google Scholar returned 138 results, while a direct search on Scopus produced 232 results. Table 9 details the search criteria and the corresponding results.

Table 9: Criteria and results of the search

Database	Software/Query Used	Search Parameters	Results
Crossref	Harzing's Publish or Perish (vers. 8.8)	**Title words**: "Communit* of practice" **Keywords**: (Virtual OR digital OR distance OR online) + (effective OR "high performance" OR operative OR functioning) + (organization* OR work) **Publication years**: 2012 to 2022	379
Google Scholar	Direct search	**Title words**: "Community of practice" | "communities of practice" **Publication years**: 2012 to 2022	138
Scopus	Direct search	TITLE ("community of practice" OR "communities of practice") AND PUBYEAR > 2011 AND PUBYEAR < 2023 ALL ((virtual OR digital OR distance OR online) AND (effective OR "high performance" OR operative OR functioning) AND (organization* OR work)) AND (LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (SRCTYPE, "j"))	232

After importing the results on excel database, the search results from Scopus and Crossref were further filtered based on specific criteria. From Crossref, only results classified as journal articles were selected, resulting in 251 results. Furthermore, only papers cited more than 5 times were filtered (on Google Scholar was possible to obtain this filter directly from the personal library of Google Profile). After these exclusion parameters, 106 paper from Scopus, 81 paper from Google Scholar and 116 paper from Crossref were considered after disregarding duplications. Out of 303 papers, only 6 duplicated were eliminated and the remained 297 papers were considered for a title and abstract analysis.

The table 10 reports the inclusion and exclusion criteria.

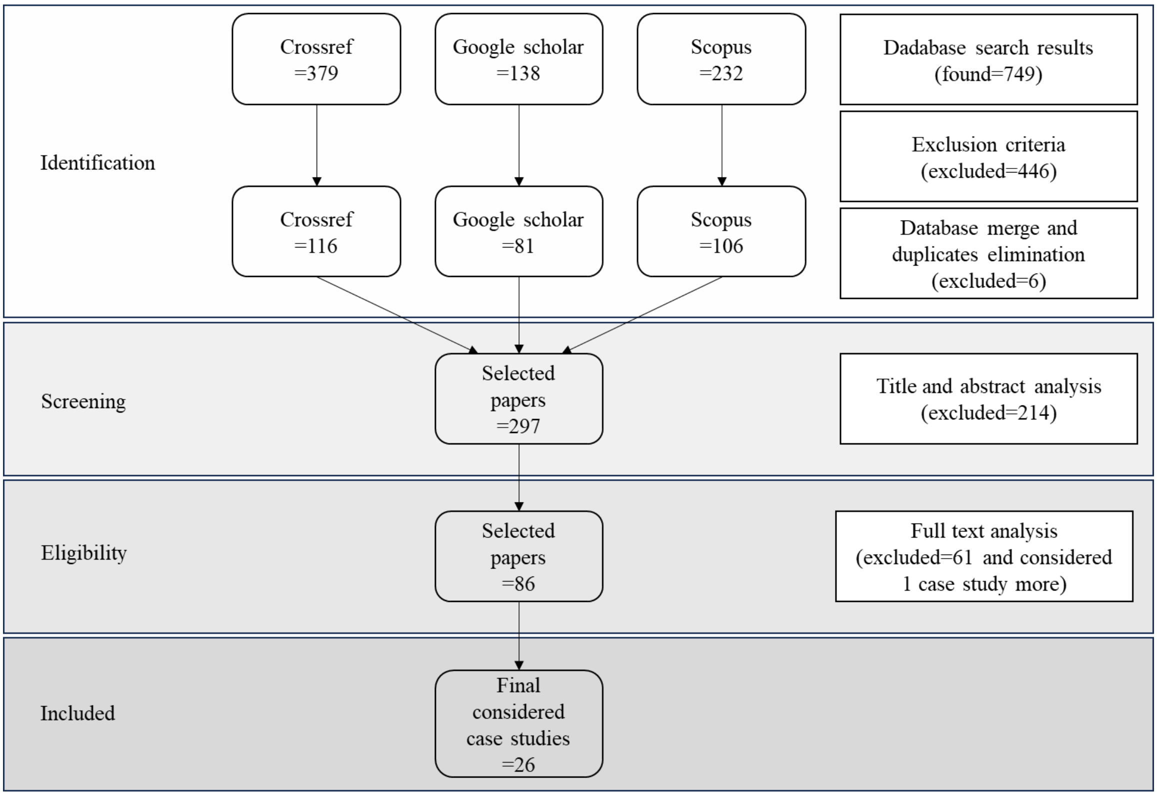
Table 10: Inclusion and exclusion criteria applied to the review

Inclusion Criteria	Exclusion Criteria
Peer reviewed Journal-articles	Less than 6 citations
"Communit* of Practice" in the title	Not in English
Search timeframe: 2012-2022	

To analyse the abstracts, an analysis was conducted based on the merged dataset. Papers irrelevant to the research objective were excluded. A total of 86 papers were selected for full-text reading and analysis.

In figure 13 the flow followed in the searches and the selection process is depicted.

Figure 13: Prisma flow diagram

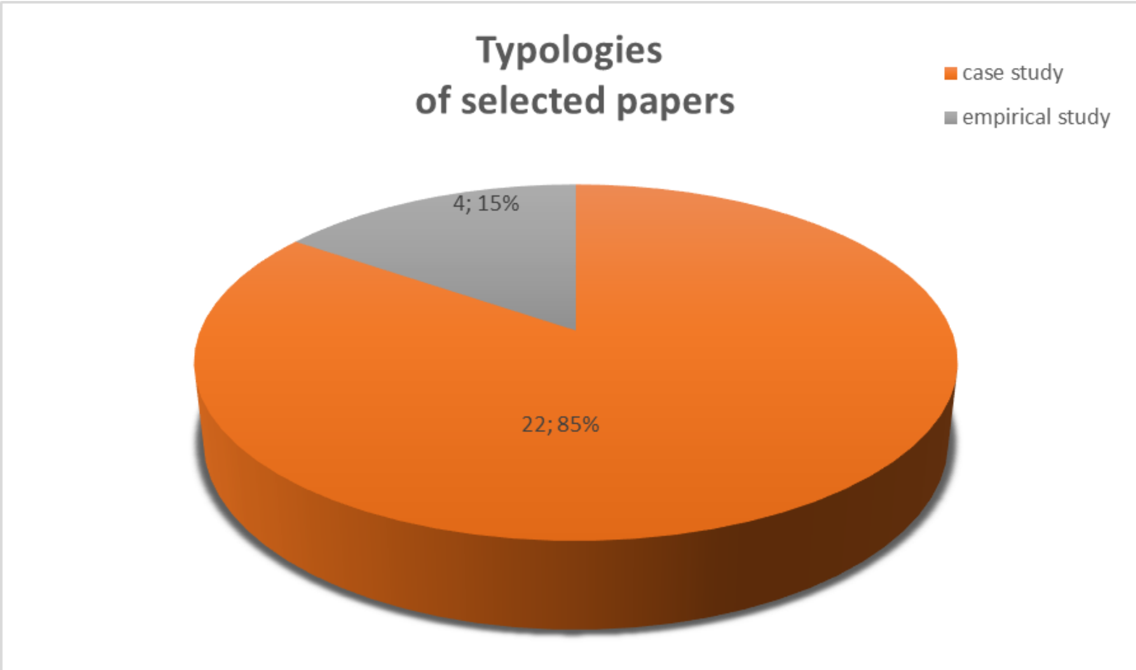


The 86 papers underwent a full-text analysis. Further exclusions were made, specifically: if the paper is a review (n=16); if the evidences in the paper were not relevant for answering the research questions of this study (n=27); if the paper was not pertinent to the research topic (n=13); if the described CoP did not had any digital component (n=4), and one was excluded because it was identified as a working paper. This filtration resulted in 25 papers being considered. One of these papers (the “Kline 2013” paper) described two separate case studies, both of which were considered as observable cases to answer the research questions.

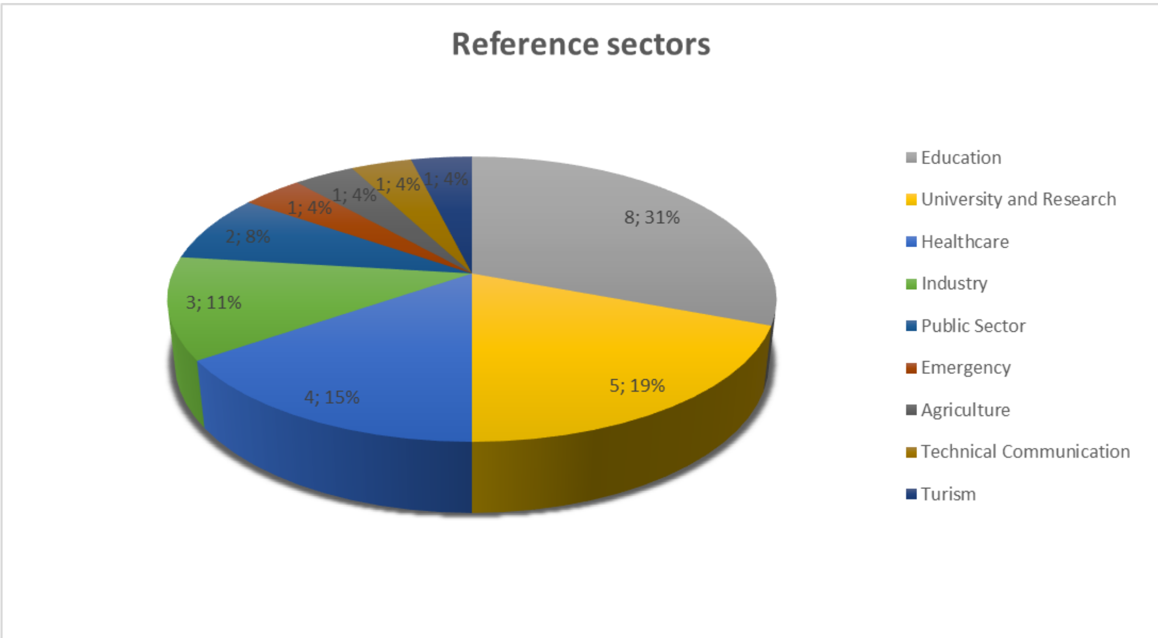
5.6 Composition of the sample

The following charts depict the statistical composition of the 26 records deemed useful for addressing the research questions.

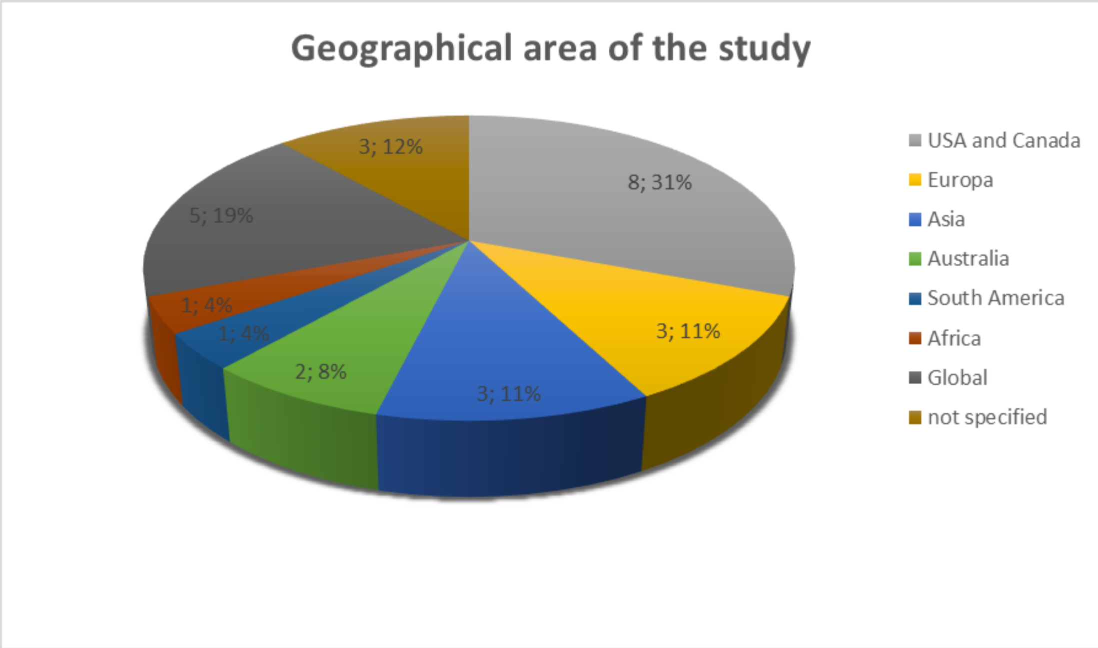
Graph 3: Typologies of selected papers.



Graph 4: Reference sectors of the considered studies.



Graph 5: Geographical distribution of the VCoPs considered.



5.7 Findings and discussion

Each full text analysis enabled the classification of individual papers according to the research sub-questions:

- RQ1: In which business area can an OVCoP be effective?
  - What impact can an OVCoP have on the organization?
  - Which areas of the organization are affected?
- RQ2: What characteristics define an effective OVCoP?
  - What methods are used in an effective OVCoP?
  - What factors determine user engagement?

RQ1: “In which business area can an OVCoP be effective?”

Data extracted from the papers were re-categorized based on tags selected by the authors. For RQ1, responses to the question "a) What impact can an OVCoP have on the organization?" were labeled "relevant" if the paper indicated a significant impact in terms of outcomes, long-term effects, or sustained improvement. The label "irrelevant" was assigned to papers reporting low user participation, outcomes tied to the project's duration, or results that fell short of expectations. For the question "b) Which areas of the organization are affected?", papers were categorized into one or more of the following areas: Innovation/Creativity, Knowledge Sharing, Problem Solving/Decision Making Processes, Efficiency in BaU (Business as Usual), HR Development, and External Relationships. Resuults related to the first research question are presented in the table below.

Table 11: Results related to the first research question

Papers	Kind of impact	Innovation / Creativity	Knowledge Sharing	Problem solving/Decision making processes	Efficiency on BaU	Human Resource Development	External Relationships
Kim 2012	relevant	X			X	X	
Murugaiah 2012	irrelavant		X				
Urquhart 2013	relevant		X				X
Friberger 2013	relevant		X			X	
El-Hani 2013	relevant	X	X			X	
Martins 2013	relevant		X	X			
Kirkman 2013	relevant	X					
Kline 2013 (a)	relevant		X		X	X	
Kline 2013 (b)	irrelavant		X				
Davis 2013	relevant		X			X	
Cowen 2014	relevant				X	X	
Farrell 2014	relevant		X				X
Pharo 2014	relevant						X
Materia 2015	irrelavant						
Mazer 2015	irrelavant						
Duffield 2016	relevant		X		X		X
Liu 2016	relevant					X	X
Gimenez 2017	relevant		X	X	X		X
Musteen 2018	relevant	X					X
Inel Ekici 2018	relevant					X	
Duryan 2019	irrelavant		X	X			
Abiodun 2020	relevant		X	X		X	
Embrett 2021	relevant	X	X		X	X	
Bolisani 2020	relevant		X	X	X		
Carroll 2021	relevant	X	X		X	X	
Rosen 2022	relevant				X	X	

The initial analysis that can be performed on the data presented in table 11 is the tally of the frequencies of positive impacts that the VCoPs have been reported by the authors of each paper. The frequency values are detailed in table 12.

Table 12: frequency of enunced impacts for business area

Impacted areas	Enunced impacts
Knowledge Sharing	16
Human Resources Development	12
Efficiency on BaU	9
External Relationships	7
Innovation/Creativity	6
Problem Solving/Decision Making Processes	5

Table 12 clearly illustrates that the areas where the authors of the case studies report the most significant positive impact are knowledge sharing, human resource development (HRD), and the streamlining of business-as-usual (BaU) operations.

It is important to note that the area of knowledge sharing demonstrated a positive impact even in those case studies where the overall effect of the Virtual Communities of Practice (VCoP) on the organization was deemed negligible (3 out of 5 cases). In fact, the analyzed studies suggest that an impact solely in the realm of knowledge sharing does not constitute a success factor for the effectiveness of the VCoP. Knowledge sharing can indeed be considered a hallmark of VCoPs, and as such, a fundamental function that on its own does not ensure the VCoP's efficacy in adding value to an organization.

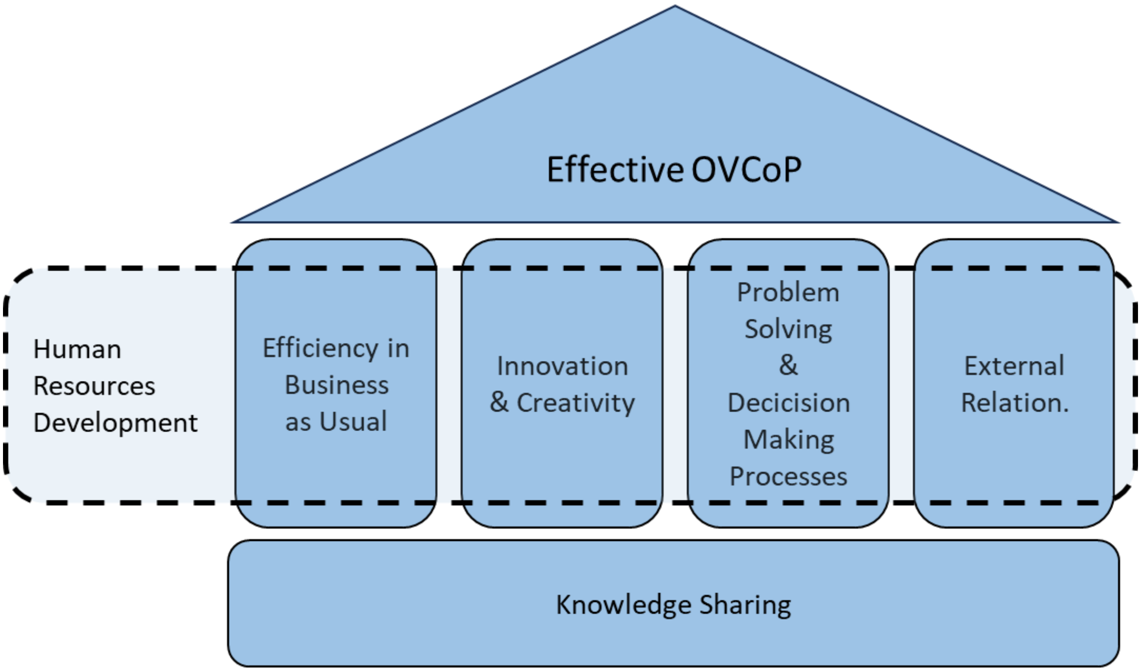
When conceptualizing the effectiveness of VCoPs, one might employ the metaphor of a well-constructed house. At the foundation of this house lies knowledge sharing. While it is a fundamental component, our analysis indicates that knowledge sharing alone is insufficient to determine the success of a VCoP. It serves as a foundational element but does not single-handedly confer efficacy in enhancing organizational value.

Building upon this foundation are four key pillars: Efficiency in BaU operations, Innovation and Creativity, Problem-Solving and Decision-Making Processes, and External Relationships. These pillars represent the core areas where VCoPs can significantly influence an organization.
Human Resource Development serves as a cross-cutting influence that reinforces all four pillars, underscoring its ubiquitous importance across these domains. In other words, HR development permeates these four dimensions and is vital for the overall stability and integrity of the 'house.'

Crowning this structure is the 'roof,' which symbolizes an effective VCoP. This represents the ultimate goal, the attainment of which signifies a well-functioning, beneficial community that adds real value to an organization.

By examining VCoPs through the lens of this metaphor, we gain a multidimensional perspective that transcends the limitations of evaluating effectiveness based on single metrics or isolated practices. This metaphor is depicted in following figure 14.

Figure 14: Metaphoric model for effective OVCoPs



<u>RQ2 'Which characteristics has an effective OVCoP</u>

To address the research question, 'Which characteristics has an effective OVCoP?', we excluded from our analysis the five cases where the impact of the VCoP was considered negligible. Consequently, the analysis was conducted on the 21 cases detailed in table 13.

Table 13: Results related to the first research question

Case Studies	Face-to-face component	Modality	Engagement strategies
Kim 2012	blended	multi-tool asynchronous	Rich interaction media. Adaptation of specific strategies for different types of members and CoPs.
Urquhart 2013	residential start	synchronous+asynchronous	Professional development.
Friberger 2013	totally virtual	synchronous+asynchronous	Recognition of "guiding" roles. Professional development. Structured agenda.

El-Hani 2013	blended	multi-tool asynchronous	Affirmative environment. Recognition of "guiding" roles. Professional development.
Martins 2013	blended	asynchronous	Affirmative environment. Institutional Recognition and Support.
Kirkman 2013	blended	synchronous+asynchronous	Affirmative environment. Rich interaction media. Access to posted content.
Kline 2013 (a)	totally virtual	multi-tool asynchronous	Rich interaction media. Access to posted content.
Davis 2013	totally virtual	multi-tool asynchronous	Rich interaction media. Recognition of "guiding" roles. Access to posted content.
Cowen 2014	blended	synchronous+asynchronous	Rich interaction media. Recognition of "guiding" roles. Structured agenda.
Farrell 2014	totally virtual	asynchronous	Professional development. Institutional Recognition and Support.
Pharo 2014	blended	asynchronous	Recognition of "guiding" roles. Institutional Recognition and Support. Professional development.
Duffield 2016	totally virtual	synchronous+asynchronous	Rich interaction media.
Liu 2016	residential start	multi-tool asynchronous	Professional development. Rich interaction media. Recognition of "guiding" roles.
Gimenez 2017	totally virtual	multi-tool asynchronous	Institutional Recognition and Support. Rich interaction media.
Musteen 2018	totally virtual	multi-tool asynchronous	Institutional Recognition and Support. Professional development. Rich interaction media.
Inel Ekici 2018	totally virtual	asynchronous	Affirmative environment. Recognition of "guiding" roles. Professional development.
Abiodun 2020	totally virtual	asynchronous	Professional development.
Embrett 2021	totally virtual	synchronous+asynchronous	Professional development. Rich interaction media.
Bolisani 2020	totally virtual	synchronous+asynchronous	Professional development. Institutional Recognition and Support.
Carroll 2021	totally virtual	synchronous+asynchronous	Small dimension. Recognition of "guiding" roles.
Rosen 2022	totally virtual	synchronous+asynchronous	Institutional Recognition and Support.

The first aspect to consider is the modality of the CoP, as there could be varying degrees of face-to-face meetings. From this perspective, we considered three levels of face-to-face modality: 1) residential start, when the VCoP is initiated with an in-person meeting but then continues entirely remotely; 2) blended, when face-to-face modality is employed occasionally to support the VCoP, with sporadic scheduled face-to-face meetings; 3) totally virtual, when the VCoP does not involve any face-to-face meetings.

We also observed the consistency of synchronous and asynchronous online modalities, identifying four different situations in the analysed papers: 1) multi-tool asynchronous, where multiple asynchronous digital communication tools and document-sharing methods are used (e.g., forums, wikis, document sharing); 2) asynchronous, where only a single asynchronous communication or document-sharing tool is mentioned; 3) synchronous, where one or more synchronous communication or collaboration tools are used (e.g., videocalls, or whiteboards); 4) synchronous+asynchronous, where synchronous communication/collaboration tools are used in addition to asynchronous communication/collaboration tools.

When we plot the impact case frequencies from the papers on the graph 6, it is easy to see that the VCoP mode recognised as the most impactful is the fully digital environment that offers the possibility to interact both asynchronously and synchronously. This is closely followed by a mode that uses multi-tool asynchronous approach in a totally virtual environment. However, it's important to highlight that the last five case studies considered are from the period 2020-2022, years when, due to the pandemic emergency, all social and work interactions had to take place on digital platforms. This factor must be taken into account for our research purposes.

Graph 6: Percentage modalities recorded in effective VCoPs.

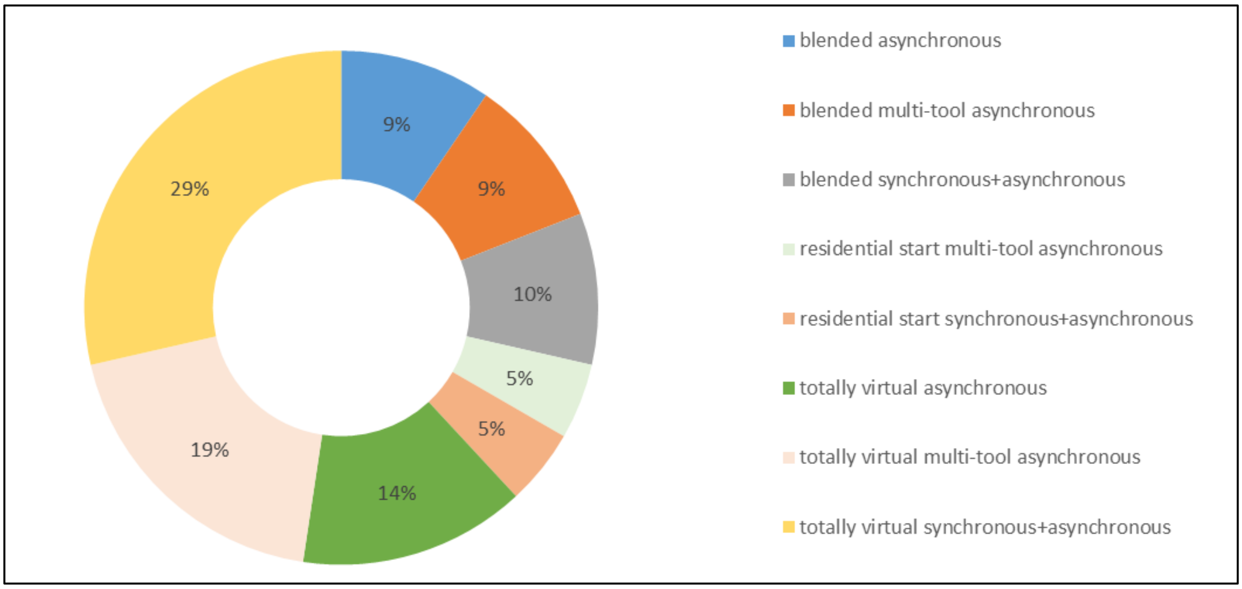
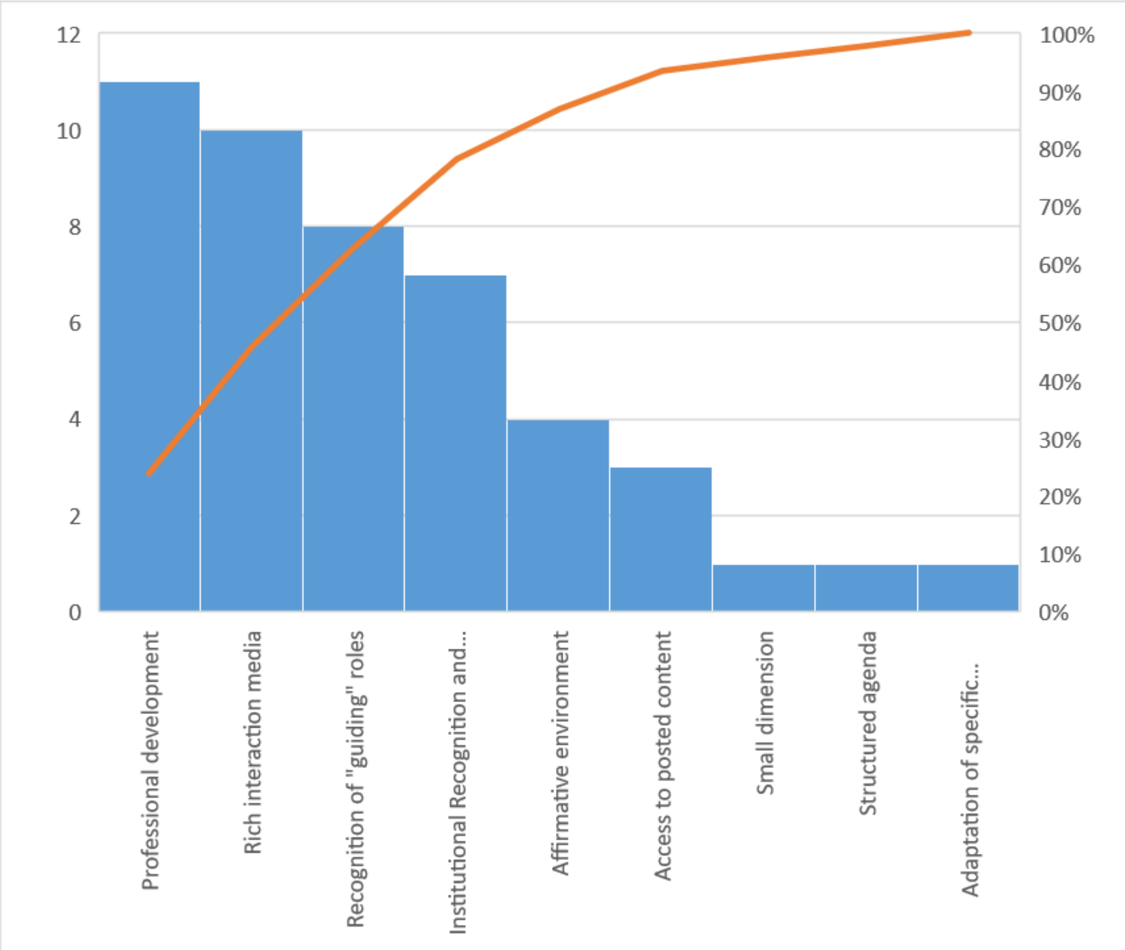


Table 13 also presents data pertaining to the sub-research question b) "Which elements determined the engagement of users in it?". To address this question, table 13 compiles the elements identified by each author as key factors in ensuring the engagement of members in the studied VCoP. Definitions for each element are provided below.

1. Affirmative Environment (or psychological safety): The environment of the CoP results to the participants as a place where to feel safe in sharing their own experiences, doubts, and feelings. In some cases, member behavior is guided by well-defined regulations, guidelines, and ethical standards.
2. Professional development: Participants believe that the Community of Practice (CoP) facilitates their professional development. At times, this occurs for novices who learn from the shared experience provided by 'facilitators'; at other times, it happens when professionals from various fields engage in discussions that enrich their perspectives
3. Recognition of "guiding" roles: Leadership appears crucial for guiding and fostering collaboration. A moderator, facilitator, or expert leads the discussion, ensures smooth transitions between topics, and summarizes key points. This role is recognized not only by the community but also by the organization.
4. Institutional Recognition and Support: It describes the formal acknowledgement of the significance of a CoP within an organizational structure. This recognition is not just symbolic but extends to tangible benefits such as financial support and the allocation of time away from other responsibilities. Institutional recognition may also feature a reward system to acknowledge key contributions in both quality and quantity, thereby encouraging active participation and maximizing the CoP's impact within the organization.
5. Rich interaction media: The use of rich communication media like video conferencing and teleconferencing also acts as a moderating factor.
6. Access to posted content: The ability to review materials posted since the inception of the Commons. The better organized and tagged the posts and topics are, the easier it is for members to find contributions useful to their needs.

The Pareto approach of graph 7 highlights that only four elements (Professional Development, Rich Interaction Media, Recognition of "Guiding" Roles, and Institutional Recognition and Support) account for about 80% of the occurrences of features mentioned to promote engagement in an effective VCoP.

Graph 7: Pareto approach



5.8 Conclusions, limitations an future implications

The study discussed in this chapter provides valuable decision support for knowledge managers in various organizations considering the implementation of a community of practice (CoP) to enhance organizational performance. Insights from this research, grounded in scientific literature, can guide the proper establishment and management of a CoP. This research aims to explore the effects and characteristics of a Virtual Community of Practice (VCoP) as a tool in organizational sciences, addressing a gap in the current literature.

This study has several limitations. First, to narrow down the sample, we included only papers with a minimum of six citations, leading to the exclusion of many recent studies from 2021-2022, despite the growing prevalence of digital CoPs in response to the pandemic. Additionally, the impact of fully digital OVCoPs may be influenced by the limited social interaction during pandemic times. Second, due to the lack of specific case studies on OVCoPs (only five were reported), this study offers a partial view of the phenomenon. More case studies are needed to enrich the literature. Lastly, the limited number of observations prevented reliable statistical analyses, suggesting a need for more extensive studies.

In this pagraph are presented findings from a systematic literature review of 25 peer-reviewed papers on VCoPs in organizational contexts. It is the first to address the characteristics of effective OVCoPs in specific business areas.

RQ1: Effectiveness of OVCoPs

Our analysis indicates that OVCoPs significantly impact key organizational areas: efficiency in business-as-usual operations, innovation and creativity, problem-solving and decision-making processes, and external relationships. While knowledge sharing is foundational, it does not always correlate with success. In contrast, VCoPs associated with HR development consistently demonstrate effectiveness. These findings highlight the added value OVCoPs provide to knowledge managers and high-performance organizations, emphasizing the strategic focus on HR development to foster innovation and enhance decision-making processes.

RQ2: Characteristics of an Effective OVCoP

The study identifies the attributes of effective OVCoPs, with fully digital environments offering both synchronous and asynchronous interactions proving most impactful. This observation is influenced by the COVID-19 pandemic, which accelerated digital transformation. Engagement in OVCoPs is driven by four primary elements: professional development, rich interaction media, recognition of guiding roles, and institutional recognition and support.

The study's implications support further academic inquiry into VCoPs in organizational contexts and provide practical guidance for practitioners to enhance their practices or implement new strategies. Organizations should view OVCoPs as multi-faceted tools that yield benefits across operational and strategic areas when well-structured. Interaction modalities should be adaptable, considering technological trends and global events that accelerate digital adoption.

Future studies should explore OVCoPs in specialized contexts or different time periods to understand their long-term impacts and effectiveness better. This research advocates continued studies to maximize positive aspects of OVCoP management and optimize their effectiveness in organizational contexts.

PART III
KNOWLEDGE MANAGEMENT IN ITALIAN AIR FORCE: CASE STUDIES

Effective leaders know their impact shifts with context, powered by their soft skills and empathy—cognitive, emotional, and compassionate. Through active listening, self-control, resilience, adaptability, and the ability to inspire and mentor, they define the essence of true leadership.

Daniel Goleman

Conference on March 9, 2023 at Centro Alti Studi della Difesa: *La mia leadership*

Chapter 6 - Overview of the Italian Air Force

In the 2018 edition of the CSA-001 directive (Comando Squadra Aerea, 2018), the mission of the Air Command is clearly articulated: "To train, prepare, and deploy highly skilled forces with advanced C6ISTAR-EW capabilities, continuously innovating and integrating the best operational capacity at the inter-force, inter-agency, and multinational levels. To project and employ Aerospace Power in an agile, adaptive, and effective manner in operations, fulfilling the mission of the Air Force in service to the nation." This statement underscores that the concept of continuous innovation is inherently embedded within the mission of one of the key commands of the Italian Air Force (IAF).

The Air Force has consistently demonstrated, more so than other branches of the military, a distinct DNA inherently oriented toward innovation, from its inception to the present day. This drive for continuous improvement and adaptation has been a defining characteristic, shaping its operational strategies and technological advancements over time. Not only for the challenges it has faced in its glorious history, foremost among them the challenge of transforming the dream of flight into a domain for the defense of the country, but also for the highly technological connotation that distinguishes its areas of expertise, from aerospace control systems to the projection of aerospace dominance.

These elements denote a particularly complex environment in which personnel, at all levels, find themselves operating and making decisions.

I would like to share a literary passage that particularly represents this concept, one that I personally could not express better:

> *Un pilota da caccia diretto verso una battaglia aerea certamente affronta un ambiente VICAR[11] per eccellenza, anche in un aereo supertecnologico. In un ambiente multi-bogey, con molti velivoli, non può sapere con certezza quanti aerei nemici ci sono in giro e dove essi siano. Egli sa che il nemico farà di tutto per ingannarlo, contrastare le sue tattiche, evitare le sue armi e abbatterlo. La situazione evolve molto velocemente, considerate le elevate velocità relative e le manovre: il combattimento può esprimere tutta la sua ferocia in pochi, densissimi minuti. Se ingaggiato in combattimento ravvicinato, la sua percezione della situazione si restringe improvvisamente all'ambiente circostante e sotto l'enorme stress fisico dei G elevati, focalizzato sul colpire e sopravvivere, adrenalina al massimo, la sua capacità di processare le informazioni si riduce altrettanto. L'inaspettato è la norma e il termina VICAR sembra proprio il nome adatto a quel pericolosissimo gioco. Per questi motivi un pilota da caccia opera su un ampio spettro di parametri di controllo per assicurarsi il successo: la cultura professionale, l'addestramento, l'organizzazione, la tecnologia e altro. (from "Leadership agile nella complessità. Organizzazione, stormi da combattimento" of Giancotti, F., Shaharabani, Y. 2008).*

The Italian Air Force was born from humanity's ambitious quest to push the boundaries of flight and is founded on a shared consciousness of possessing a common history, a "continuum" of values, traditions, sacrifice, and activities related to its "core business" in the service of the community, which constantly characterizes and enriches the course of its history (www.aeronautica.difesa.it). The establishment of the Air Force as an independent armed force, both from an organizational and administrative standpoint, dates back to March 28, 1923, the year of the founding of the Royal Air Force (Regia Aeronautica). However, the origins of Italian military aviation date back a few decades earlier when, within the ranks of the Royal Army (Regio Esercito), a new specialty related to the "lighter-than-air" emerged. On November 6, 1884, under the orders of Lieutenant Alessandro Pecori Giraldi, an Aeronautical Service was established, which in January 1885 became the Aerostatic Section.

[11] VICAR is the Italian acronym corresponding to VUCA, which stands for: Volatile, Uncertain, Complex, Ambiguous, with the additional concept of Rapid evolution.

In 1921, Giulio Douhet, an officer of the Royal Army, was the first to develop a professional doctrine for the use of aviation, advocating the importance of conquering air dominance and considering the airplane as an independent mean, not auxiliary to the army or navy (Errico, 2017). Therefore, the Italian Air Force was born from innovative ideas aspiring to unknown realms. Italy was the third nation in the world, after the USSR and the USA, to put its own artificial satellite into orbit, followed by the launch of San Marco 2 in 1967 and San Marco 3 in 1971 from the San Marco platform in Kenya (UGIS, 10.07.2024). The evolution of the IAF is focused on developing flexible, agile, and rapidly deployable air capabilities for broad spectrum of operational requirements. This transformation is achieved by integrating the potential of Aerospace Power within the broader framework of national defense and international organizations (SMA 9, 2011).

The highly innovative connotation that characterizes the Air Force from a technological and mission perspective permeates all sectors. Some examples, although not exhaustive, include the continuous research and development in the field of training and education by the Training and Managerial Development Unit (Reparto per la Formazione Didattica e Manageriale), which operates at the Institute of Aeronautical Military Sciences (Cacicia & Fontana, 2023), and the continuous research and development in the organizational field, in terms of project/program/portfolio management, quality management, and knowledge management by the General Office for Managerial Innovation (Ufficio Generale per l'Innovazione Manageriale)[12].

6.1 The Importance of Knowledge Management in the Air Force

Knowledge is an intangible organizational asset that must be managed like any other asset. Knowledge Management (KM) is a holistic approach process that creates value by optimizing knowledge and enhancing organizational learning and effectiveness. The quality of data, accuracy of information, and creation of a higher organizational layer of knowledge

[12] The General Office for Managerial Innovation (UIM) is an entity directly under the Chief of the Italian Air Force Staff, responsible for Research & Development in the field of organizational innovation. It provides consultancy to the top management of the organization for the implementation and management of Integrated Innovative Services in Project, Quality, Knowledge, and Human Resource Management, aimed at the continuous improvement of organizational and decision-making processes, as well as the execution of its programs and projects. Additionally, the UIM serves as the Portfolio, Programme, and Project Office (P3O) for the Italian Air Force (www.aeronautica.difesa.it).

(both tacit and explicit) have become strategic capabilities to enable quick and informed decisions with minimal uncertainty.

The application of KM can enhance operational efficiency in military organizations by strengthening group cohesion through team-building activities, informal group meetings, and post-factum analyses. These methods promote communication and collaboration, leading to better decision-making and increased productivity. Furthermore, structured KM training ensures that knowledge is effectively disseminated from decision-makers to operational teams, fostering a culture of knowledge sharing and continuous improvement—essential for adapting to evolving geopolitical and economic realities (Pîrșoi, 2022).

According to UIM-005 Directive (Ufficio Generale per l'Innovazione Manageriale, 2024), in the context of military aviation, the sheer volume, speed, and variety of data and information exchanged make searching complex and costly, increase duplication, and cause misalignment between different versions, resulting in information overload that negatively impacts the organization's ability to make effective, timely, and informed decisions. Furthermore, a significant portion of tacit knowledge, embedded in individuals and built from their experiences, often fails to be transmitted and is lost.

KM encompasses the creation, sharing, use, transfer, development, and storage of knowledge within an organization. It is a fundamental component for any organization, and its principles must be applied at every level. Recent Organizational Analysis activities have highlighted the need to improve the management of informational assets through greater sharing and valuing of knowledge. For example, handling daily work practices via documentary tools, the correspondence of past projects, and the experience accumulated by personnel often are not preserved, tracked, or shared.

Implementing a Knowledge Management System (KMS) supports the paradigm shift from "need to know" to "need to share," where information is managed integrally, emphasizing the responsibility to share, facilitate access, reduce redundancy, and maximize reuse. This approach brings notable benefits, including faster decision-making processes and reduced impacts on knowledge preservation and organization due to personnel turnover.

The objectives of KM in military aviation include (Ufficio Generale per l'Innovazione Manageriale, 2024):

- Enhancing decision-making processes through faster and higher-quality responses to problems.
- Limiting the loss of know-how due to to the high outflows of experienced personnel and frequent turnover.
- Increasing collaboration, idea generation, and the culture of knowledge sharing.
- Gaining organizational advantages from sharing experiences and work methods dispersed across various areas but leading similar processes for service provision.
- Acquiring and storing knowledge in an organized manner to create databases suitable for predictive analytics, estimating future outcomes based on historical data.
- Preparing the organization for the effective use of current and emerging technologies, such as Artificial Intelligence.
- Developing "organizational knowledge" that enables skill growth at both leadership and personnel levels, involving and valuing individuals for their knowledge.

A KM culture must be established, where KM becomes also a modus operandi aiming to limit knowledge loss (due to personnel turnover) and maximize its sharing for continuous cultural growth. The utility and benefits of this approach must be recognizable and tangible at all involved levels, fostering a culture of "good knowledge management." This can be achieved through adequate training via seminars, workshops, and specific courses on KM policies and procedures, sharing and using knowledge techniques, and operational tools. Additionally, leadership must play a proactive role in developing and implementing KM, defining its structure, allocating necessary resources, setting guidelines for objectives and priorities, and applying appropriate performance indicators.

6.2 Squadra 4.0 and Communities: KM strategies in IAF

In recent years, the Operational Command of the Italian Air Force has embarked on a comprehensive modernization process aimed at improving its ability to meet institutional objectives while optimizing the use of its limited resources. Central to the success of this transformation is the implementation of effective governance, which can be understood as the structured management of complex systems. In this context, governance refers to a distributed approach to managing the systemic operations of the Air Force, with a focus on continuous innovation in training, preparation, and command and control functions (Comando Squadra Aerea, 2018).

This holistic governance system is built upon three fundamental pillars: Quality Management (QM), Change Management (CM), and Knowledge Management (KM). These pillars support not only vertical communication within the organization but also horizontal and cross-functional collaboration, ensuring that decision-making and operational processes are more agile and effective. The traditional method of merely digitizing analog processes and compartmentalizing information has proven inadequate, particularly for those in leadership or coordination roles. As a result, the Operational Command is now prioritizing the development of an organizational culture where strategic alignment, knowledge sharing, and process optimization are central to achieving its goals.

One of the key initiatives driving this cultural shift is the "Squadra 4.0 Plan" (Comando Squadra Aerea, 2018) which establishes cross-functional teams, referred to as "maglie," aimed at enhancing transparency, streamlining processes, and encouraging the dissemination of best practices across the organization. These efforts are designed to foster an integrated and dynamic work environment that supports continuous learning and operational excellence, thereby ensuring the highest levels of readiness and capability for the Air Force.

In line with this vision, the Air Force has also experimented with Communities of Practice (CoPs) as a strategy for knowledge sharing. "Squadra 4.0" is one of the organizational contexts where CoPs have been implemented, alongside communities dedicated to specific professional roles. For many of the courses provided by the Department of Educational and Managerial Training (Reparto per la Formazione Didattica Manageriale) at the Institute of Air Force Military Sciences, participants who successfully complete qualifying programs (such as for Project Managers, Moodle Administrators, Quality Managers, and Experiential Trainers) are enrolled in a community that brings together all individuals certified for that particular professional role (Cacicia & Fontana, 2023).

This initiative not only ensures access to updated and relevant work materials but also fosters mutual support among professionals transitioning to practical experience. Additionally, more experienced members can offer advice, share insights, and even learn from the questions posed within the community. This informal approach to training is becoming increasingly valuable for professionals working in their respective departments after obtaining certification. It represents a crucial tool for knowledge management in an organization like the Air Force, where both foundational training and the sharing of field-acquired knowledge are essential.

In my doctoral research, I have identified Communities of Practice as a topic worthy of further investigation. My aim is to explore how this tool, already in use within the Air Force, can be further enhanced to unlock its full potential in improving organizational performance, which still holds significant room for growth.

The case studies presented in Part III of this thesis aim to provide the reader with a clearer understanding of the current state of several important aspects of KM within the IAF. As highlighted in the introductory section of this part, the IAF, due to its unique characteristics in terms of operational activity, innovation, and an organizational culture focused on continuous improvement, has embraced some of the most relevant KM approaches. These include Communities of Practice, Lessons Learned, and Artificial Intelligence, with a particular emphasis on its application in the field of training and education. For this reason, it is considered valuable to dedicate part of this thesis to exploring case studies that specifically examine these three branches developed within the IAF.

In particular, Chapter 7 presents a study I conducted directly on an Organizational Virtual Community of Practice (OVCoP) within the IAF. This study involved a questionnaire administered to participants of an institutional community consisting of Moodle administrators across the IAF. The case study aims to identify the specific features of this community and compare them with the findings from the OVCoP study presented in Chapter 5.

The case study presented in Chapter 8 focuses on the Lessons Learned Management System implemented within the IAF. This chapter provides an analysis of the data related to the process that, within the IAF, moves from the submission of a new observation (i.e., the identification of a problem to be solved) to the definition of a lesson identified and finally to the dissemination of the lesson learned. This analysis helps to understand how the unique organizational aspects of the IAF can influence the process of defining and disseminating lessons learned.

The topic of Artificial Intelligence applied to training in the defense sector is presented in Chapter 9, through the study of a case that describes an innovative project, in which the IAF played a key role in all phases of the project.

Chapter 7 - Case Study 1: A Virtual Community of Practice in the Air Force

As outlined in PART II, my doctoral research focuses on further investigating Organizational Virtual Communities of Practice in IAF. In fact, the model I aim to develop will build on the tools and practices already in use within the IAF, identifying areas for improvement that can optimize performance through effective knowledge management, while taking into account the unique characteristics of the IAF.

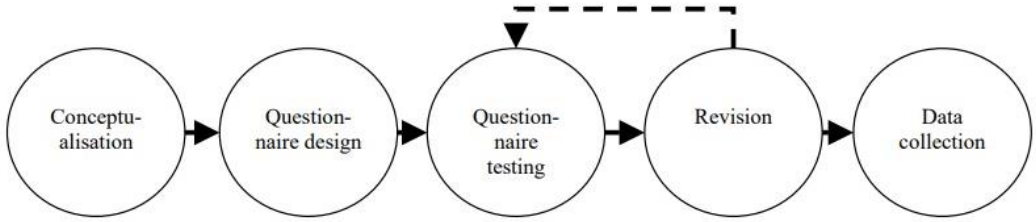
This chapter proposes a case study to delve deeper into the aspects discussed in the chapter 5 regarding OVCoPs. The study is based on a questionnaire administered to a VCoP of Moodle administrators in the Italian Air Force. The questionnaire was chosen as it is a useful tool for gauging the opinions, attitudes, feelings, beliefs, behaviors, etc. of a population (Beck, 2024). Specifically, the purpose of this investigation is to determine whether the findings from the systematic literature review can be empirically observed in an OVCoP whose members are military personnel operating in the organizational contexts of the IAF distributed across the national territory.

The reference sample consists of personnel enrolled in the OVCoP following a course for Moodle Administrators in IAF and likely operating as administrators in anIAF unit using the IAF Moodle platform for organizational purposes such as training, document sharing, questionnaire administration, or evaluation tests.

The Community was established in 2016 and currently consists of 261 participants with varying levels of participation. Additionally, due to turnover in the IAF and changes in assignments, not all 261 members of the community continue to be Moodle administrators in their respective Units.

The design and administration of the questionnaire follow the guidelines indicated by ISTAT in the "Handbook of Recommended Practices for Questionnaire Development and Testing in the European Statistical System" (Brancato et al. 2006).

Figure 15: The stages of questionnaire design and testing (from Brancato et al. 2006)



7.1 Conceptualization

The research questions and themes that guided the composition of the survey are:

1. What is the level of participant engagement?
2. Which elements are necessary for greater engagement.
3. What is the currently perceived utility of the OVCoP?
4. In which of the following areas are the OVCoP's potentialities seen the most:
    a) Human resource development.
    b) Knowledge sharing between experts and newcomers.
    c) Efficiency improvement of work processes.
    d) Innovation/creativity.
    e) Problem solving and decision making.
    f) External relations (between Units).

The questionnaire also aimed to gather additional insights to improve the effectiveness of the OVCoP.

7.2 Questionnaire Design

The survey consisted of 9 questions divided into 3 sections. It was administered anonymously through the Moodle platform (within the Community page itself). The digital format of the survey was preferred both to reach administrators across the national territory and to reduce the burden on respondents and interviewers, allowing for more complex questionnaires to be administered (Vannette & Krosnick, 2017). Additionally, the questionnaire allowed for the modification of previously given responses without losing any relevant information (Brancato et al., 2006).

The questionnaire was divided into 3 parts:

- **Part 1: "General Information"**, which investigates the type of activities performed by participants in the community, the length of membership, and the commitment required for managing Moodle in their respective Units.
- **Part 2: "Level of Engagement"**, which investigates participation in created topics and the participants' inclination to start new topics. One question also revisits engagement aspects in an OVCoP as highlighted in the study presented in Chapter 2:
    1. Positive environment (or psychological safety)
    2. Professional development
    3. Presence of "guiding" roles
    4. Institutional recognition and support
    5. Advanced interaction media
    6. Access to published content

  It also investigates which of these elements are considered most important for engagement in the Moodle Administrators community.

- **Part 3: "Potential Utility and Development"**, which includes 5 Likert-scale items (5 levels) to measure the perceived utility level by participants (for problem-solving and knowledge sharing); one question evaluating on a 5-level scale the participants' perception of the Community's usefulness concerning the dimensions highlighted in the study presented in Chapter 2:
    1. Personnel development (informal learning)
    2. Knowledge sharing (between experts and novices)
    3. Efficiency improvement of work processes
    4. Innovation/creativity (bring innovation to Moodle and new ideas to their respective Unit)
    5. Problem solving and decision making
    6. External relations

Moreover, a final open-ended question was included to gather any improvement suggestions from participants.

7.3 Reliability and Validity of the Survey

To maximize the reliability and validity of the survey, the questions were formulated following the guidelines of Vannette & Krosnick (2017, Chapter 13). Specifically, the following principles were followed in composing the survey questions:

- Use questions that can be asked and answered quickly.
- Ensure questions are clear and precise to minimize incomplete or incorrect responses.
- Motivate respondents by emphasizing the importance of the questionnaire and the contribution they can offer to improving the Community's organization.
- Facilitate understanding of the question's intent.
- Use Open and Closed Questions, considering their peculiarities:
    - **Open Questions**:
        - Standardize only the questions.
        - Do not suggest response alternatives.
        - Require verbatim transcription and complex coding.
    - **Closed Questions**:
        - Standardize both the questions and the responses.
        - Respondents code their own answers.
        - Interviewer training is simple, and data analysis is faster.
- Use five-point scales for unipolar questions.
- Label the scale points clearly and uniformly to facilitate interpretation.
- Follow best practices for question formulation:
    - Be simple, direct, and understandable.
    - Avoid jargon, ambiguity, double-barreled questions, negations, and leading questions.
    - Include filter questions and ensure questions flow smoothly when read aloud.

7.4 Questionnaire Testing and Revision

Questionnaire testing is crucial for identifying issues for both respondents and interviewers related to aspects such as question wording and content, order/context effects, and visual design. Problems with question wording can include confusion over the overall meaning of the question as well as misinterpretation of individual terms or concepts. Issues with skip instructions may lead to missing data and frustration for interviewers and/or respondents (Brancato et al., 2006).

A random sample of 44 Community members was chosen to test the structure and composition of the questionnaire and highlight any critical issues (Bowden et al., 2002; Collins, 2003). The pre-testing phase was conducted anonymously using Moodle's feedback activity. Open-ended questions were included to allow for corrections to the survey and to expand the response options for some multiple-choice questions. Specifically, in question 1, "What activities do you normally perform on Moodle in your Unit?", three additional response options were added that had not been considered previously.). The pre-testing was active for 10 days and collected 17 responses.

7.5 Data Collection

The revised version of the survey was administered to the remaining participants from June 11 to July 4, collecting 58 responses. The pre-testing phase, which included open-ended responses, ensured that all anticipated feedback was integrated. Since the questions were well understood and remained unchanged in the final survey, it was deemed appropriate—though uncommon in the literature—to combine the pre-test results with the subsequent survey data. This approach resulted in a total dataset of 75 records for analysis (see Kelemen, 2022).

7.6 Dataset Preparation

Some categorization operations were necessary to prepare the data for optimal analysis:

1. Among the activities performed, "no activity performed" was introduced since three observations reported not performing any administrative activities at the moment.
2. The entry "I manage exam sessions" received 0 selections. One user indicated "exam sessions" in the "other" field, suggesting a misunderstanding of the entry "I manage exam sessions." Therefore, this column was removed from the dataset as it was not considered a valid measure.

3. Regarding the Engagement dimension, the following dichotomous variables were derived from the question "Which of these elements do you think should be prioritized to ensure a good level of engagement in this community?":

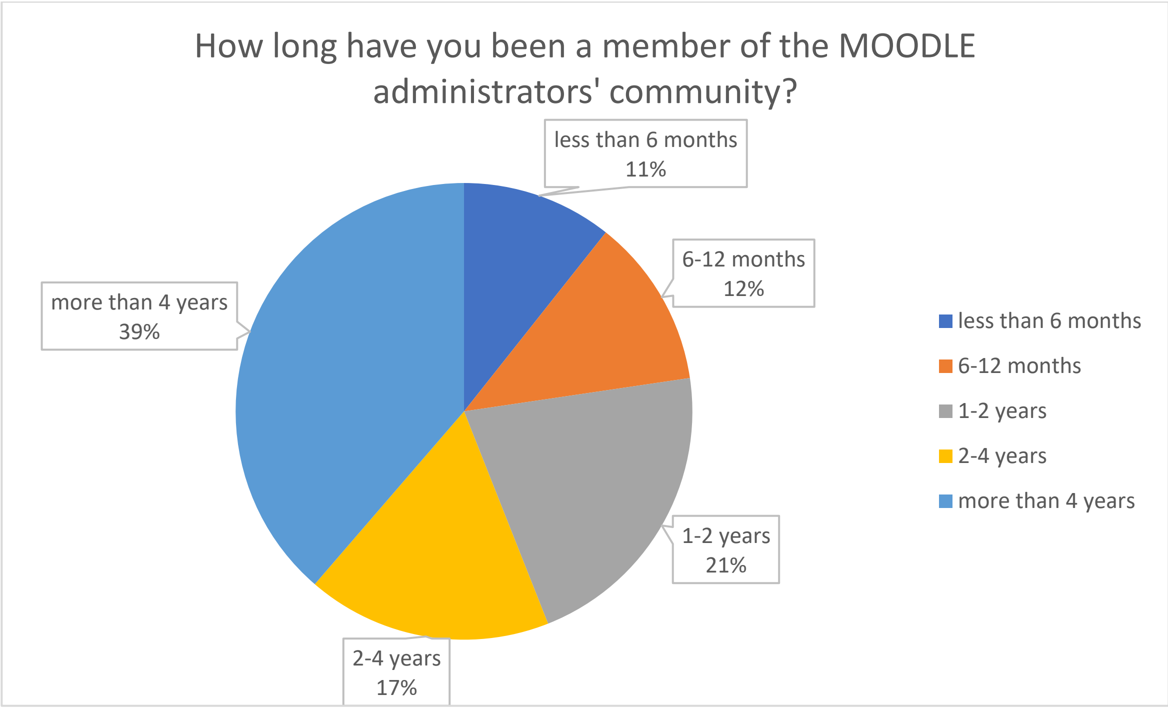
    a. Positive environment
    b. Professional development
    c. Presence of "guiding" roles
    d. Institutional recognition and support
    e. Advanced interaction media
    f. Access to published content

7.7 Results

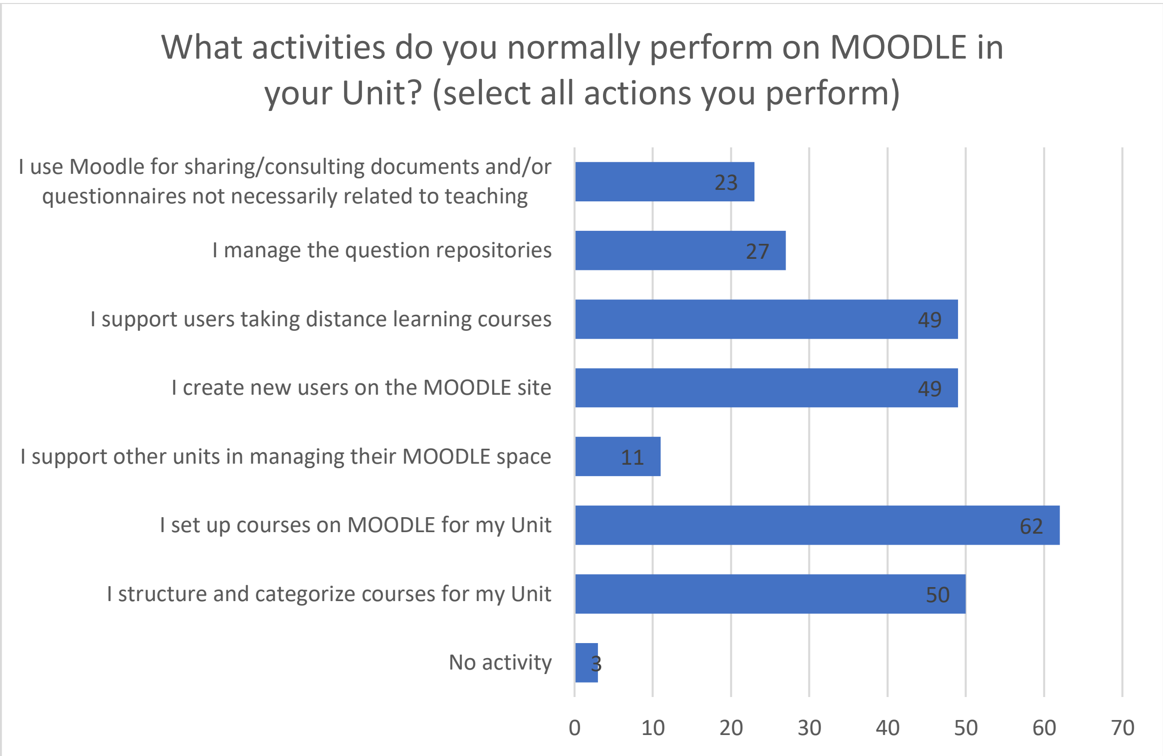
A statistical analysis revealed that the group of respondents is predominantly composed of personnel who have been present in the community for over 2 years (58%). Their main activities on Moodle include setting up course areas for their departments, creating user accounts on Moodle, and providing user support. Only a minority support other departments or do not perform activities within their own department, usually when personnel change roles.

It is interesting to note that 23 out of 75 administrators (30%) use Moodle as a work tool for activities not exclusively related to teaching but for document sharing, thus using Moodle in a broader sense as a Learning Content Management System (Cacicia & Cambria, 2023).

Graph 8: Length of participation in the community

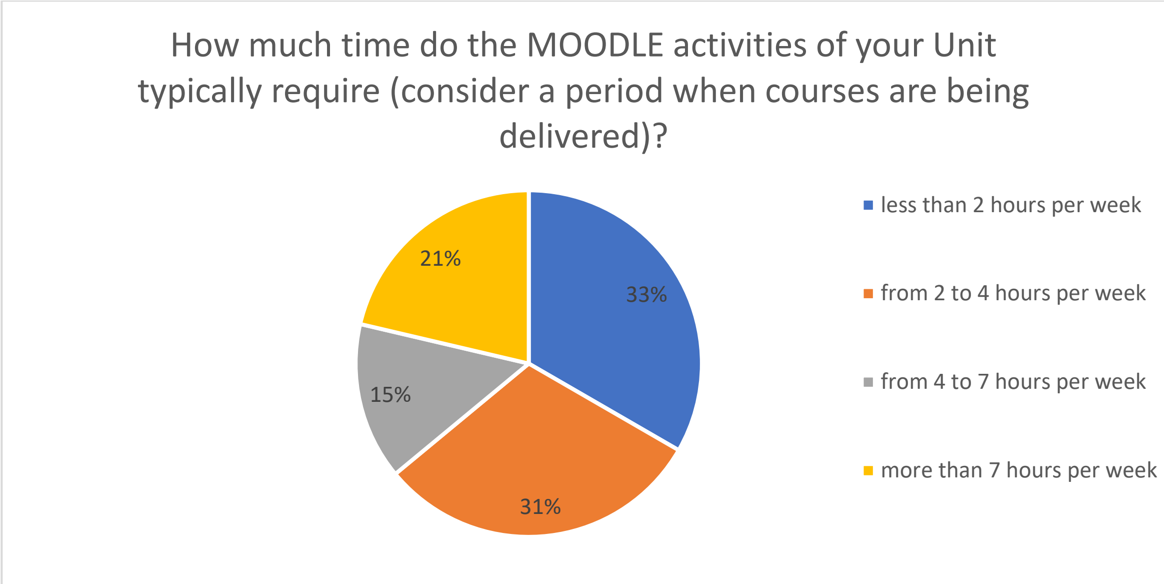


Graph 9: Activities carried out within one's department



It is evident from the results shown in the following graph that most of them do not perform the role of Moodle Administrator exclusively: 64% dedicate less than 4 hours per week to Moodle activities.

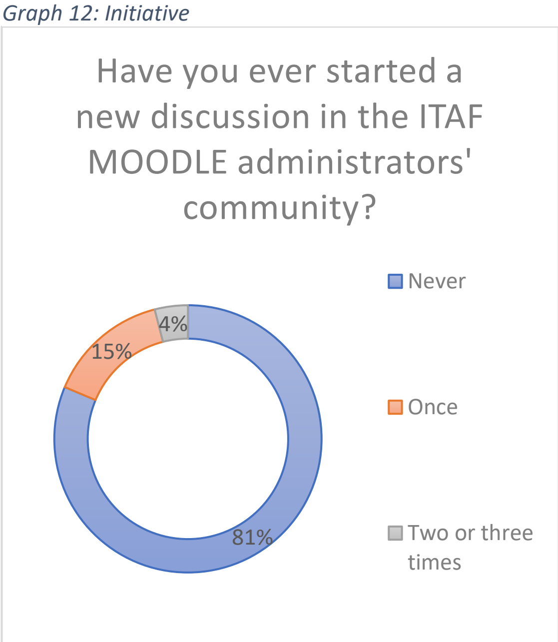
Graph 10: Weekly commitment required from the Moodle administrator



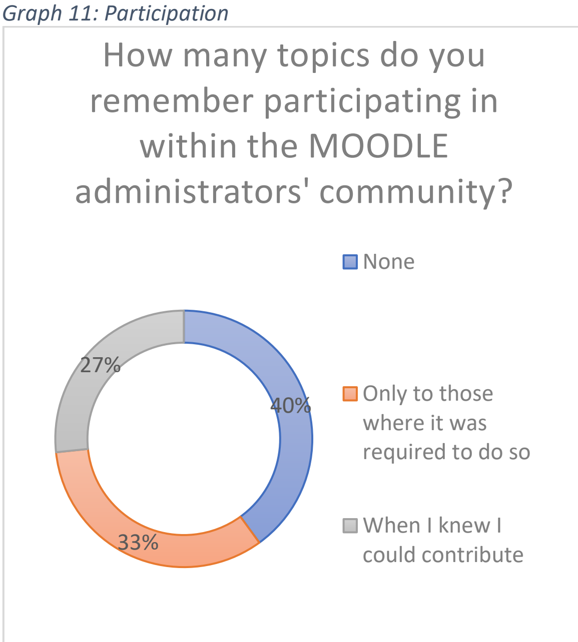
7.8 Engagement

The following charts illustrate the engagement situation, particularly describing the level of participation (Graph 11) and the level of initiative in discussions (Graph 12).

Graph 12: Initiative



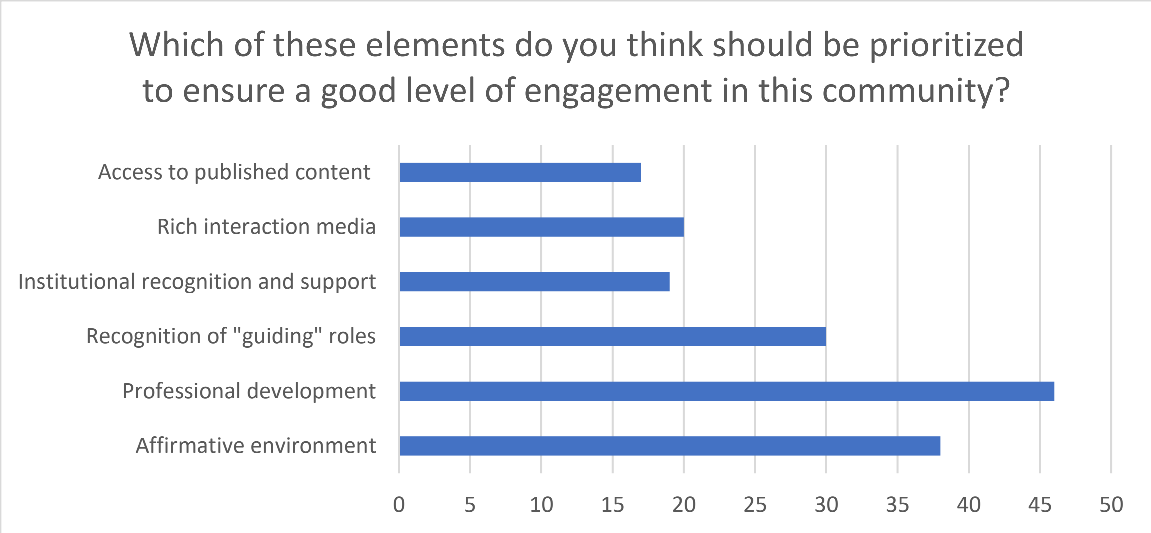
Graph 11: Participation



Engagement is very low: 81% of participants have never written a post, and 40% have never participated in any discussion, while only 27% of members have participated in a discussion, believing they could contribute. Engagement is therefore a critical issue for this OVCoP, both due to the low level of initiative from participants and the limited participation in open topics on the forum.

One question in the survey aimed to investigate the aspects that emerged from the systematic literature review (Chapter 5), specifically which elements, according to the community in question, could increase the level of participant engagement. The distribution of responses is shown below.

Graph 13: Bar Chart: Factors identified by the Community to enhance participant engagement

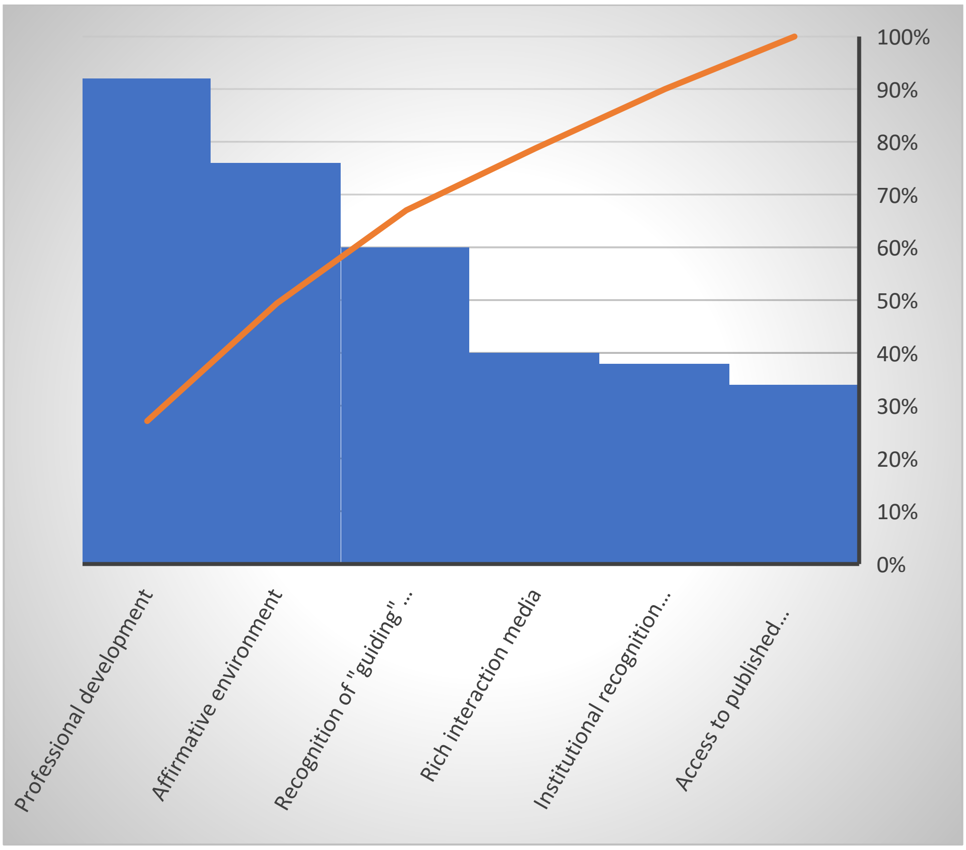


By using a Pareto chart[13] to represent these results, it is possible to display the cumulative frequency curve and highlight the three main elements that together have the greatest impact on engagement. Additionally, to compare these results from the survey with those obtained from the SLR in Chapter 5, a revised version of the Pareto chart from Chapter 5 is provided below, excluding the three least impactful elements (Small dimension, Structured agenda,

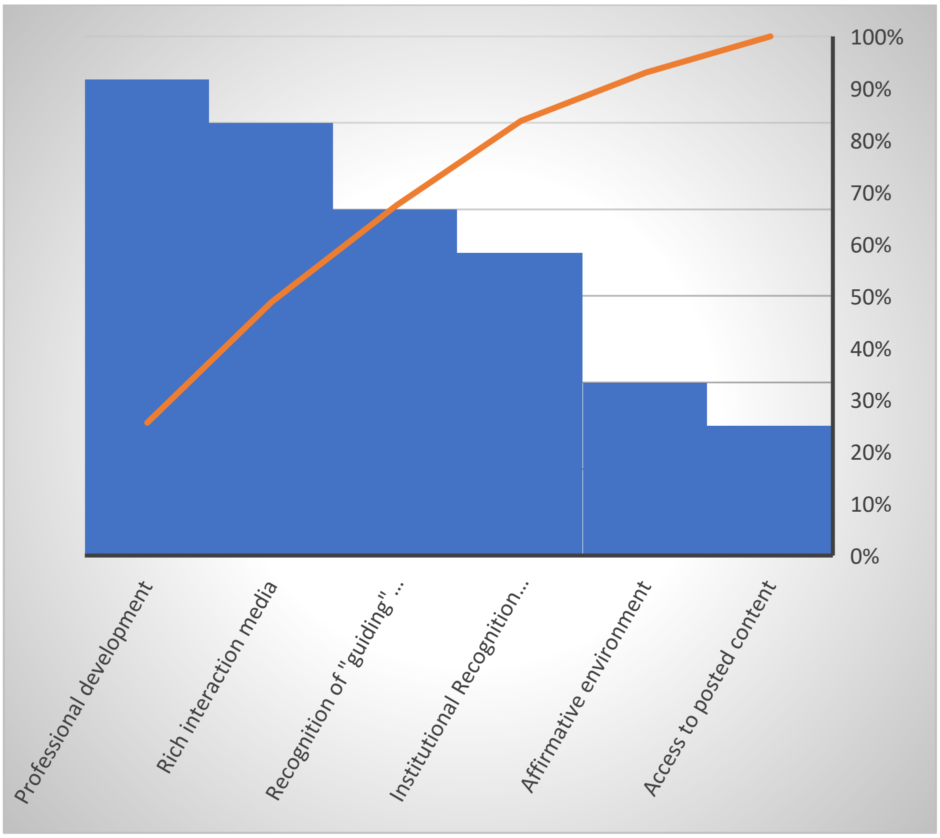
[13] A Pareto chart is a type of bar graph that represents the frequency or impact of certain factors in a dataset, ordered from the most to the least significant. It is based on the Pareto principle, also known as the 80/20 rule, which suggests that roughly 80% of effects come from 20% of the causes. In a typical Pareto chart, bars represent individual factors, while a cumulative line shows the cumulative percentage of the total impact.

and Adaptation of specific strategies for different types of members and CoPs), which were not considered for this study on OVCoP in the IAF.

Graph 14: Pareto chart related to the survey results



Graph 15: Pareto chart elaboration based on the results of the SLR in Chapter 5



This result is very interesting: according to the Systematic Literature Review (SLR), 60% of the relevance to engagement is covered by the following elements:

- Professional development
- Rich interaction media
- Recognition of "guiding" roles

According to the survey conducted on the VCoP in question, 70% of the relevance to engagement is covered by the following elements:

- Professional development
- Affirmative environment
- Recognition of "guiding" roles

This result is intriguing because it highlights a significant alignment between the findings of the SLR and the survey, especially regarding the importance of professional development and the recognition of guiding roles. However, the difference in the third element—"rich interaction media" in the SLR versus "affirmative environment" in the survey—suggests that the specific context of the VCoP may shape which factors are most influential in driving engagement. Understanding these nuances is critical for tailoring engagement strategies to the unique characteristics of different communities of practice.

7.9 Perceived Utility of the Community

Part 3 of the survey aims to measure the perceived utility, both current and potential, of the community and to explore what aspects of improvement might emerge from the participants' opinions. In this section, a question with five items on a five-point bipolar Likert scale is used.

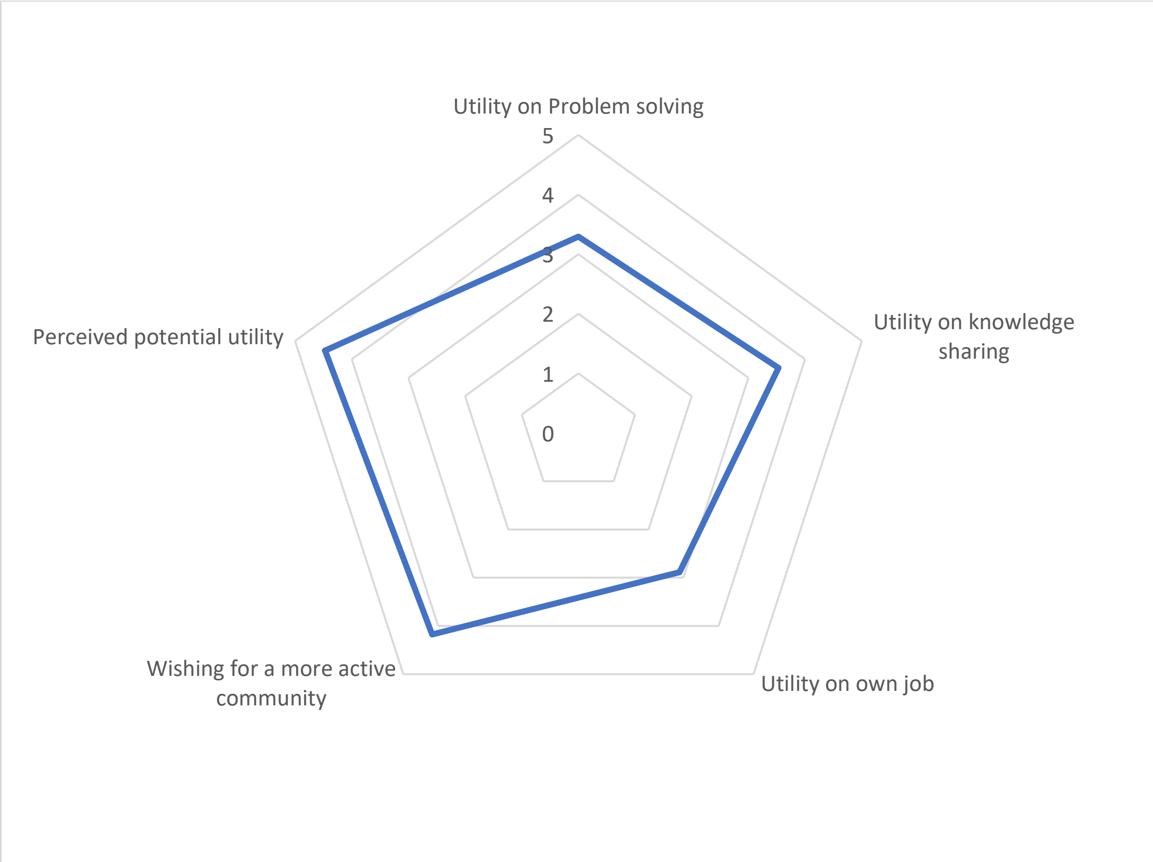
It is important to note that, according to Willits et al. (2016), using multiple items rather than a single question is expected to yield an index that is more reliable, valid, and discriminatory. Single items have considerable random measurement error; instead, a total scale developed from multiple items is expected to be more consistent and reliable than responses to any single item. Such variation is expected to average out when multiple indicators are used (Willits et al., 2016).

Although there are no fixed rules concerning the number of items to include in the final scale, at least four are needed for the evaluation of internal consistency (Diamantopoulos et al., 2012). Moreover, Willits (2016) specifies that many researchers defend the use of data from individual Likert-type items, arguing that single item responses may often be the “best that can be obtained” in practice.

Stand-alone items and those included in multi-item scales can be analyzed separately to provide information on subjects’ responses to specific aspects or components of the whole of which they are a part (Willits et al., 2016).

With this necessary premise on the use of the Likert scale and the interpretation of the resulting data, the following graph shows the averages of the responses divided by item.

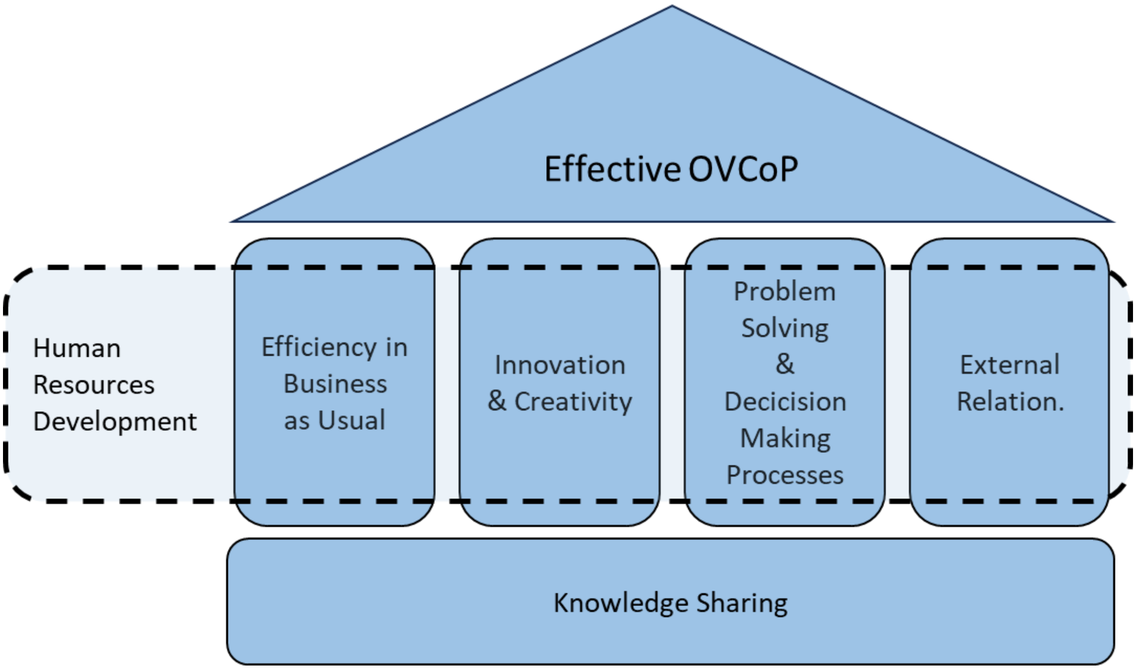
Graph 16: Average values attributed to each item



This representation highlights a strong confidence in the potential of the VCoP tool ("Perceived potential utility" and "Wishing for a more active community" scored high) and a currently perceived utility with an average between indifferent (level 3) and useful (level 4).

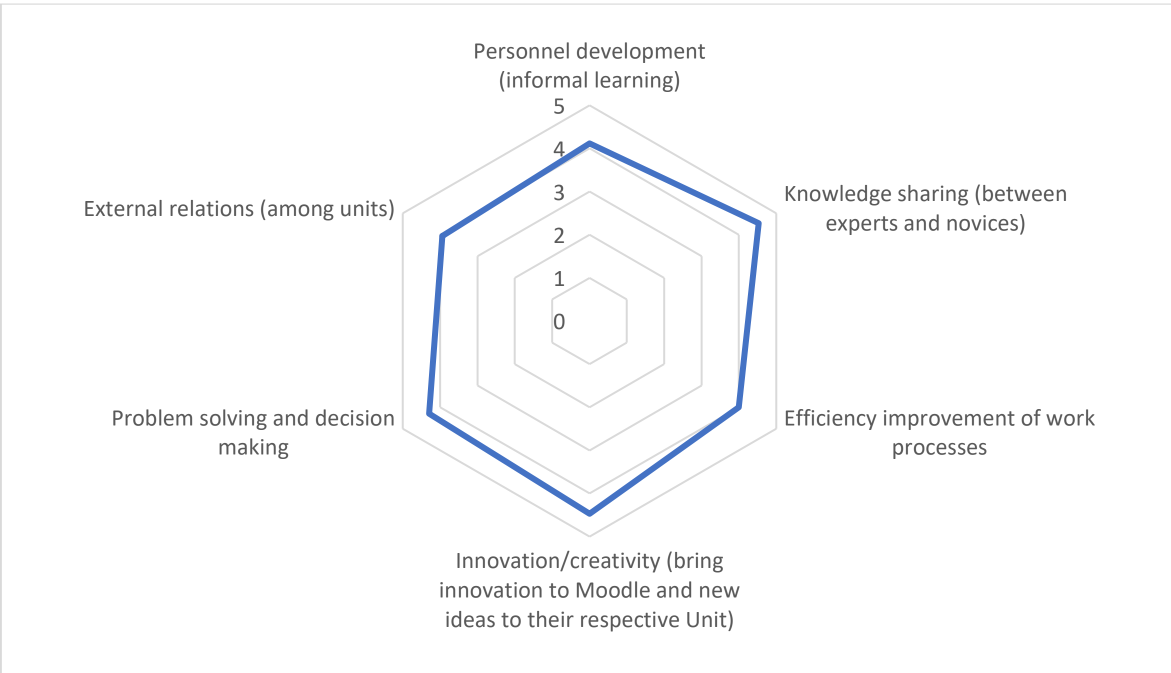
Regarding the model proposed in Chapter 5, which highlights five main areas (plus the KS area) that an OVCoP should target to be an effective tool for the organization, respondents generally agree that the community can be useful in all six areas.

Figure 16: Metaphoric model for effective OVCoPs (see Chapter 5)



The average level of agreement for each area ranges from 3.94 ("external relations") to 4.53 ("Knowledge sharing"), as shown in the follow graph.

Graph 17: Average level of agreement for each area



Finally, here are the results from the open-ended question: "What suggestions would you give to improve the F.A. Moodle Administrators community?" The open-ended responses were reviewed, and a coding activity was conducted to highlight the key concepts from each response. The occurrences of the key concepts are highlighted in the following word cloud

Figure 17: Key concepts emphasized based on the frequency of occurrences in open-ended responses

The main suggestion is to schedule regular meetings, preferably in person (though most suggest VTC using distance meeting platforms). There is a need for tools that enhance direct networking among participants (for example, listing the names and contacts of administrators in the community along with their respective organizations). Updates are requested, either synchronously or asynchronously (for example, by providing shared informational resources on the community or including them in regular meetings). Greater involvement from leadership is desired (Commanders of Departments should be more aware of this tool and encourage participation). Tools supported by artificial intelligence to assist user requests (such as AI-chatbots) are also suggested. Lastly, the creation of a training area is recommended so that administrators can continue to practice the skills acquired during the course without having to operate solely within their Department's area.

7.10 Discussions

The results of this survey confirm many of the elements highlighted in the SLR of Chapter 5. In particular, it has emerged that the participants view the Moodle administrators' OVCoP as a useful tool for knowledge sharing and problem-solving, and they hope for an increase in activity. The business areas that an effective OVCoP should impact are confirmed. The community was found to be not very active, and elements emerged, consistent with what was highlighted in Chapter 5, that are considered useful for increasing engagement: Professional development and Recognition of "guiding" roles. This tells us that, on one hand, the motivation of participants is intrinsic, as they find the tool appealing when it facilitates their professional development. On the other hand, the motivation to participate in a CoP, at least in an organizational context like the one studied, should also be extrinsic, as it requires leadership to drive activities, propose updates, and organize regular meetings.

Chapter 8 – Case Study 2: The Lessons Learned System in IAF

The identity of pilots in the Italian Air Force was once deeply rooted in a cultural system that celebrated risk-taking, where safety and error reporting were secondary to maintaining a reputation of fearlessness. In the past, any mistake made by a pilot was seen as a blemish on their professional image, leading to feelings of shame, loss of esteem, and peer pressure to conceal errors. However, this culture has undergone a significant transformation. Today, safety is regarded as a public good, and error reporting is not only encouraged but considered an ethical responsibility. As one senior pilot put it, "an expert pilot is one who has experienced many errors," reflecting the shift toward a culture that values transparency and learning from mistakes. This new approach places greater respect on squadrons that report more flight mishaps, underscoring the critical importance of openness and continuous improvement in operational safety (Catino & Patriotta, 2013).

To support this cultural shift, structured systems such as the Lessons Learned management system and the Incident Reporting System have been implemented. These systems institutionalize the sharing of knowledge and experiences, transforming individual responsibility into a collective safeguard for the organization. Pilots are encouraged to report their errors, not only to learn from them personally but to ensure that the lessons benefit the entire organization. This culture of reciprocity—where one pilot's mistake or lesson learned in the field becomes valuable knowledge for all—forms the cornerstone of these systems and is essential to fostering a safer, more informed operational environment.

A key element in enhancing this learning process, especially when lessons are drawn from direct experience, is the concept of "Just Culture." Just Culture refers to a balanced approach to managing errors and accountability within organizations, particularly in high-risk fields such as aviation, healthcare, or the military (Marx, 2001). In a Just Culture, human errors are not automatically met with punishment but are instead analyzed in an open and transparent manner to promote learning. This approach strikes a balance between individual accountability and systemic understanding of errors, distinguishing between unintentional mistakes (caused by systemic or human factors) and reckless or negligent behavior that requires corrective action (Dekker, 2016). The goal is to create an environment where members feel safe reporting errors without fear of unfair repercussions, enabling the organization to learn from its mistakes and enhance both safety and operational efficiency.

Numerous organizations, for a long time, have already transitioned into the Knowledge Era, evolving into "knowledge organizations" that recognize the value of knowledge and strategically utilize their intellectual capital and knowledge assets both internally and externally. The desired outcome is a more informed and service-oriented organization, where lessons learned, best practices, expertise, and essential knowledge are effectively shared with employees, management, shareholders, and customers (Liebowitz, 1998).

Moreover, in a military contest (COI-O-AVC-19(C), ed. 2013) the Lessons Identified/Lessons Learned (LI/LL) process generally involves a critical review of completed activities to identify insights that:

- Provide substantial added value in the execution of preparation and conduct of Operations and Exercises;
- Enhance operational capabilities for future activities;
- Ultimately contribute to the development of the military instrument.

Specifically, the LI/LL process comprises a series of activities conducted cyclically and continuously. Its purpose is to transform, through an analytical process, a general Observation made during operations, exercises, seminars, or training activities into a Lesson Identified (LI). Subsequently, by applying at least one Remedial Action (RA), the LId is further developed into a Lesson Learned (LL).

In a complex organization like the Air Force, the Lessons Learned System (LLS) aims to facilitate, promote, and streamline processes aimed at improving the Air Force. These processes often require a cross-functional and hierarchical approach. To this end, the LLS provides a standardized process (the LL Process), an IT platform for managing it (the LL Portal), and a widespread network of officers qualified to manage both.

It is important to highlight that the LL System interfaces with the Defense LLS (SMD[14] and COVI[15]) when necessary. Specifically, the LL Portal is used by the entire Defense Sector

[14] The Defense General Staff, referred to by the acronym SMD (Stato Maggiore della Difesa), is a body of the Italian Armed Forces that falls within the technical-operational area of the Ministry of Defense. It is represented by the Chief of the Defense General Staff and their personnel.

[15] The COVI (Joint Operational Command) is the High Command of the Joint Operational Area and serves as a staff body for the Chief of the Defense General Staff. It is responsible for the planning, coordination, and direction of military operations and exercises, both nationally and internationally, across the five domains: land, sea, air, space, and cyber (www.difesa.it).

through a compartmentalized management system, allowing cross-visibility of processes in each domain only if explicitly permitted by the respective domain procedures

In accordance with the Directive SMA-PIANI-096, the Italian Air Warfare Centre (IT-AWC) serves as the focal point and coordinator for the Air Force in matters related to Lessons Learned (LL). It fulfills this role through its subordinate Operational Analysis and Lessons Learned Section (AOLL).

In this Chapter, a revised excerpt from a statistical report produced during the internship project at the IT-AWC of the COA, the sole holder of the original report, is presented. This revision aims to represent the methodologies adopted and the results useful for this research, omitting data that could be traced back to specific military operations.

The statistical investigation aimed to identify which characteristics, found among the elements of the Lessons Learned (LL) system, can influence the success of the process that moves from a "New Observation" state to a "Lesson Learned" state.

The analysis was conducted using statistical calculation tools (Ms. Excel and SPSS) on a database of 358 cases (also called records) filtered solely within the aeronautical field and downloaded on 27.06.2024.

The study aimed to answer the following questions:

1. Is there a relationship between the current status[16] of the record and the type of originating entity?
2. Is there a relationship between the current status of the record and the sectors of interest assigned to the records?
3. Is there a relationship between the current status of the record and the type of event?
4. Which process activities entail a higher risk of non-completion?

8.1 Composition of the reference sample

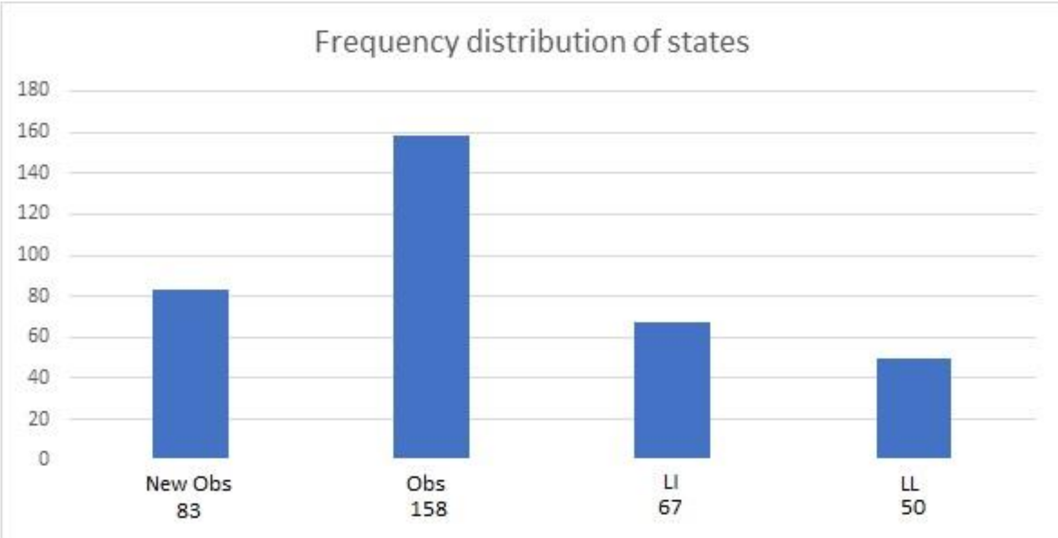
The analyzed dataset consists of 358 records, each corresponding to a case acquired in the LL system as a "New Observation" deemed worthy of analysis to potentially arrive at a solution and, subsequently, shareable as a "Lesson Learned." At the time of analysis, the system reports 83 records in the "New Observation" state, 158 records in the "Observation"

[16] In other words, the current stage of the LL process.

state, 67 records in the "Lesson Identified" state, and 50 records in the "Lesson Learned" state.

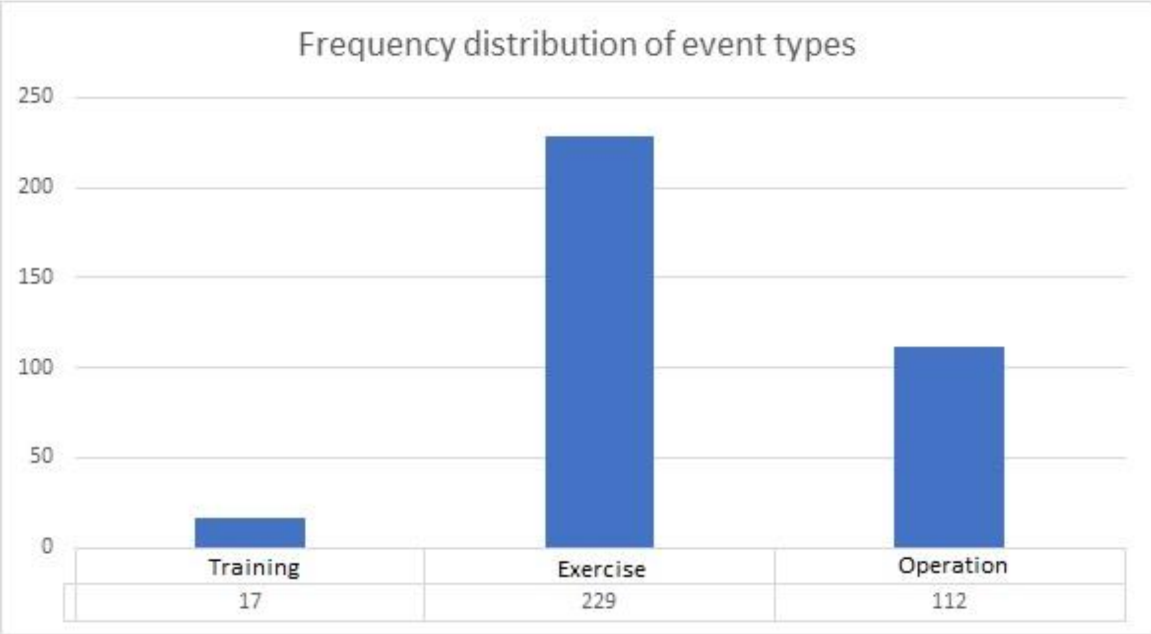
These four states represent the four necessary steps to move from identifying a problem recorded on the LL platform (a "New Observation") to identifying a lesson to share and disseminate within the platform (a "Lesson Learned"). The frequency distribution of the states of the records is shown in the following bar chart.

Graph 18: The frequency distribution of the states of the records



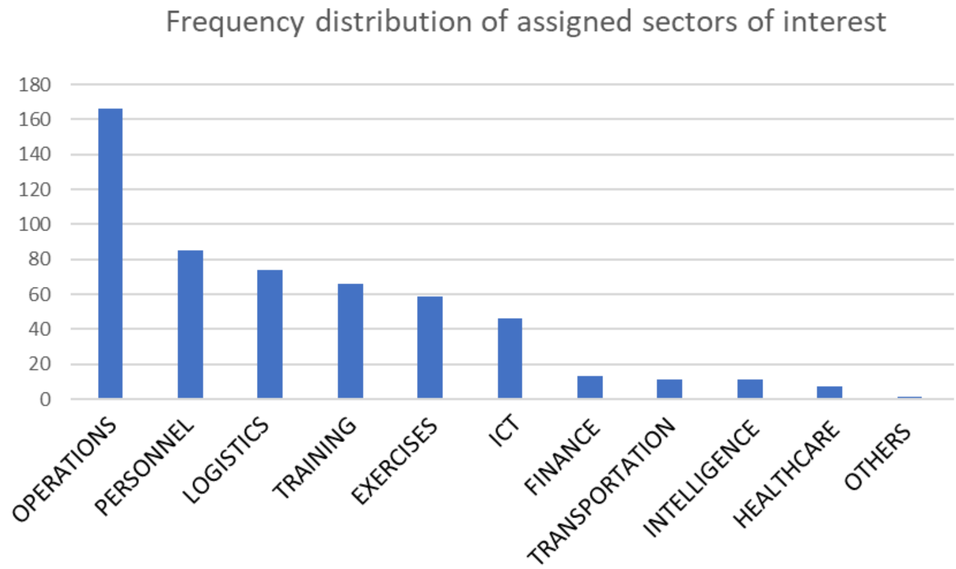
Each record was acquired along with a label indicating the type of event in which the observation occurred. At the time of analysis, 17 records are associated with a training event, 229 records are associated with an exercise event, and 112 records are associated with an operational event. Below is a graphical representation of the distribution of event types associated with the records present on the platform.

Graph 19: Distribution of event types associated with the records present on the platform



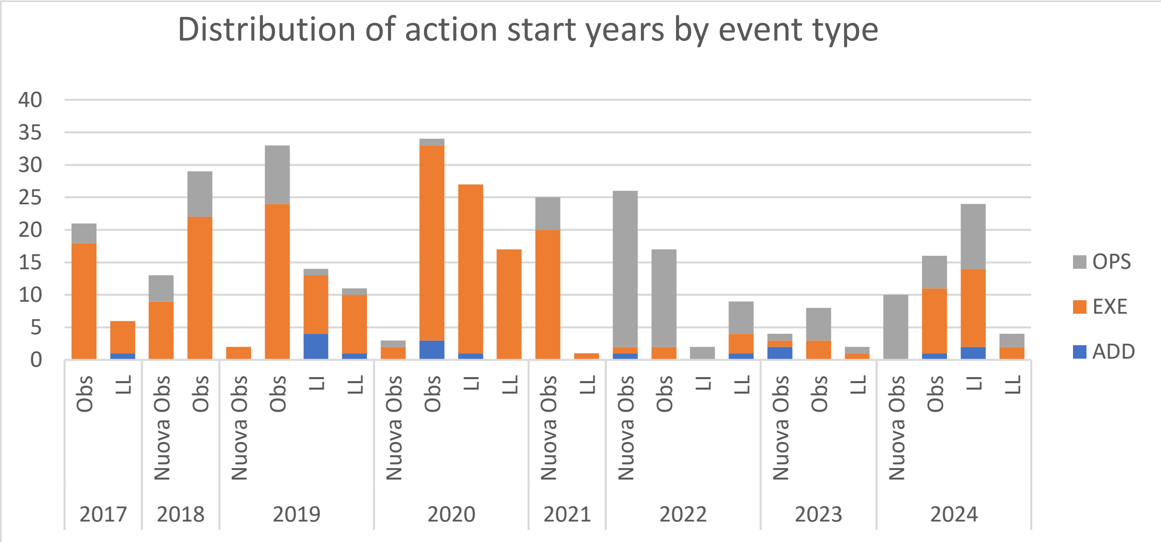
At the time of entering a new observation, the user assigns one or more labels to the record related to the sectors of interest they believe are most relevant to the problem being analyzed. The following chart shows the frequency distribution of the sectors of interest for the records on the platform. The most significant specific sectors of interest (excluding the "operations" label) recorded on the platform are: personnel, logistics, and telecommunications.

Graph 20: Frequency distribution of the sectors of interest for the records on the platform



If we consider the "action start date" field, it is possible to determine when the last action related to each record began. Consequently, we can get an idea (albeit approximate) of when the current status of the record started. With these premises, we can analyze the percentage of new observations, observations, lessons identified, and lessons learned recorded each year across different types of events, as shown in the following chart.

Graph 21: Distribution of action start years by event type



8.2 Inferential Statistical Analysis

To address the questions posed in the introduction, inferential statistical analyses were conducted. For this purpose, the dataset was recoded to prepare the variables of greatest interest.

8.2.1 Question 1: "Is there a relationship between the current status of the record and the type of originating entity?"

To categorize the originating entities present on the platform, a research effort was undertaken to identify the most relevant characteristics of the entities associated with the records. For each originating entity, a "hierarchical context" category with four exclusive modes was assigned (each entity has one and only one of the following modes): 1. COMMAND; 2. BRIGADE; 3. WING/UNIT; 4. TASK FORCE AIR. Additionally, each originating entity was assigned a "mission" category, highlighting one or more capabilities for BRIGADE and WING/UNIT entities among the following:

- AIR DEFENSE;
- COMBAT;
- TRANSPORT;
- SEARCH & RESCUE;
- TRAINING;
- SUPPORT;
- ELECTRONIC WARFARE.

Strings indicating originating entities that would result in the inclusion of characteristics attributable to an excessively small number of entities (47 records) were eliminated.

Regarding the hierarchical context, let's formulate the two hypotheses to be studied:

H_0: The variable "current status of the record" and the variable "hierarchical context" are statistically independent.

H_1: The variables "current status of the record" and "hierarchical context" are related to each other.

A contingency table was constructed and a Chi-square test was performed. The contingency table below shows the values of the two variables in comparison: the hierarchical levels of the originating entities (1=COMMAND; 2=BRIGADE; 3=WING/UNIT; 4=TASK FORCE AIR) and the status of the record (1=New Observation; 2=Observation; 3=Lesson Identified; 4=Lesson Learned). In the analysis, these two variables can be considered as ordinal qualitative variables (Stevens, 1946). The contingency table, shown below, illustrates the distribution of cases between the variables "Status" and "Hierarchical Context".

*Table 14: Contingency Table: Status * Hierarchical Context*

			Hierachical Context				Total
			1	2	3	4	
State	1	Count	16	3	30	11	60
		Expected count	28,0	3,5	19,1	9,5	60,0
	2	Count	64	10	49	25	148
		Expected count	69,0	8,6	47,1	23,3	148,0
	3	Count	32	4	12	9	57
		Expected count	26,6	3,3	18,1	9,0	57,0
	4	Count	33	1	8	4	46

	Expected count	21,4	2,7	14,6	7,2	46,0
Total	Count	145	18	99	49	311
	Expected count	145,0	18,0	99,0	49,0	311,0

In the contingency table "Status * Hierarchical Context," the rows represent different states or categories for "Status," while the columns represent the "Hierarchical Context" levels. For each combination of "Status" and "Hierarchical Context," the table provides two values: the observed count (i.e., the actual number of cases observed in the dataset) and the expected count (i.e., the number of cases we would expect if the two variables were independent)[17]. By comparing the observed and expected counts, we can see discrepancies that suggest a potential relationship between the variables. When the observed counts significantly differ from the expected counts, it may indicate that "Status" and "Hierarchical Context" are not independent, implying a possible association between the two variables.

Hierarchical Context 1 (COMMAND):

- Status 1 (New Observation): 16 (expected 28.0)
- Status 2 (Observation): 64 (expected 69.0)
- Status 3 (Lesson Identified): 32 (expected 26.6)
- Status 4 (Lesson Learned): 33 (expected 21.4)
- Total: 145

[17] The expected count is calculated based on the assumption of independence between the variables, using the following formula:

$$Expected\ Count = \frac{Row\ Total \times Column\ Total}{Overall\ Total}$$

Where:

- The *Row Total* is the sum of the observed counts for a given row (i.e., for a specific "Status").
- The *Column Total* is the sum of the observed counts for a given column (i.e., for a specific "Hierarchical Context").
- The *Overall Total* is the sum of all observed counts in the table.

For example, for the first row (State 1, Hierarchical Context 1):

- The row total for State 1 is 60.
- The column total for Hierarchical Context 1 is 145.
- The overall total is 311.

Thus, the expected count for State 1, Hierarchical Context 1 would be:

$$Expected\ Count = \frac{60 \times 145}{311} \approx 28$$

Hierarchical Context 2 (BRIGADE):

- Status 1 (New Observation): 3 (expected 3.5)
- Status 2 (Observation): 10 (expected 8.6)
- Status 3 (Lesson Identified): 4 (expected 3.3)
- Status 4 (Lesson Learned): 1 (expected 2.7)
- Total: 18

Hierarchical Context 3 (WING/UNIT):

- Status 1 (New Observation): 30 (expected 19.1)
- Status 2 (Observation): 49 (expected 47.1)
- Status 3 (Lesson Identified): 12 (expected 18.1)
- Status 4 (Lesson Learned): 8 (expected 14.6)
- Total: 99

Hierarchical Context 4 (TASK FORCE AIR):

- Status 1 (New Observation): 11 (expected 9.5)
- Status 2 (Observation): 25 (expected 23.3)
- Status 3 (Lesson Identified): 9 (expected 9.0)
- Status 4 (Lesson Learned): 7 (expected 7.2)
- Total: 49

Totals by Status:

- Status 1 (New Observation): 60
- Status 2 (Observation): 148
- Status 3 (Lesson Identified): 57
- Status 4 (Lesson Learned): 46

Totals by Hierarchical Context:

- Hierarchical Context 1 (COMMAND): 145
- Hierarchical Context 2 (BRIGADE): 18
- Hierarchical Context 3 (WING/UNIT): 99
- Hierarchical Context 4 (TASK FORCE AIR): 49

The Chi-square test, used to determine whether there is a significant relationship between the variables "Status" and "Hierarchical Context," produced the following results:

- Pearson Chi-square: 27.531, with 9 degrees of freedom (df) and a p-value (Asymp. Sig.) of 0.001
- Likelihood Ratio: 28.061, with 9 degrees of freedom (df) and a p-value (Asymp. Sig.) of 0.001
- Linear-by-Linear Association: 19.691, with 1 degree of freedom (df) and a p-value (Asymp. Sig.) of 0.000

Table 15: Chi-square test

	Value	df	Asymp. Sig. (2-seded)
Pearson Chi-square	27,531[a]	9	,001
Likelihood Ratio	28,061	9	,001
Linear-by-Linear Association	19,691	1	,000
Number of Valid Cases	311		

a. 3 cells (18.8%) have an expected count less than 5. The minimum expected count is 2.66.

The Chi-square test, used to determine whether there is a significant relationship between the variables "Status" and "Hierarchical Context," produced the following results:

Pearson Chi-Square:

- The Pearson Chi-square value is 27.531 with 9 degrees of freedom and a p-value of 0.001.
- Since the p-value is less than 0.05, we can conclude that there is a statistically significant relationship between "Status" and "Hierarchical Context."

Likelihood Ratio:

- The likelihood ratio is 28.061 with 9 degrees of freedom and a p-value of 0.001.
- This test also confirms a significant relationship between the two variables.

Linear-by-Linear Association:

- The linear-by-linear association value is 19.691 with 1 degree of freedom and a p-value of 0.000.
- This suggests that there is a significant linear relationship between the variables "Status" and "Hierarchical Context."

The tests conducted lead to the exclusion of the null hypothesis and consider hypothesis H_1 as plausible (Greenland, 2016), showing that there is a statistically significant relationship between "Status" and "Hierarchical Context." The differences between observed and expected counts indicate that the distribution of cases across categories is not random. This may suggest that the hierarchical context impacts the observed status.

The following table provides the values of the tests that typically provide information on the "measure" of the relationship in terms of intensity and direction.

Table 16: Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Nominal by Nominal	Phi	,298			,001
	Cramer's V	,172			,001
	Contingency Coefficient	,285			,001
Interval by Interval	Pearson's R	-,252	,053	-4,578	,000[c]
Ordinal by Ordinal	Spearman Correlation	-,249	,053	-4,517	,000[c]
Number of Valid Cases		311			

a. Not assuming the null hypothesis.
b. Using the asymptotic standard error based on the null hypothesis.
c. Based on the normal approximation

The Phi coefficient shows a moderate relationship between the two nominal variables, with a value of 0.298 suggesting a medium-strength association. The significance, indicated by a p-value of 0.001, means this relationship is highly significant.

Similarly, Cramer's V, which also measures the strength of association between nominal variables, has a value of 0.172, indicating a weak to moderate relationship. Again, the significance of 0.001 confirms that the association is statistically relevant.

The contingency coefficient, used to evaluate the strength of association between nominal variables, shows a value of 0.285, indicating a moderate relationship. Once more, the p-value of 0.001 supports the significance of this relationship.

For interval variables, Pearson's correlation coefficient reveals a weak to moderate negative relationship, with a value of -0.252. This suggests that as one variable increases, the other tends to decrease (i.e., moving from Command to Task Force Air, it is more likely to transition from Lesson Learned to New Observation). The significance of 0.000 indicates this relationship is highly significant.

Regarding ordinal variables, Spearman's correlation coefficient measures a weak to moderate negative relationship, with a value of -0.249. Here too, the significance of 0.000 confirms the importance of the observed relationship.

The number of valid cases used in the analysis is 311, suggesting a sufficiently large sample to ensure the robustness of the results. Overall, the results indicate significant associations between the variables. The strength of the association ranges from weak to moderate, but all relationships are significant with a p-value < 0.05.

Regarding the mission, it was necessary to create the following dichotomous variables (with possible values of 1 or 0):

- AIR DEFENSE
- COMBAT
- TRANSPORT
- SEARCH & RESCUE
- TRAINING
- SUPPORT
- ELECTRONIC WARFARE

Moreover, for this analysis, only the records of Brigades and Wings/Units were considered, as only these were deemed related to a mission with specific peculiarities. The reference sample thus consists of 127 records.

The composition of the dataset lends itself well to a cluster analysis (Hennig, 2015). In particular, the K-means algorithm was used, because particularly useful when classical second order statistics (the sample mean and covariance) cannot be used (Morissette & Chartier, 2013), setting K=4 (since there are 4 possible states) to verify if the cluster composition indicates a statistical relationship between the state of a record and the peculiar mission of the originating entity.

The results were evaluated through the final cluster centers, ANOVA, and the iteration history.

Table 17: ANOVA (with K=4)

	Cluster		Error		F	Sig.
	Mean square	df	Mean square	df		
State	21,361	3	,239	123	89,333	,000
AIR DEFENSE	,380	3	,086	123	4,444	,005
COMBAT	4,903	3	,100	123	48,965	,000
TRANSPORT	,445	3	,109	123	4,088	,008
SEARCH & RESCUE	,304	3	,081	123	3,758	,013
TRAINING	2,583	3	,139	123	18,531	,000
SUPPORT	1,445	3	,107	123	13,468	,000
ELECTRONIC WARFARE	,067	3	,045	123	1,505	,217

F tests should be used only for descriptive purposes since the clusters were chosen to maximize the differences between cases in different clusters. The observed significance levels are not corrected and thus cannot be interpreted as tests of the hypothesis that the cluster means are equal.

ANOVA was used to determine which variables contribute most to differentiating between clusters:

- The ordinal qualitative variable "State" is highly significant in differentiating between clusters. (F: 89.333, Sig.: 0.000)
- The dummy, categorical dichotomous variables that are statistically significant in differentiating between clusters are:
  - **AIR DEFENSE** (F: 4.444, Sig.: 0.005)
  - **COMBAT** (F: 48.965, Sig.: 0.000)
  - **TRANSPORT** (F: 4.088, Sig.: 0.008)
  - **SEARCH & RESCUE** (F: 3.758, Sig.: 0.013)
  - **TRAINING** (F: 18.531, Sig.: 0.000)
  - **SUPPORT** (F: 13.468, Sig.: 0.000)

Convergence was achieved at the second iteration, with minimal changes in the cluster centers.

Table 18: Final cluster centers (with K=4)

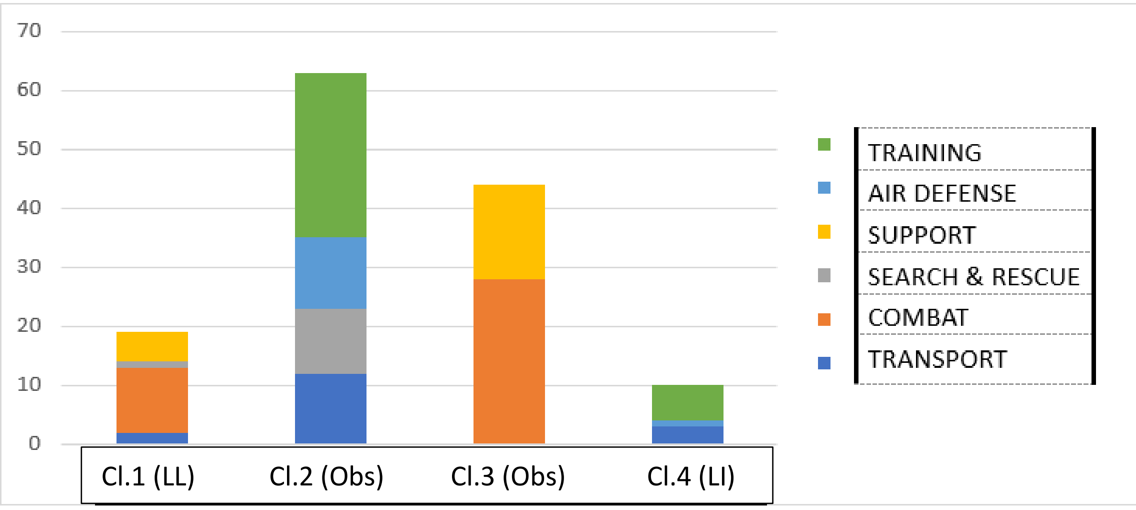
	Cluster			
	1	2	3	4
State	4	2	2	3
AIR DEFENSE	0	0	0	0
COMBAT	1	0	1	0
TRANSPORT	0	0	0	0
SEARCH & RESCUE	0	0	0	0
TRAINING	0	0	0	1
SUPPORT	0	0	0	0
ELECTRONIC WARFARE	0	0	0	0

The final cluster centers provide an average representation of the variables for each cluster:

- **Cluster 1:** Associated with state 4 "Lesson Learned"
- **Cluster 2:** Associated with state 2 "Observation"
- **Cluster 3:** Associated with state 2 "Observation"
- **Cluster 4:** Associated with state 3 "Lesson Identified"

Below is the graphical representation of the composition of the four clusters, considering only the specific missions that were found to be significant.

Graph 22: Composition of the clusters (with K=4)



Clusters 2 and 3 both correspond to the "Observation" state and mostly include records from entities whose mission is related to training, combat, and support. Cluster 4 corresponds to the "Lesson Identified" state and primarily contains records from training and transport entities. Cluster 1 corresponds to the "Lesson Learned" state and mainly includes records from combat, support, and transport entities. This analysis suggests, with appropriate caution, that observations originating from entities with missions related to combat, transport, and support activities are more likely to complete the lessons learned process and be disseminated within the Air Force as learned lessons.

Let's delve deeper with a cluster analysis with K=5. The results are presented below.

Table 19: Final cluster centers (with K=5)

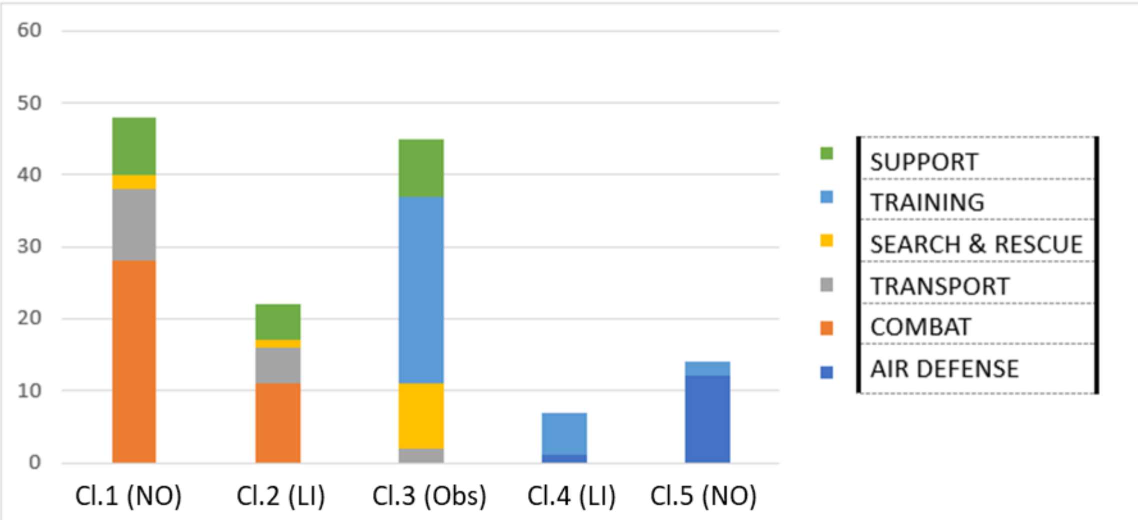
	Cluster				
	1	2	3	4	5
State	1	3	2	3	1
AIR DEFENSE	0	0	0	0	1
COMBAT	1	1	0	0	0
TRANSPORT	0	0	0	0	0
SEARCH & RESCUE	0	0	0	0	0
TRAINING	0	0	1	1	0
SUPPORT	0	0	0	0	0
ELECTRONIC WARFARE	0	0	0	0	0

Table 20: ANOVA (with K=5)

	Cluster		Errore		F	Sig.
	Mean square	df	Mean square	df		
State	19,368	4	,131	122	147,437	,000
AIR DEFENSE	2,709	4	,007	122	396,596	,000
COMBAT	2,954	4	,125	122	23,692	,000
TRANSPORT	,338	4	,110	122	3,082	,019
SEARCH & RESCUE	,202	4	,082	122	2,449	,050
TRAINING	3,063	4	,104	122	29,556	,000
SUPPORT	,172	4	,138	122	1,246	,295
ELECTRONIC WARFARE	,037	4	,046	122	,818	,516

F tests should be used only for descriptive purposes since the clusters were chosen to maximize the differences between cases in different clusters. The observed significance levels are not corrected and thus cannot be interpreted as tests of the hypothesis that the cluster means are equal.

Graph 23: Composition of the clusters (with K=5)



In this case, besides the "Electronic Warfare" capability, the "Support" capability also turns out to be not statistically significant. Let's analyze the composition of the 5 clusters: in clusters 1 and 5 (corresponding to the "New Observation" state), we mainly find records originating from AIR DEFENSE, combat, and transport entities. In clusters 2 and 4 (corresponding to the "Lesson Identified" state), we find many records originating from combat entities but very few from AIR DEFENSE, transport, and SEARCH & RESCUE entities (training, SEARCH & RESCUE, and support entities are instead found among the originators of records in the "Observation" state).

This evidence tends to confirm the conclusions previously drawn and introduces another element: DAMI[18] and S&R entities are less likely to originate records that will progress to the LL state. In light of this, regarding the first question, we can conclude that Wings/Units operating in the S&R and DAMI domains are less likely to see the process from observation to LL completion compared to entities with missions related to Combat, Support, and Transport tasks. Finally, observations identified by Command entities are more likely to successfully complete the entire LL process.

8.2.2 Question 2: "Is there a relationship between the current status of the record and the sectors of interest assigned to the records?"

Since it is possible to assign more than one label to a record regarding the sector of interest at the time of entry, for the correlation analysis, the "Sector of Interest" variable was transformed into 11 boolean dummy variables (0 or 1) as follows: OPERATIONS; TRANSPORT; PERSONNEL; LOGISTICS; FINANCIAL; TRAINING; EXERCISES; HEALTHCARE; ITC; SIMULATION; INTELLIGENCE.

To answer question 2, similar to question 1, various cluster analysis alternatives were explored, choosing K=2,3,4,5, but in no case did the results suggest a correlation between the assigned sectors of interest and the record's status.

8.2.3 Question 3: "Is there a relationship between the current status of the record and the type of event?"

The variables "Current Status of the Record" and "Type of Event" are two qualitative variables. The first is ordinal with 4 modes (1=New Obs., 2=Observation, 3=LI, 4=LL), while the second is nominal with 3 modes (1=Operation, 2=Exercise, 3=Training). To study a correlation between these variables, the Chi-square test can be applied on the following hypotheses (Gunawardana, 2004):

H_0: The variables "Current Status of the Record" and "Type of Event" are independent.

[18] DAMI is an acronym that stands for Difesa Aerea Missilistica Integrata (Integrated Air and Missile Defense).

H_1: The variables "Current Status of the Record" and "Type of Event" are correlated.

Table 21: Chi-Square Test

	Value	df	Asympt. Sig. (2-sided)
Pearson Chi-Square	30,654[a]	6	,000
Likelihood Ratio	28,380	6	,000
Linear-by-Linear Association	17,417	1	,000
Number of Valid Cases	322		

The Chi-square test highlights a statistically significant correlation between the two variables. Therefore, we reject the null hypothesis and consider hypothesis H_1 acceptable (Greenland, 2016). In particular, looking at the Table 22, it is noticeable that the counts for type 1 (Operation) and type 2 (Exercise) differ from the expected counts, indicating that operations register statistically more LL and LI compared to exercises and training events. This suggests that operational events are more likely to result in LI and LL compared to training and exercise events.

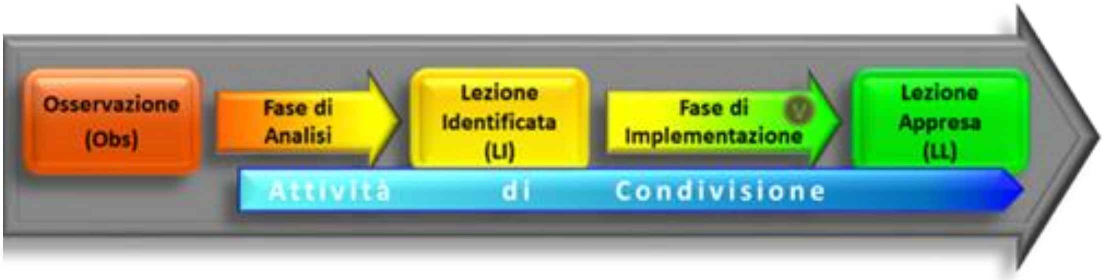
*Table 22: : Contingency Table: State * Event Type*

			Event type			Totale
			1	2	3	
State	1	Count	38	30	2	70
		Expected count	21,5	45,4	3,0	70,0
	2	Count	41	104	4	149
		Expected count	45,8	96,7	6,5	149,0
	3	Count	11	40	6	57
		Expected count	17,5	37,0	2,5	57,0
	4	Count	9	35	2	46
		Expected count	14,1	29,9	2,0	46,0
Total		Count	99	209	14	322
		Expected count	99,0	209,0	14,0	322,0

8.2.4 Question 4: "What are the process activities that entail the highest risk of non-completion?"

To perform this analysis, it is essential to identify the chronological order of possible actions on the platform relative to the four possible states:

Figure 18: Graphical Representation of the Lessons Learned Process



NEW OBSERVATION

- Completeness assessment

OBSERVATION

- Execution of the analysis phase
- Completion of the analysis
- Execution of the evaluation phase
- Completion of the evaluation phase

LESSON IDENTIFIED

- Lesson identified and pending approval
- Lesson identified and approved
- Execution of the corrective phase
- Completion of the corrective phase

LESSON LEARNED

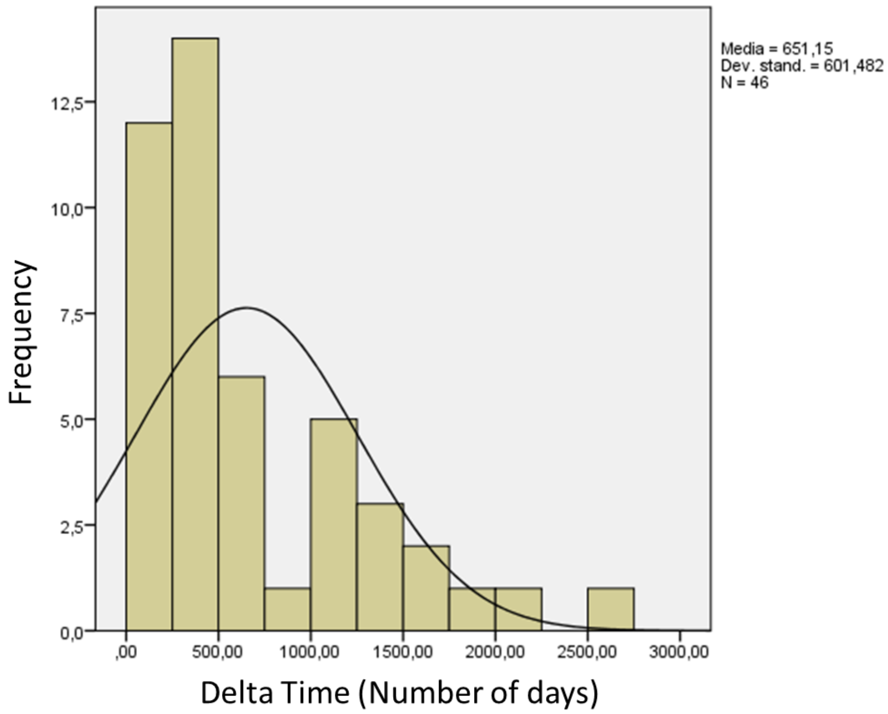
- Dissemination of the learned lesson

Now, we create three new time-related variables:

- **"Delta time"** which calculates in days the time between the date of observation and the date of the ongoing action.
- **"Record age"** which is the difference in days between the dataset download date and the record observation date.
- **"Waiting time"** which is the difference in days between the dataset download date and the start date of the last action.

Next, we calculate the average "Delta time" for the LLs, which determines the average number of days it takes for a process to conclude optimally, that is, with the dissemination of an LL. The result is 651 days (std. dev. 601.48), with a maximum value of 2,631 days and a minimum value of 81 days, indicating that, on average, it takes almost two years to complete the entire LL process successfully. Below is the Delta time statistics.

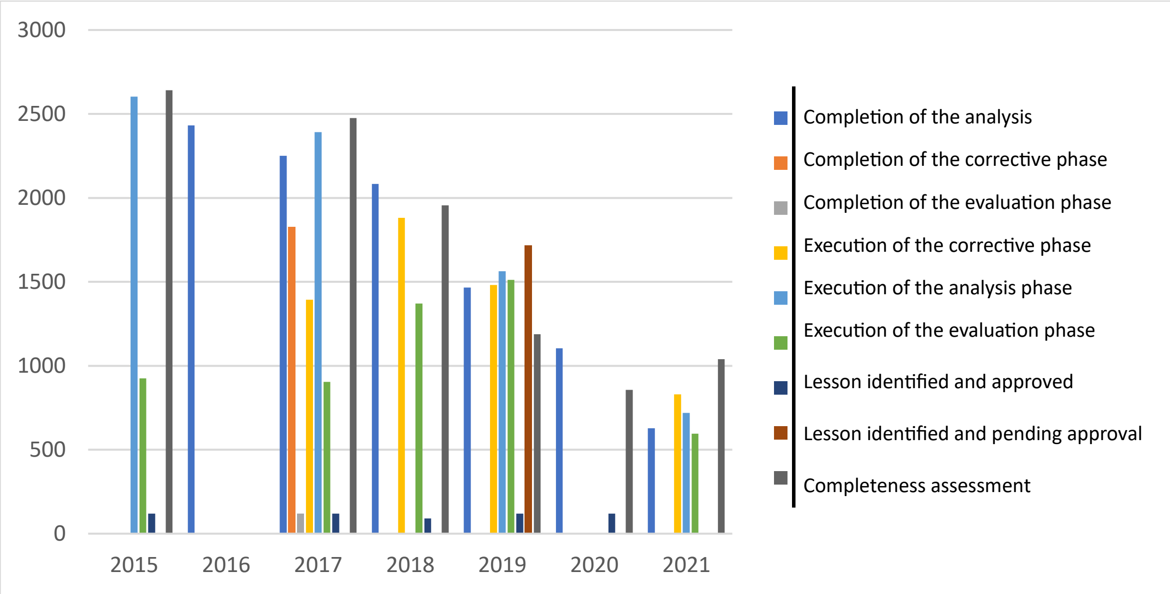
Graph 24: Frequency distribution of average "Delta time" for the LLs



This statistic indicates that a record has only a 25% probability of reaching the LL state if it has been registered as an observation on the platform for more than 1,011 days, meaning if its "record age" is 1,011 days or more. Therefore, we choose this value to select the records, which are not yet LL, that are unlikely to reach the LL state.

For this selected sample of 241 records, evaluations will be made to highlight the activities that have an average "waiting time" longer than other activities. Below is a histogram to highlight the activities that are most critical in terms of "waiting time."

Graph 25: most critical activities in terms of "waiting time"



In the chart, the average "waiting times" for each ongoing action (thus started and not completed until 27.06.2024) are reported, divided by the year of entry into the system (i.e., based on the record's observation date).

This chart shows that the most critical actions, which may determine the failure to complete the LL process, are:

- The completeness assessment of the new observation
- The execution of the analysis phase
- The completion of the analysis phase

8.3 Conclusions

From the findings, it is possible to affirm that the type of entity originating the observation influences the outcome of the process. If the entity is a Command entity, the issue identified is more likely to complete the process and become a learned lesson. In contrast, Wings/Units operating in the S&R and DAMI domains are less likely to see the process from observation to LL completion. This does not apply to Wings/Units operating in the Combat, Support, and Transport domains, which still report a good number of observations becoming LL. No statistical correlations were found concerning the sectors of interest indicated in the records. The statistical analysis highlighted a higher probability of reaching the LL state in operational contexts, even though exercise contexts characterize most records. A critical point is that the process takes an average of nearly two years to complete a full cycle, resulting in many new observations remaining in this state for more than two years without reaching the completion of the definition and dissemination of the respective lesson learned. Finally, it was found that the most critical activities, where there is a greater risk of the LL process being interrupted, are the completeness assessment of the new observation, the execution of the analysis phase, and the completion of the analysis phase.

Chapter 9 - Case Study 3: Intelligent content recommendation systems: a lifelong learning project for the Defense sector

Numerous organizations have melded KM practices with e-learning, or technology-mediated learning, moving beyond traditional classroom-based instruction. This integration is pivotal in the KM cycle, particularly where knowledge needs to be reused, applied, and, fundamentally, understood and internalized. E-learning emerges as a dynamic channel for sharing knowledge, leveraging digital technologies such as computers and the internet, while necessitating significant social presence and media richness to be effective.

A key benefit of traditional classroom learning is the direct, face-to-face interaction it facilitates. However, this format is often constrained by the logistics of time and space, limiting the depth of individual engagement. e-learning, conversely, offers the flexibility for learners to revisit instructional materials, like videos or slides, and engage with peers and instructors asynchronously, enhancing the learning process through repetition and reflection. The primary advantage of e-learning lies in its efficiency, eliminating the need for travel and enabling a larger cohort of students to enroll in a course. To offset the absence of direct interpersonal interaction, a blended learning approach often combines e-learning with face-to-face sessions, tutoring, or discussions, offering a more comprehensive learning experience.

A notable innovation within e-learning is the development of learning objects—self-contained units of learning content designed for online use. These learning objects, ranging from modules on specific subjects to tests and multimedia demonstrations, form the backbone of e-learning libraries or repositories. Once created, these objects can be repeatedly utilized, adapted, or modified to suit various educational needs, ensuring their content remains accessible and relevant across different contexts without compatibility issues. Learning objects exemplify reusable knowledge assets within the KM cycle, fostering knowledge sharing, dissemination, and application among users. This approach underscores the synergistic potential of combining KM practices with e-learning strategies to facilitate ongoing learning and knowledge utilization within organizations.

Starting in 2017, the Ministry of Defense launched the ValForDife Program (Enhancement of Defense Education) with the goal of promoting change and adaptability within the Defense sector. A critical area of focus was the education and training of personnel, which needed to be seamlessly integrated into daily operations as part of a continuous learning approach, rather than being divided into isolated phases as seen in traditional models. This challenge is especially relevant in large organizations, both public and private, where the expertise and operational readiness of human resources are vital.

The program concentrated on key areas such as organizational development, innovation, global strategy, security, and the digital landscape, including cybersecurity. As a component of ValForDife, the SFIDA[19] project was initiated to develop an advanced, digitally integrated training system to drive the digital transformation within the Defense sector. A key feature of the SFIDA project was the implementation of artificial intelligence algorithms designed to enhance learning processes in digital environments. This initiative aimed to improve the digital skills of all personnel, from operational staff to senior management, fostering cycles of innovation and systemic change throughout the organization. In this Chapter, a case study analyzed during the doctoral course is presented. In addition to me as author of this thesis and part of the project team, the following contributions must be acknowledged for the development of the project and the writing of this section: Lt. Col. Luca Fontana, PhD (Istituto di Scienze Militari Aeronautiche, Italian Air Force, Florence), Eng. Paolo Ongaro (M.E.T.A. s.r.l., Pisa), Eng. Alberto Raggioli, (M.E.T.A. s.r.l., Pisa), Mr. Daniele Ugoletti (M.E.T.A. s.r.l., Pisa).

One critical area that demands attention is manpower education and training. These must become embedded in daily activities (life-long learning) and ubiquitous, rather than fragmented over time as seen in traditional learning models. This challenge is particularly pronounced in large organizations, both public and private, where the professionalism and operational readiness of human resources are paramount. In the Defense sector, where decision-making is a strategic value at every hierarchical level, learning paths can become highly complex, difficult to apply, and prone to rapid obsolescence.

In response to these challenges, the ValForDife Program aimed to promote the capacity for change within the Defense sector. This included a focus on organizational development, innovation, global strategy, security, and the digital dimension, including cybersecurity. As part of ValForDife, the SFIDA project was initiated to create an advanced digital integrated training system to support the digital transformation of Defense. This project centers on

[19] SFIDA: Italian acronym for Sistema Formativo Integrato Digitale Avanzato - Advanced Digital Integrated Training System.

enhancing the digital skills of every individual employee, operational staff, executive, and manager, thereby activating virtuous cycles of change and innovation at the system level.

Artificial Intelligence (AI) presents a significant opportunity to address these needs. The capacity and speed of AI, combined with the availability of large quantities of digitized data, can make learning processes more efficient. Specifically, AI enables the creation of fully automated training courses managed by Intelligent Tutoring Systems (ITS), which provide users with the most suitable resources and support according to their learning style, previous knowledge, time availability, and individual needs.

The SFIDA project aimed to offer an integrated intelligent training system to enhance the digital skills of all Italian Defense personnel, serving as an enabler for innovation and digital transformation within the broader Italian Ministry of Defense. The project's main objective was to develop an intelligent content recommendation system integrated with a Moodle platform. This system was designed to suggest selected didactic content items and exercises to trainees, ensuring each user attended a reduced subset of lessons necessary to fill their training gaps, as detected in an initial assessment. The benefits of this system included optimized time and costs for the organization and higher student retention compared to traditional methodologies. Additionally, the active recall mechanism re-proposed didactic content not yet learned at the end of the training process, improving learning and performance. This case study aims to outline the steps taken from the design of the educational and assessment aspects to the implementation on the Moodle platform for course delivery and data acquisition, in order to create learning patterns using machine learning algorithms. This exploration contributed to the development and implementation of innovative KM models tailored to the needs of the Italian Air Force and beyond.

9.1 Background

The literature offers a diverse array of approaches, technologies, and methods for creating a more efficient digital learning environment for students. This section aims to review the current state of the art regarding key elements incorporated in the SFIDA project, including recommendation systems, the application of machine learning in education, and SCORM (Sharable Content Object Reference Model).

9.1.1 Recommendation system

A recommendation system typically collects data about a user's implicit preferences (e.g., from their list of viewed items or navigation tracking) or explicit preferences (e.g., wish lists or personal preference settings) across various domains such as movies, shopping, tourism, and TV, to predict which content a specific user might prefer (Ahuja, Solanki, & Nayyar, 2019). Today, recommendation systems are pervasive in entertainment and e-commerce, found on online platforms like YouTube, Amazon Prime, and Netflix, which aim to keep users engaged for as long as possible.

This strategy has also been adapted for education. Verma et al. (Verma, Patel, & Patel, 2015) explore two types of recommendation systems in this context. Collaborative filtering approaches are based on a user's past behavior compared with similar decisions made by other users. This method clusters users into groups with similar preferences and recommends content based on what others in the cluster have liked. In contrast, content-based filtering approaches rely on the description of items and user preferences, recommending content similar to what the user has liked in the past based on specific features (e.g., main actors, duration, or category of a movie). These two approaches are more effective when used together in a hybrid system.

A recommendation system can be an excellent strategy for personalizing a user's learning experience if the recommended content is selected according to parameters reflecting the user's learning behavior. Adaptable systems allow users to change specific system parameters and adjust the system's behavior accordingly, as analyzed by Oppermann (Oppermann, 1994) in the context of distance learning. Additionally, automatic adaptive solutions can detect needs and propose new correlated learning paths. Over the past decades, various forms of smart systems have emerged, such as Adaptive Educational Hypermedia (AEH) systems (Akbulut, 2012), Reinforcement Learning (RL) systems (Intayoad, 2020), and Intelligent Learning Systems (ILS) (Marković, 2014; Osadchyi, 2020).

9.1.2 Machine learning in education

At the core of every intelligent recommendation system is the need for high-quality data. This involves essential data mining activities such as data collection/generation, data harmonization, tagging, and data enrichment.

The application of data mining methods in the educational sector is now widely adopted at various levels. Numerous studies focus on analyzing data generated in educational settings to develop models aimed at improving the learning experience and institutional effectiveness (Baker, 2009). For instance, Dutt et al. (Dutt, 2015) provide a comprehensive review of research, highlighting study objectives such as identifying significant variables that affect and influence undergraduate student performance (Pechenizkiy, 2008), predicting student performance potential (Bovo, 2013; Osmanbegovic & Suljic, 2012; Ramesh, 2013), and teaching basic computer skills courses to students from rural or urban backgrounds (Ibrahim, 2007).

K-means is one of the simplest unsupervised learning algorithms, designed to solve clustering problems by classifying each observation into a certain number of clusters containing sufficiently homogeneous elements (Mahesh, 2020). Examples of K-means applications include recommender systems for user preferences on movies and clustering students based on their behavior in online courses (Kuo, 2021). Notably, Talavera et al. (2004) applied K-means to student interaction data to cluster student behaviors in a course on Internet use, using data from forums, email, and chat.

Other studies demonstrate the application of the K-means algorithm to improve training in digital environments. For instance, Perera et al. (2008) mined data from students working in teams using an online collaboration tool during a one-semester software development project, aiming to support the development of group skills. In general, K-means has been used to cluster students based on their behaviors (Li, 2021), learning performances (Tuyishimire, 2022), and to predict student performance (Kabakchieva, 2013).

The K-means algorithm (Jain, 1988; Sinaga, 2020) partitions objects into k groups based on their attributes, aiming to minimize the total intra-group variance. It follows an iterative procedure: creating k partitions, calculating group centroids, reassigning points to the nearest centroid, and repeating until convergence. The algorithm uses Euclidean distance to measure the closeness of points to centroids (Chen, 2019).

Nalli et al. (2021) compared six machine learning algorithms, concluding that K-means is the best performer for clustering students in a Moodle environment, based on Silhouette Analysis. However, K-means has limitations, such as sensitivity to the initial number of clusters and inability to handle noisy data or outliers (Qi, 2016; Chen, 2019). These issues can be addressed by the DBSCAN algorithm, which does not require a predetermined number of clusters and effectively handles noisy data and outliers (Chakraborty, 2011).

DBSCAN, proposed by Ester et al. (1996), is a density-based clustering method connecting regions of high point density. It is widely cited in literature for its effectiveness in machine learning and data mining. DBSCAN defines clusters based on density-reachability, requiring an ε-neighborhood and a minimum number of points (minPts) (Schubert, 2017).

The k-Nearest Neighbors (k-NN) algorithm, used in pattern recognition, classifies objects based on the characteristics of their nearest neighbors. The choice of neighborhood radius and minimum points is crucial for ideal clustering (Tuyishimire, 2022). k-NN can also be used for regression, averaging the values of the k closest neighbors, sometimes weighing contributions by distance.

9.1.3 Sharable Content Object Reference Model

The Sharable Content Object Reference Model (SCORM) is a collection of specifications derived from multiple sources, designed to provide a comprehensive suite of e-learning capabilities that ensure interoperability, accessibility, and reusability of web-based learning content (Mödritscher et al., 2004). SCORM was developed by the Advanced Distributed Learning (ADL) Initiative, established in 1997 by the US Department of Defense (DoD). The goal was to modernize training strategies and foster collaboration among government, industry, and academia to standardize e-learning.

A single SCORM-compliant learning object, known as a Sharable Content Object (SCO), can provide the Learning Management System (LMS) with detailed information about the interaction between the learner and the content, such as time spent, completion percentage, and accuracy of responses. However, a SCO can also introduce higher cognitive load for users, as it might be perceived as a separate entity from the LMS (Bohl, 2002).

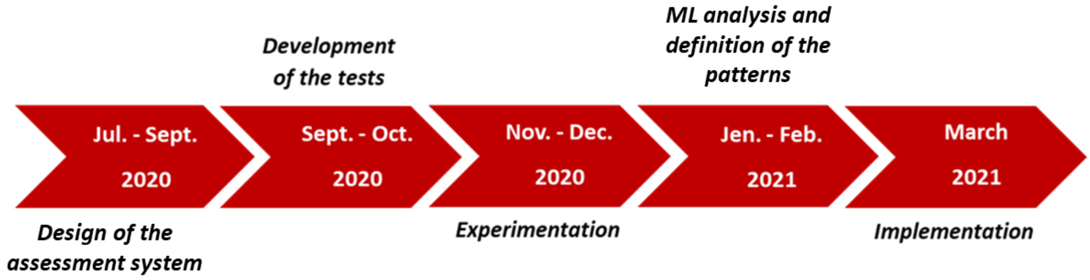
The effective use of SCORM in digital learning environments is crucial for developing adaptive learning systems. Baldoni et al. (2004) describe how SCORM-compliant LMSs can leverage standard Artificial Intelligence techniques to achieve learning objectives. Rey-López et al. (2009) demonstrate that extending the SCORM standard allows for the creation of adaptive courses, while Gjermeni and Percinkova (2018) propose an agent-based algorithm where each agent represents a SCO within the platform's database. Additionally, SCORM standards can facilitate collaborative learning in digital environments (Ip, 2003).

9.2 Phases of the project

The project was structured into five phases:

1. **Design of the Assessment System:** From July to September 2020, the team designed the assessment system, including topics, didactic objectives, complexity levels, test types, and the structure on Moodle.
2. **Development of the Tests:** Utilizing authoring software, the team created simulations in SCORM format and quizzes directly on the Moodle platform. This phase spanned from September to October 2020.
3. **Experimentation:** Between November and December 2020, selected personnel from the Italian Defense were invited to participate in the project and complete the assessments on Moodle.
4. **ML Analysis and Definition of Patterns:** Machine learning analysis was conducted on the assessment results, with over 2,500 participants completing the entire assessment. The personalized learning paths were derived from a combination of AI algorithms and instructional designers' inputs.
5. **Implementation:** The Moodle platform was configured to support the personalized delivery of content.

Figure 19: Project Phases



9.3 Design and development of the assessment system

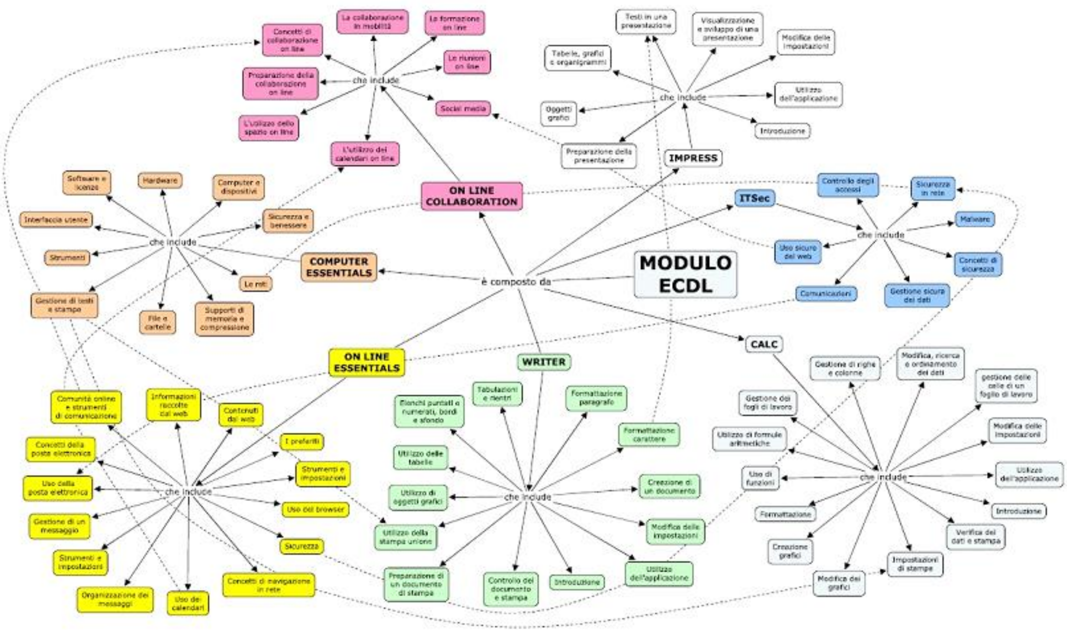
First, all the items of the entire course were mapped out (figure 20). The course focused on basic informatics competencies and the use of the LibreOffice suite, and it was divided into seven macro-areas (or modules).

Figure 20: Conceptual map of the course

the 7 macro-areas of the course:

M1. Computer essentials M2. On line essentials M3. Writer

M4. Calc M5. IT Security M6. Impress M7. On line collaboration



Each macro-area consists of a specific number of items, with each item encompassing one or more didactic objectives. These objectives can be addressed either conceptually or practically, depending on their nature. To determine the complexity of the objectives, Bloom’s Taxonomy, as revised by Anderson and Krathwohl (Krathwohl, 2002; Wilson, 2016), was utilized. Figure 21 illustrates the six levels of complexity for didactic objectives, providing a description of the expected learner behavior and examples of keywords for formulating each objective at every level.

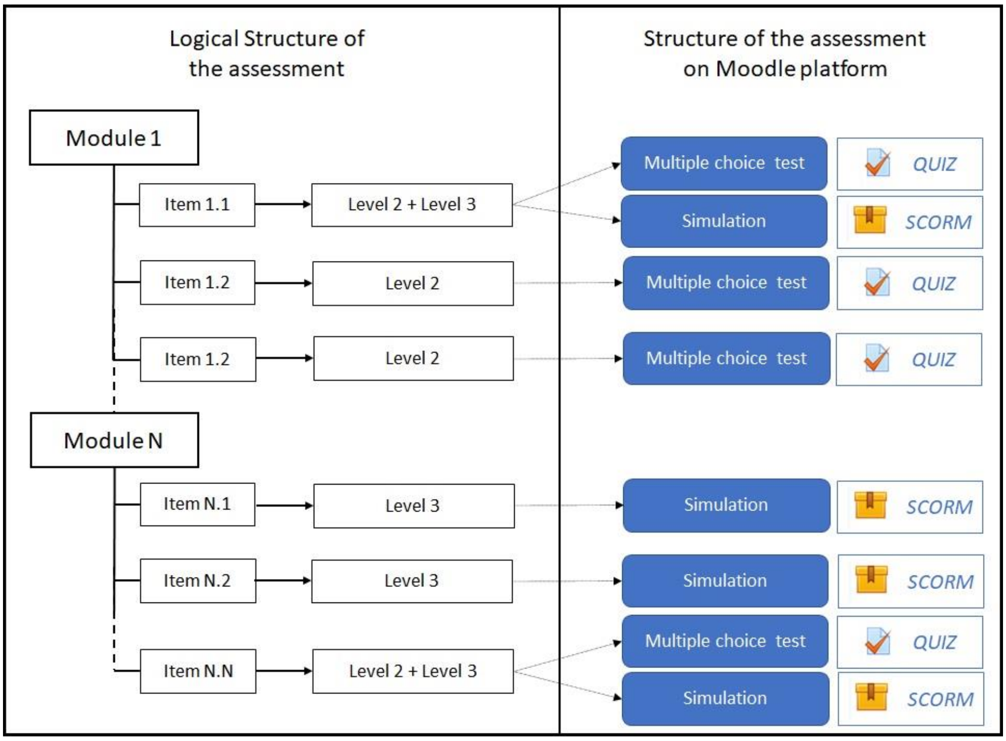
Figure 21: Revision of Bloom's Taxonomy by Anderson and Krathwohl

Level of cognitive complexity	***Description of expected behaviour***	***Didactic objective***
1. Remember	Retrieving relevant knowledge from long-term memory	Recognizing
		Recalling
2. Understand	Determining the meaning of instructional messages, including oral, written, and graphic communication	Interpreting
		Exemplifying
		Classifying
		Summarizing
		Inferring
		Comparing
		Explaining
3. Apply	Carrying out or using a procedure in a given situation	Executing
		Implementing
4. Analyze	Breaking material into its constituent parts and detecting how the parts relate to one another and to an overall structure or purpose	Differentiating
		Organizing
		Attributing
5. Evaluate	Making judgments based on criteria and standards	Checking
		Critiquing
6. Create	Putting elements together to form a novel, coherent whole or make an original product	Generating
		Planning
		Producing

For simplicity, it was assumed that all conceptual didactic objectives (levels 1 and 2) could be assessed using multiple-choice quizzes. For level 3 objectives, which involve application, practical tests were designed in the form of software context simulations. Consequently, an assessment system was constructed on the Moodle platform, consisting of 73 quizzes and 138 simulations created in SCORM format.

Figure 22 illustrates the transition from the logical structure of modules and their respective items to the objects used in Moodle. Each simulation was developed using authoring software such as Active Presenter 8 (developed by Atomy System Inc.) and Storyline 3 (developed by Articulate Global Inc.).

Figure 22: Transition from the logical structure of modules and their respective items to the objects used in Moodle



9.4 Experimentation and data mining

As is well known, machine learning applications require a substantial amount of data. Therefore, it was essential to have a reference sample as large as possible. The SFIDA project involved approximately 5,000 participants, including both military and civilian personnel from the Defense Administration.

For the experimentation phase, 19 different rooms were created on the Moodle platform. Each room had a unique order for the tests to prevent any influence on the experimental results. This phase lasted two months, culminating in a dataset collected from 2,652 individuals who completed the entire assessment.

Each SCORM module was configured to provide a Boolean result: 1 if the simulation was successfully passed, and 0 if the simulation was not completely exceeded. The same type of data was recorded for the quizzes. The result is a matrix similar to the one shown in table 23.

Table 23: Boolean results from SCORMs

M1.L1	M1.L2.01	M1.L2.02	M1.L2.03	M1.L3.01	M1.L3.02	M1.L3.03	M1.L3.04	M1.L3.05
0	1	1	1	0	0	1	0	0
1	0	0	0	0	0	1	0	0
0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	1	1	0
1	1	0	0	0	0	0	0	0
0	1	1	1	0	0	1	0	0
0	0	0	1	0	0	1	0	0
0	0	0	0	0	0	1	0	0
0	0	0	0	0	0	0	0	0
1	1	0	0	0	0	1	0	0

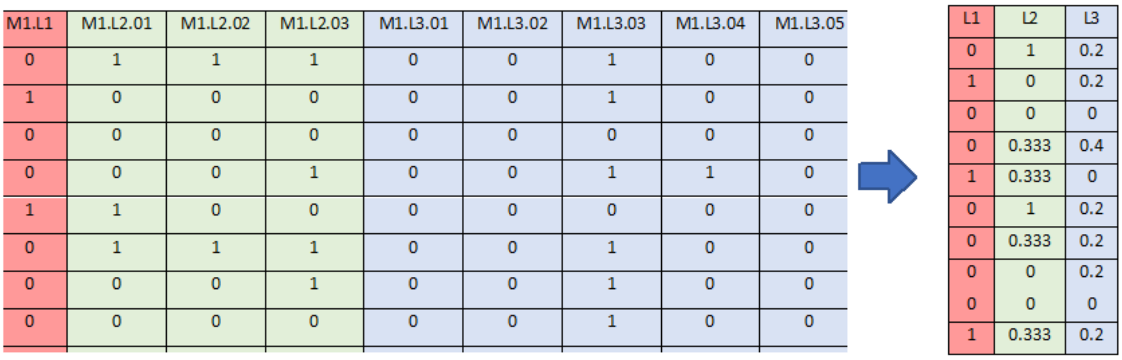
To illustrate, M1.L2.O1 refers to objective 1 of item 2 in module 1, where:

- **Module M1:** Computer Essentials
- **Item L2:** Hardware
- **Objective O1:** "To be able to define the main hardware components"

This objective was assessed through a quiz.

Before clustering, the data were processed as follows: for each item, the average score obtained by each user was calculated. This transformed the binary input (0/1) of each evaluation into a continuous variable (ranging from 0 to 1) associated with an Lx score, representing the score for each item. This approach reduced the number of features to be clustered and facilitated the calculation of similarities.

Figure 23: Steps for features reduction



M1.L1	M1.L2.01	M1.L2.02	M1.L2.03	M1.L3.01	M1.L3.02	M1.L3.03	M1.L3.04	M1.L3.05
0	1	1	1	0	0	1	0	0
1	0	0	0	0	0	1	0	0
0	0	0	0	0	0	0	0	0
0	0	0	1	0	0	1	1	0
1	1	0	0	0	0	0	0	0
0	1	1	1	0	0	1	0	0
0	0	0	1	0	0	1	0	0
0	0	0	0	0	0	1	0	0

L1	L2	L3
0	1	0.2
1	0	0.2
0	0	0
0	0.333	0.4
1	0.333	0
0	1	0.2
0	0.333	0.2
0	0	0.2
0	0	0
1	0.333	0.2

Figure 23 illustrates an example of this feature reduction, which decreased the number of features from 211 to 73. Specifically, the data clustering was performed based on the identified features, resulting in:

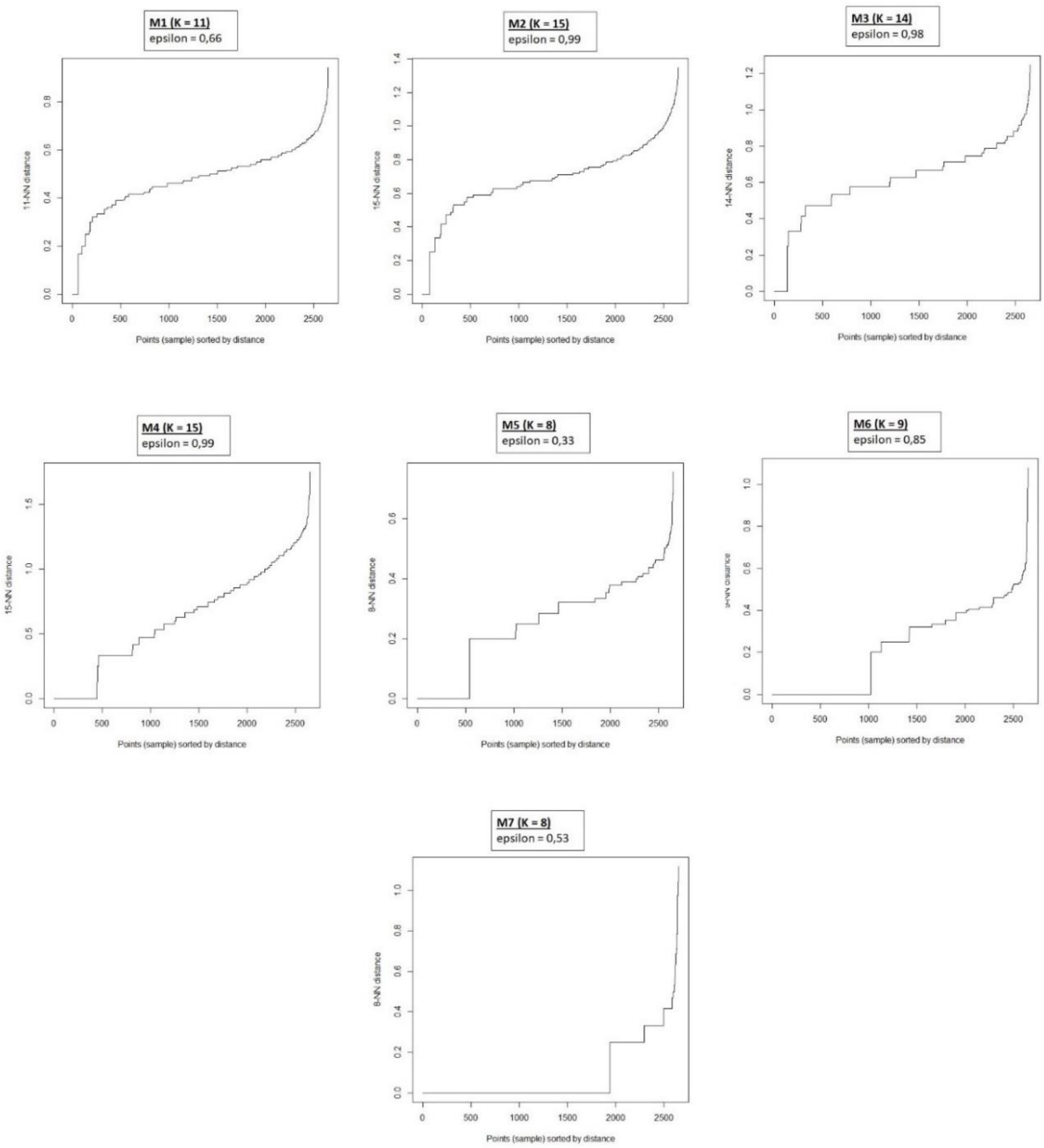
- **M1:** 10 features (L1 ... L10)
- **M2:** 14 features (L1 ... L14)
- **M3:** 13 features (L1 ... L13)
- **M4:** 14 features (L1 ... L14)
- **M5:** 7 features (L1 ... L7)
- **M6:** 8 features (L1 ... L8)
- **M7:** 7 features (L1 ... L7)

This reduction streamlined the clustering process by focusing on a manageable number of key features.

9.5 Clustering

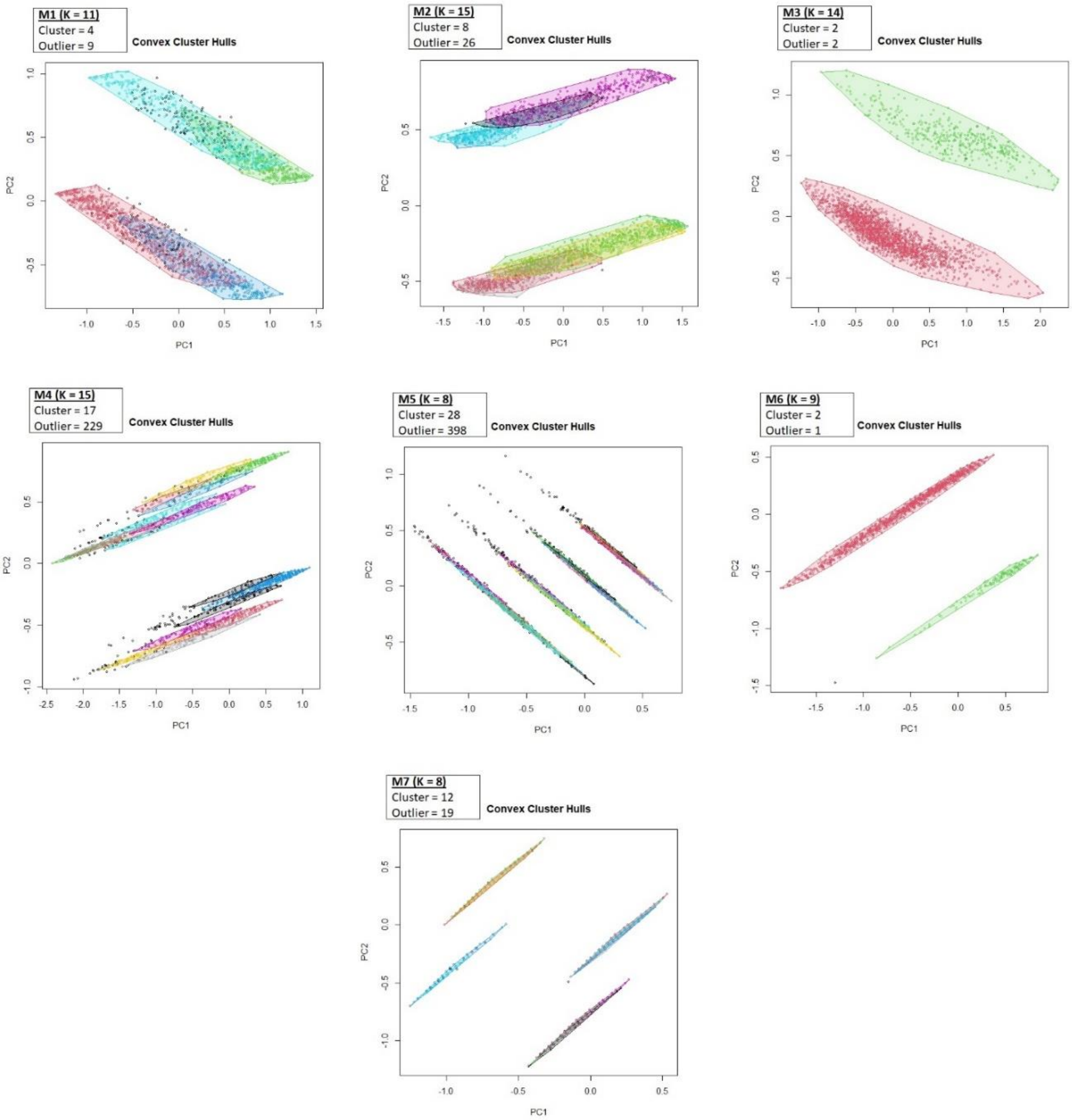
The software used for the analysis was R (https://www.r-project.org/). For each area, clusters were identified based on the considered features. Initially, the DBSCAN algorithm was employed to determine the optimal number of clusters. The key parameter for DBSCAN is “epsilon,” which can be estimated initially through a kNN plot. As shown in figure 24, for each area, the inflection point was selected to identify the "epsilon," using a k-value equal to the number of features.

Figure 24: kNN plots



DBSCAN was applied using the parameters obtained from the kNN plots. The epsilon parameter was then varied to minimize the number of clusters and the number of outliers (values not associated with any cluster). The final results of the DBSCAN analysis are illustrated in the hull plots shown in figure 25.

Figure 25: DBSCAN hull plots



Each plot in figure 25 displays the clusters obtained using the DBSCAN algorithm for each of the seven areas. In some cases, the number of clusters was significantly higher than desired for the final purposes. Therefore, a reduction was made based on visual inspection of the hull plot diagrams. Specifically, we reduced the clusters to two instead of eight for M2, four instead of seventeen for M4, four instead of twenty-eight for M5, and four instead of twelve for M7.

Subsequently, the K-means algorithm was employed. Unlike DBSCAN, K-means does not produce outliers but requires initialization with the desired number of clusters, which were identified using DBSCAN. Additionally, K-means provides centroids that can be used to determine the average level of competence in each cluster.

The final result is a clustering of individuals for each of the seven areas. The K-means clustering results, along with the corresponding centroids, are presented in the following tables. Each row represents a cluster, each column represents an item, and the values (ranging from 0 to 1) are the centroids of each cluster for every item.

Figure 26: Centroids of each cluster

Module M1: "Computer essentials"									
L1	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**	**L8**	**L9**	**L10**
1	0.6727	0.2904	0.89	0.72	0.91	0.461	0.7916	0.5945	0.4989
0	0.519	0.2113	0.79	0.55	0.84	0.371	0.6423	0.4505	0.4448
1	0.4379	0.1909	0.29	0.18	0.53	0.237	0.311	0.382	0.3371
0	0.2999	0.1304	0.11	0.11	0.29	0.209	0.1758	0.2084	0.21

Module M2: "On line essentials"													
L1	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**	**L8**	**L9**	**L10**	**L11**	**L12**	**L13**	**L14**
0.1365	0.2389	0.1232	0.09	0.01	0.11	0.160	0.3229	0.2924	0.4111	0.38	0.07	0.083	0.1365
0.2895	0.4305	0.4831	0.45	0.54	0.77	0.429	0.6016	0.548	0.9381	0.92	0.28	0.127	0.2895

Module M3: "Writer"												
L1	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**	**L8**	**L9**	**L10**	**L11**	**L12**	**L13**
0.3634	0.7254	0.3627	0.71	0.57	0.55	0.71	0.3979	0.7276	0.5888	0.43	0.38	0.556
0.0436	0.3114	0.1634	0.40	0.18	0.26	0.265	0.1009	0.4731	0.1869	0.12	0.20	0.349

Module M4: "Calc"													
L1	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**	**L8**	**L9**	**L10**	**L11**	**L12**	**L13**	**L14**
0.1732	0.521	1	0.44	0.33	0.34	0.163	0.1273	0.2211	0.3159	0.00	0.05	0.161	0.2723
0.0766	0.221	0	0.24	0.13	0.01	0.027	0.0458	0.0821	0.0637	0.00	0.00	0.052	0.0965

Module M5: "IT security"						
L1	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**
0.2931	0.1361	0.1934	0.11	0.81	0.30	0.412
0.4003	0.1632	0.243	0.16	0.16	0.37	0.495
0.6501	0.3142	0.4968	0.41	0.87	0.59	0.646
0.1108	0.0587	0.0787	0.05	0.05	0.10	0.200

Module M6: "Impress"							
L1	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**	**L8**
0.0548	0.5498	0.034	0.05	0.10	0.11	0.062	0.061
0.4859	0.9894	0.3881	0.37	0.49	0.45	0.516	0.684

Module M7: "On line collaboration"						
L1	**L2**	**L3**	**L4**	**L5**	**L6**	**L7**
0.1526	0	0.3236	0.11	0.07	1	0.582
0.0797	0	0.1977	0.12	0.08	0	0.444
0.0754	1	0.0689	0.07	0.06	0.03	0.371
0.1605	1	0.4627	0.17	0.09	0.32	0.769

Finally, the didactic contents were assigned to the clusters using 0.5 as the discriminating value, which is the median between 0 and 1. We assumed that if a cluster's centroid for a particular item was below 0.5, the members of that cluster would need to take all the educational contents related to that item. The following table provides an example of this association for module M1, "Computer Essentials."

Table 24: Example of the association for module M1, "Computer Essentials."

Module M1: "Computer essentials"										
	L1	L2	L3	L4	L5	L6	L7	L8	L9	L10
Cluster 1	1	0.6727	0.2904	0.8963	0.7238	0.9105	0.4618	0.7916	0.5945	0.4989
Cluster 2	0	0.519	0.2113	0.7967	0.5566	0.8491	0.3711	0.6423	0.4505	0.4448
Cluster 3	1	0.4379	0.1909	0.2904	0.1832	0.5362	0.2377	0.311	0.382	0.3371
Cluster 4	0	0.2999	0.1304	0.1122	0.119	0.2918	0.2092	0.1758	0.2084	0.21

In table 24, red cells indicate where the centroid of a specific cluster is lower than 0.5, signifying that the cluster requires the didactic contents for that particular item (Lx). Conversely, green cells indicate a centroid above 0.5, meaning the cluster does not need the associated didactic contents. For example, the didactic contents for item M1.L1 will be recommended to clusters 2 and 3, the contents for item M1.L2 will be recommended to clusters 3 and 4, and the contents for item M1.L3 will be recommended to clusters 1, 2, 3, and 4. This approach determines the didactic path for each cluster within every module.

The results (user clusters) were then used to streamline the number of tests in the entrance assessment, enhancing user retention and saving time (and therefore costs for the organization). By applying "recursive feature elimination" and "random forest" algorithms, the number of tests was reduced from 275 to 41. However, this paper does not focus on that specific analysis.

9.6 Implementation

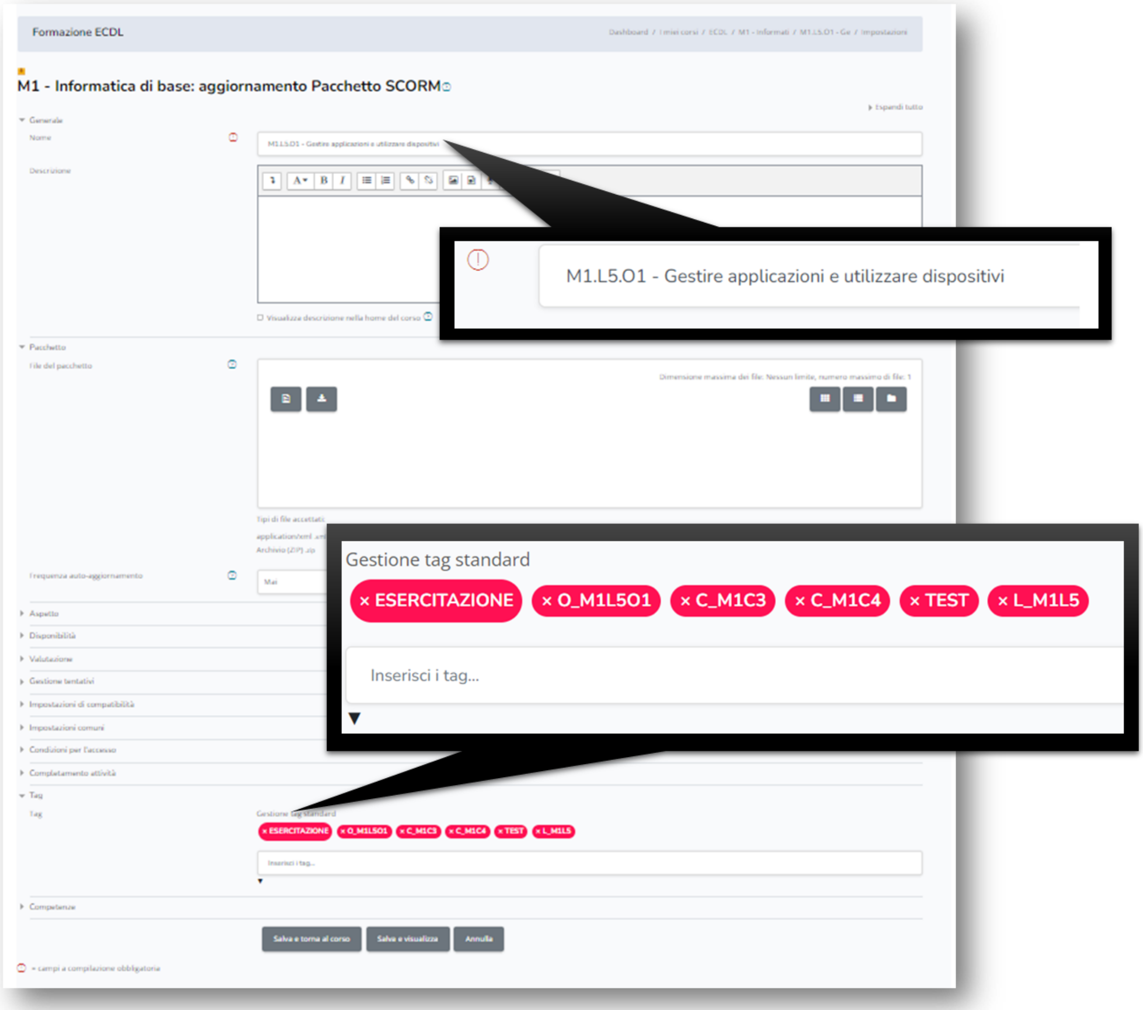
The SFIDA project integrates AI-based tools into a Moodle platform to provide personalized recommendations from ICDL educational courses. A specific plugin was developed for Moodle to test the effectiveness of the SFIDA digital learning environment, leveraging AI to create more effective learning experiences for students. The system addresses user retention by offering relevant content tailored to each user, thereby enhancing engagement, performance, focus, and time efficiency. The innovative aspects of the system include information clustering and visualization techniques. Due to the large number of tests (211 quizzes and simulations), dimensionality reduction techniques were implemented to offer personalized recommendations for new, relevant training content to achieve specific competencies.

To organize the course, each topic includes entrance tests, video lessons, and exercises, all in SCORM format (with quizzes also converted to SCORM). For each module's content, it was necessary to specify whether it belonged to a cluster, a lesson, or an objective. The tagging system used includes a prefix indicating the cluster assignment (C_), the didactic objective (O_), and the lesson reference (L_). Additionally, each SCORM item was tagged based on its content type:

- **Entrance tests:** Each test has a "TEST" tag and one or more lesson tags (e.g., L_M1L2, L_M1L3) since it is also used as an evaluation test at the end of the lesson.
- **Video lessons:** Each lesson has a "LEZIONE" tag, one or more cluster tags (e.g., C_M1C1, C_M1C2, depending on the recommended cluster), one or more lesson tags (e.g., L_M1L2, L_M1L3), and one or more objective tags (e.g., O_M1L2O1, O_M1L3O2).
- **Exercises:** Each exercise has an "ESERCITAZIONE" tag, along with the same tags as the associated video lesson.

As a result, every piece of content (lesson, exercise, or test) was uploaded to Moodle with a comprehensive set of tags, ensuring precise content recommendation and organization.

Figure 27: Screenshot of the SCORM tagging system on Moodle



In figure 27, an example of tagging is shown. The SCORM item displayed is used as an entrance test, related to lesson M1L5, specifically addressing the objective M1.L5.O1 ("Managing applications and using devices"). It is recommended for clusters M1C3 and M1C4 and also serves as a practical exercise.

The system enables each user to attend only the necessary subset of lessons to fill their training gaps, as identified during the assessment phase. This approach avoids repeating well-known resources and instead focuses on less familiar content. The analysis phase utilized a structured system of tests based on the organization's curriculum to perform reliable assessments on real users and real courses.

The AI-based recommendation system, named meta-AI, performs the following operations:

A) Courses Preparation Phase - Skills Tagging: The organization's Moodle platform, an LMS, allows educators to create or upload new courses. During course creation, a plugin enables manual tagging of content against a curriculum map (a document outlining training objectives, usually created by instructional designers). SCORM content is tagged by training staff, linking it to target educational skills. Moodle administrators also upload tests that will be used to assess users and activate the AI recommender.

B) Test and Clustering Phase: After authentication, students are invited to assess their knowledge through a series of quizzes and tests. The AI algorithm uses these user-generated test results and SCORM tags to generate clusters of trainees. The Clustering module analyzes the assessment results to identify each trainee's learning gaps, which will be used by the profiling system and the recommendation component.

C) Courses Utilization Phase: Clustered trainees access the activated lessons. An AI plugin (meta-Recommender) offers the best-fit content to be used. The Recommendation module identifies the most effective educational content for achieving full acquisition of the expected skills and promotes a list of contents to be learned based on the assessment results.

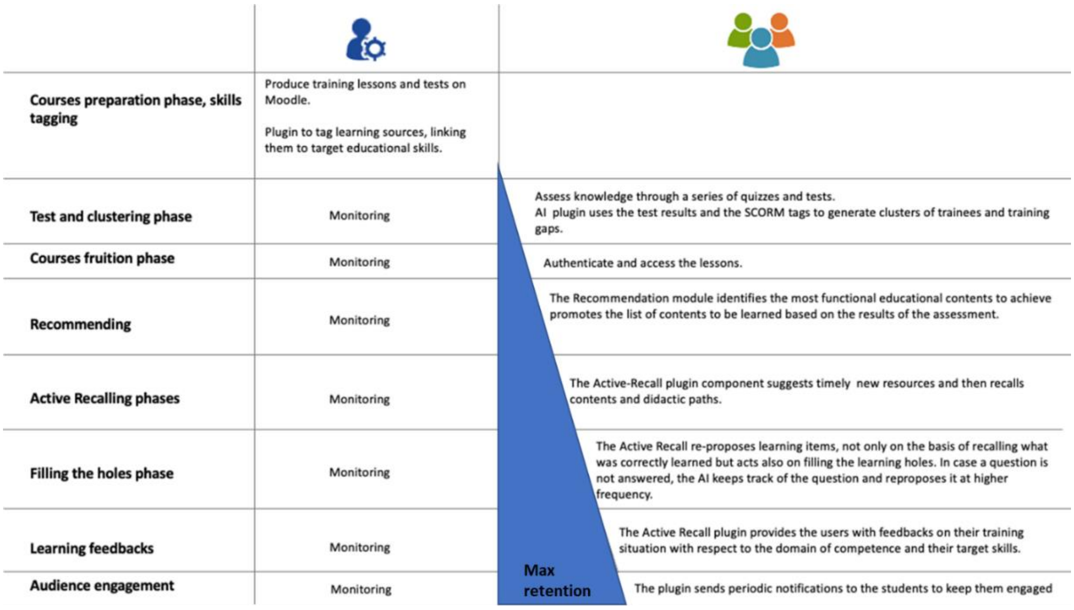
D) Recommending and Active Recalling Phases: A recommendation engine is configured to enhance memorization performance by proposing items before users completely forget learned lessons (Active Recall). The plugin suggests (Recommender) new resources and then recalls (Active Recall) contents and didactic paths prepared by the administration.

E) Filling the Gaps Phase: The Active Recall function not only revisits correctly learned items but also focuses on filling learning gaps. If a question is unanswered, the AI tracks it and reintroduces it at higher frequencies.

F) Learning Feedback and Audience Engagement: The Active Recall plugin for Moodle provides users with feedback on their training status concerning the domain of competence and target skills. Additionally, the plugin sends periodic notifications to keep students engaged and participative.

In the following figure, the implementation scheme of the system is illustrated.

Figure 28: Implementation scheme of the system



9.7 Time saving estimation

The SFIDA project aimed to optimize users' learning processes, with one of the primary goals being to save time by eliminating unnecessary learning content from each learning path. A digital learning environment (such as an LMS) can accurately select content based on the user's initial knowledge, ensuring significant customization possibilities. Artificial intelligence enhances the efficiency of this process.

In the Moodle system implemented for the SFIDA project, each user is assigned a vector after the assessment, indicating all the clusters they belong to. The system then recommends only the relevant didactic content for each cluster to the user. This approach results in significant time savings for each user and, consequently, for the entire organization.

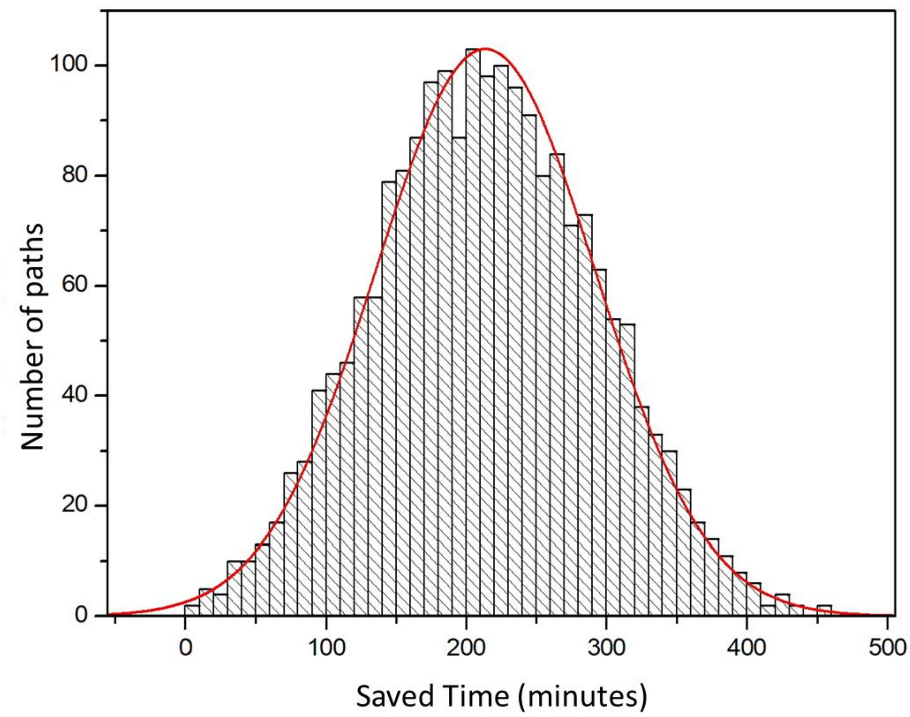
An estimation of the impact on the Defense organization in terms of time savings is provided in this section. To calculate the saved time, the duration of each didactic content item is considered. The time saved is represented by the didactic videos not recommended to the user. For example, if a learner already knows how to save a word document with a specific name, the saved time would be the duration of the video explaining this process. Based on this premise, two approaches are followed:

1. **Duration-based Calculation:** The total duration of non-recommended videos is summed to estimate the time saved.
2. **Content-specific Calculation:** The specific content areas where time is saved are analyzed to provide a detailed understanding of the impact.

9.8 First approach – all possible paths

The first approach is more general and involves calculating the time saved for each possible cluster vector. Given that there are 7 topics, each with clusters ranging from 2 to 4, the total number of possible vectors (i.e., all potential training paths) is 2048. By calculating the time saved for each of these vectors, the resulting graph is shown below:

Graph 26: Time saved for each vector



As shown, the time saved is optimally distributed along a normal curve centered at 213.5 minutes, with a standard deviation of 78.7 minutes. The time is plotted in 10-minute intervals on the x-axis.

In an organization with a well-distributed range of digital skills, an average of 213.5 minutes per user would be saved. For the Defense Administration staff, considering the 2,652 users who completed the assessment, the total time savings for the organization would exceed 560,000 minutes, or approximately 9500 hours, equivalent to 1200 working days.

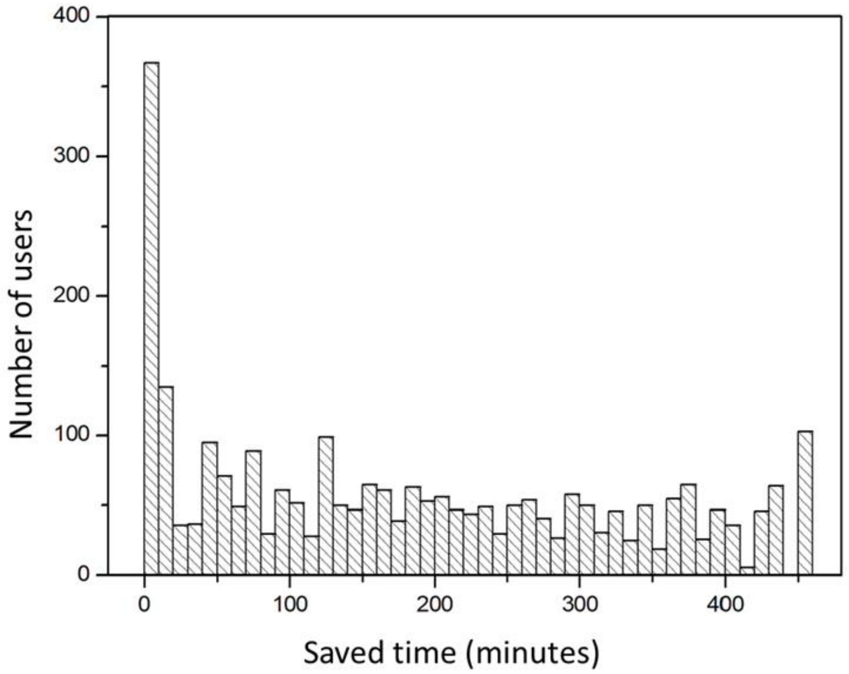
However, this approach assumes that digital skills are uniformly distributed within the group being trained, which may not always be the case.

9.9 Second approach – based on results of the assessment

A second, more specific approach was considered to tailor the analysis to our case. This approach focuses on the actual results of the assessments completed by the Defense staff, analyzing the time savings based on the real distribution of skills. Instead of considering all possible cluster vectors, we only consider the vectors that would actually be assigned after the assessment.

To implement this approach, we assigned the relevant cluster vector to each user who completed the assessment and then calculated the corresponding time savings. This method is highly tailored to the Defense, as the selection of personnel for the assessment was done randomly. The data obtained from this analysis are shown in the following graph:

Graph 27: Time Savings Calculation for Randomly Selected Defense Personnel



As observed, a substantial portion of users lack any digital skills (approximately 14%), and a significant number possess minimal skills. Based on these data, the calculated time savings are lower than those derived from the first approach but remain highly significant in terms of organizational efficiency. Specifically, the time savings amount to approximately 485,000 minutes, which is about 8,000 hours or 1,000 working days. The results of the two approaches are summarized in the following table:

Table 25: Summary of the results obtained

Approach	Time Savings (Minutes)	Time Savings (Hours)	Time Savings (Working Days)
Generic Approach	566,202	9,437	1,180
Specific Approach	483,630	8,060	1,008

9.10 Conclusions of the case study

This study presents the results of the SFIDA Project, an intelligent recommendation system designed to innovate education by personalizing the trainee's experience using machine learning algorithms. Compared to similar research, this study employs a distinct approach to determining learning paths:

1. **Knowledge Gap-Based Recommendation:** The system focuses on identifying and addressing knowledge gaps rather than user preferences. This approach ensures that users receive only the content they truly need, thereby improving focus and saving time while achieving optimal learning outcomes.
2. **Measurement of Knowledge and Skills:** The system evaluates both the users' knowledge and their practical skills. Simulations have demonstrated the system's ability to determine whether users can achieve specific practical objectives.
3. **Active Recall Integration:** By embedding an active recall tool within Moodle, the system enhances knowledge retention in existing learning environments, thereby reducing implementation costs.

The time-saving analysis for a group of 2,652 participants indicates a potential saving of 9,437 hours. This analysis shows that the actual time savings are directly related to the organization's average level of digital knowledge.

This form of personalization can be considered an 'anchored' mechanism: users are assigned a specific training path based on their initial assessment, and the path remains unchanged during the learning experience unless new assessments are conducted.

Modern digital technologies enable more dynamic and personalized learning paths. Adaptive systems that consider professional characteristics, learning styles, and user preferences are now feasible, potentially enhancing engagement, performance, time efficiency, and cost savings. For instance, incorporating an Artificial Neural Network could further improve the personalization of the recommendation system by processing interaction data more effectively.

Moreover, the system could be enhanced to be more user-friendly for operators supporting trainees. This includes providing teachers and instructional designers the ability to modify and add learning objects to the platform to address identified gaps or create additional practice exercises where needed.

Finally, implementing a collaborative approach among students, using communities of practice or SCORM, could further the goals of the SFIDA Project, fostering a more interactive and supportive learning environment.

9.11 AI for education today

It is important to note that since the inception of the SFIDA project, AI applications have evolved significantly, particularly with the development of Generative AI tools (e.g., Gemini, ChatGPT, Copilot, and others). In the Defense sector, these advancements have been taken into account, and although the original SFIDA project adopted an approach to AI in training that may now be considered outdated, it was a major innovation in the field. It laid the groundwork for the SFIDA2 project, which leverages the capabilities of today's generative AI, such as the extraction and synthesis of textual content, the generation of tests based on given texts, and other cutting-edge functionalities.

Several non-exhaustive examples of AI applications in education illustrate its growing impact. One prominent example is Duolingo's AI-driven language learning platform, which offers a personalized learning experience by adapting to each user’s proficiency level, interests, and learning style (Al-Bahrani, Majdi, Abed, & Cree, 2022). In recent years, the use of chatbots in education has gained popularity, offering personalized support to students, automating administrative tasks, and creating new opportunities for engagement. Chatbots function as virtual tutors, providing immediate feedback, answering questions, and guiding students through their learning process. Additionally, they offer personalized learning recommendations, suggest areas for improvement, and track progress, thereby enhancing the overall learning experience (Sreenivasu et al., 2023).

Another significant application of AI in education is automated grading. AI algorithms are increasingly being used to evaluate student work, offering immediate feedback based on predefined criteria. For instance, automated essay grading systems utilize natural language processing and machine learning to assess student essays, providing instant feedback and scoring (Stoica & Wardat, 2021). These advancements demonstrate the potential of AI to streamline and personalize educational experiences, offering more efficient and responsive learning environments.

PART IV
SOLUTIONS FOR ENHANCING KMS IN IAF

The best managers are not afraid to challenge conventional wisdom and question the existing norms.

Henry Mintzberg

Conference on February 12, 2024 at SDA Bocconi School of Management: *A chat with Henry Mintzberg*.

Chapter 10 - Refining the research

Part IV of this thesis aims to synthesize the key findings from the previous chapters and incorporate expert insights on Knowledge Management (KM) within the context of the Italian Air Force (IAF). By employing the Delphi technique, a qualitative analysis tool, the study will refine and develop a tailored KM model that addresses the specific characteristics and needs identified throughout the research.

To establish this model, it is essential to revisit the key elements discussed so far.

Part I laid the theoretical foundation by exploring the definitions, principles, evolution, and key models of KM, identifying critical factors relevant to building a KM framework suited to the IAF. The research emphasized the importance of people-oriented, process-oriented, technology-oriented, and goal-oriented KM practices, ensuring alignment with the operational objectives of the IAF. These dimensions are crucial for fostering human interaction, optimizing processes, integrating technology, and achieving strategic goals within the organization. A central concept examined is the DIKW hierarchy (Data, Information, Knowledge, Wisdom), which traces the progression from raw data, through analysis, into actionable knowledge, and ultimately to wisdom. This framework highlights the importance of contextualizing data to support informed decision-making and organizational efficiency, which is particularly critical in the complex environment of the IAF. Additionally, the thesis explored Scarso and Bolisani's (2004) classification of knowledge into declarative (know-about), procedural (know-how), causal (know-why), source-based (know-who), and relational (know-with) knowledge. Combined with Polanyi's distinction between tacit and explicit knowledge, this classification offers a comprehensive understanding of how knowledge can be effectively managed, shared, and applied within organizations, particularly in a military setting such as the IAF. Several KM models discussed in the literature offer valuable insights but come with limitations depending on the context. For instance, the ICAS model is well-suited to unpredictable environments, enhancing adaptability and innovation, while Boisot's I-Space model promotes social learning in complex settings. Other models, such as those by Meyer and Zack, Bukowitz and Williams, and Wiig, focus on skill preservation, operational continuity, and innovation. However, none of these models provide a fully tailored framework for application in a specific context like the IAF, which presents unique challenges due to its military structure and operational complexity.

Part II, through a systematic literature review, highlighted several key findings. It identified, in the umbrella review, the most relevant KM practices in modern organizations, including integrated digital systems, innovation, artificial intelligence, human resource development, and organizational capabilities. It also identified the KM tools most commonly used in organizations, which will be examined in this section to assess their applicability in the IAF context. Furthermore, the systematic review, underscored the elements that characterize an effective Organizational Virtual Community of Practice (OVCoP) and the business areas impacted by such KM strategies.

Part III provided a detailed analysis of the IAF's organizational context, showing how some areas of research, while aligned with the literature, require specific adaptations to optimize the proposed models. The study on the IAF's OVCoP revealed that, although this strategy is appreciated by military personnel, its effectiveness depends on maintaining engagement through key factors such as appointing a community leader, institutional recognition of the community, holding synchronous meetings (even remotely), and fostering a psychologically safe environment for sharing divergent perspectives. The analysis of the Lessons Learned Management System revealed that it is most effectively used in operational contexts, particularly in combat, support, and transportation. However, the process remains influenced by bureaucratic and hierarchical dynamics. The hierarchical level of the entities involved significantly affects the success of the LL process, with an average of nearly two years required to complete a full cycle. Many observations that remain in the system for over two years often fail to reach the final stages of definition and dissemination. The hierarchical structure within the IAF, both in terms of rank and organizational units, plays a critical role in shaping the efficiency of this process. Finally, the study on the application of artificial intelligence in defense sector training highlighted the need to improve KM systems through just-in-time training and lifelong learning approaches, making them more accessible to personnel across the defense sector.

In this section of the thesis, all of these key elements will be further explored with a specific focus on the IAF's organizational context, aiming to develop useful, tailored KM models for this environment. The Delphi method, which will be thoroughly discussed in the next chapter, has been chosen as the primary tool for supporting this analysis and contributing to the development of effective KM solutions for the IAF.

Chapter 11 - The Survey

11.1 Delphi method

The Delphi method, as reported by Dalkey & Helmer (1963), was designed to overcome the limitations of direct interaction by facilitating a controlled, anonymous communication process among experts. The method originated from defense research, specifically through a project sponsored by the U.S. Air Force and carried out by the Rand Corporation in the early 1950s. The goal was to gather reliable expert consensus through a series of questionnaires and controlled feedback. Initially, the study aimed to use expert opinion to determine the best U.S. industrial targets from the perspective of a Soviet strategic planner, as well as estimate the number of atomic bombs required to reduce munitions output. This approach was an alternative to a costly and complex data-collection process that would have been difficult to execute with the limited computing capabilities of the time (Dalkey & Helmer, 1963).

Likert scales are often used to capture opinions, and participants typically have the opportunity to revise their answers. The method is useful when accurate data is scarce or costly, and its application has expanded to fields like environment, health, and transportation.

According to Linstone and Turoff (1975), the Delphi technique is a method for gathering expert opinions on issues lacking clear evidence, often in complex situations requiring intuitive judgments. Therefore, there are no strict rules for its implementation, with panel sizes varying widely (Linstone suggests a minimum of seven, but panel sizes can range from 4 to 3000). The decision is empirical and pragmatic, based on factors like time and cost. The quality of the expert panel is more important than the number of participants, and the focus is more on the quality of the experts than the number.

While the traditional Delphi method is typically used to reach consensus on a given topic, variations such as the dissensus or Policy Delphi focus on gathering a wide range of opinions without necessarily aiming for consensus (Steinert, 2009: Diamond et al., 2014). Anyway, the Delphi method is effective for organizing and managing expert judgment, especially in complex problems that require intuitive interpretation of evidence or informed estimation. It can be employed as an alternative to traditional meetings, helping to avoid issues that arise from dominant personalities, group pressures, and hierarchical influences. This is particularly relevant in a military context, where junior officers may be hesitant to challenge the views of their senior-ranking colleagues.

The Delphi method typically involves at least two rounds, or three if the first round consists of open-ended questions. The exact number of rounds is debated, with Walker and Selfe (1996) sensibly noting that "multiple rounds can cause respondent fatigue and lead to higher dropout rates". Most studies tend to limit the process to two or three rounds (Diamond et al. 2014).

11.2 Limits of the method

Research on the Delphi method highlights some of its key limitations, particularly the challenge of achieving consensus on the issues explored. In a systematic review by Diamond et al. (2014), consensus was found to be the primary reason for concluding the Delphi process in only 23.5% of cases. Although 82.6% of these studies had predefined consensus criteria, only 60.8% specified that the process would end once consensus was reached. Additionally, the majority of Delphi studies (71.4%) followed a predetermined number of rounds, limiting the method's flexibility. McKenna (1994), building on the work of Loughlin & Moore (1979), suggests that consensus may be equated with as little as 51% agreement among participants, raising questions about the robustness of the findings.

One of the main limitations of the Delphi method is its uncertain reliability—whether different panels, given the same information, would produce similar results remains unclear. The method relies on the assumption that group decision-making is more reliable than individual judgments, strengthened by reasoned debate. However, pressures for convergence can compromise the accuracy of the method’s predictions. Despite this, the use of knowledgeable participants can enhance content validity, and successive rounds of questionnaires help improve concurrent validity. Ultimately, response rates significantly affect the overall validity of the results (Hasson et al., 2000), presenting another challenge for the method.

11.3 First round design

In the application of the Delphi method, the first round is typically dedicated to a highly divergent phase where only open-ended questions are presented, allowing experts to contribute freely without being influenced by predefined options. In the current survey, the aim is to gather the experts' views on the results presented in the preceding chapters. Consequently, the first round focuses on assessing the level of diversity in the experts' opinions concerning pre-identified elements, which emerged throughout the research and are detailed in Section 4.1. Anyway, the survey provided the options for open-ended responses, encouraging experts to offer a detailed justification or specific examples supporting their answers. The investigation aims to uncover any specific organizational traits related to the operation of officers trained as Knowledge Managers.

The questionnaire was structured into five thematic areas:

- Types of knowledge,
- KM orientation,
- KM processes,
- Potential implementations,
- KM tools.

Types of Knowledge

The questions in this section aimed to understand the experts' perspectives on the different types of knowledge and their classification and utilization within both the IAF as a whole and their specific departments. Experts were asked to rate the importance of managing each type of knowledge for the entire IAF using a 5-point Likert scale. They were also asked to evaluate the adequacy of managing each knowledge type within their department and provide specific examples to justify their assessment. Additionally, experts were asked to indicate if any knowledge types had dedicated management processes in their department, with the option to select multiple types or none.

KM Orientation

This section explored the experts' views on various possible orientations of KM, both in relation to the IAF and their own departments. They were asked to identify which orientation they believed would be most suitable for the Air Force and to provide reasoning for their choice. Similarly, they were asked which orientation they thought would be most appropriate for their department and to justify their answer. Further, experts were asked to identify the most prevalent KM orientation in the IAF and their department, providing concrete examples for each.

KM Processes

In the KM processes section, the questions focused on how KM processes are applied within each department and the experts' perceived importance of each process within the organizational framework of the IAF. Experts were asked to provide examples of how each KM process is implemented in their department and to highlight which processes they considered most important for the IAF as a whole.

Potential Implementations

This section aimed to gather insights on the potential implementation, development, and enhancement of key themes identified in the umbrella review presented in Section 1.5.5 ("integrated digital system," "innovation," "artificial intelligence," "human resource development," "organizational capabilities"). Experts were asked, through open-ended responses, to explain how they believed each of these five themes could be integrated into KM in the IAF. Additionally, they were asked to rate the relevance of each theme to KM in the IAF using a 5-point scale.

KM Tools

Referencing the platforms mentioned in Directive UIM-005 (Ufficio Generale per l'Innovazione Manageriale, 2024) for knowledge management within the IAF, this section assessed the extent to which each tool is used across IAF departments. Experts were asked to evaluate, on a 5-point scale, the usage of each tool within their respective departments.

11.4 First round delivery

A pool of 42 IAF officers was identified, located across the national territory and serving in various Air Force entities (central entities, training institutes, squadrons, detachments). Each participant was considered an expert, having successfully completed a course at the IAF and acquiring the qualification of Knowledge Manager. The course, which ran for four editions before the publication of the reference directive (UIM-005 issued in April 2024), was held from 2019 to 2023 (one edition every year) and aimed to provide participants with basic knowledge, terminology, and key KM models. The questionnaire was created on the Moodle platform, and a link to complete it was sent to each trained officer via email, which explained the objectives of the questionnaire, the procedure, and its structure. The questionnaire was available for completion from July 10 to September 3, 2024. Since the survey period overlapped with the summer season, an extended timeframe was provided to gather as many responses as possible.

11.5 Results from the first round and reflections for the design of the second round.

A total of 15 participants fully completed the first round. The sample of respondents is composed as follows:

- Ranks of the responding personnel: 11 Senior Officers (3 Majors, 7 Lieutenant Colonels, and 1 Colonel), 4 Junior Officers (3 Lieutenants and 1 Captain).
- Type of organization of the responding personnel: 6 Central Entities, 4 Squadrons, 3 Training Institutes, 2 Detachments.

To highlight the divergences and convergences of expert opinions, the mean, mode, and standard deviation were calculated for each scale item that required a scaled response.

The following are the results collected for each area of the survey.

Types of Knowledge

The questions in this section aimed to understand the experts' perspectives on the different types of knowledge and their classification and utilization within both the IAF as a whole and their specific departments. Experts were asked to rate the importance of managing each type of knowledge for the entire IAF using a 5-point Likert scale. They were also asked to evaluate the adequacy of managing each knowledge type within their department and provide specific examples to justify their assessment. Additionally, experts were asked to indicate if any knowledge types had dedicated management processes in their department, with the option to select multiple types or none.

Table 26: Statistics regarding the importance attributed in relation to the organization

Importance attributed in relation to the Organization		Mean	Mode	Standard Deviation
	know-about	4,40	4	0,63
	know-how	4,60	5	0,63
	know-why	4,60	5	0,83
	know-who	4,73	5	0,46
	know-with	4,53	5	0,74

Table 27: Statistics regarding the perceived adequacy of the management of specified form of knowledge

Perceived adequacy of the management of specified form of knowledge		Mean	Mode	Standard Deviation
	know-about	3,47	3	1,06
	know-how	3,73	4	1,03
	know-why	3,47	3	1,13
	know-who	3,87	5	1,19
	know-with	3,13	3	1,25

The respondents' opinions converge on the importance of managing the different types of knowledge effectively. However, their views are more divergent regarding the perceived adequacy of knowledge management within their respective departments. Knowledge related to finding useful information (know-who) is perceived as being better managed, with an average rating of 3.87, while the ability to understand the relationships between different types of knowledge to generate new knowledge (know-with) is considered less adequately managed, with an average rating of 3.13. The know-with category also shows the highest standard deviation among the experts' ratings, indicating significant variability in their responses. To further explore this aspect, one might hypothesize that those experts who assigned a lower score to know-with are operating in contexts where the creation of new knowledge is less relevant. Below is a table showing the average ratings for the adequacy of know-with management by department type.

Table 28: Average ratings for the adequacy of know-with management by department type

TYPE OF DEPARTMENT	AVERAGE RATING
Central entity	3.67
Training institute	2.67
Squadron	3.00
Detachment	2.50

According to the table 27, it appears that the management of know-with is more adequate in central entities compared to how it is managed in detachments. This result may seem at odds with the response to the following question: "For which of these types of knowledge do you believe a process is applied in your department?" The results, expressed as percentages, are shown in the table below.

Table 29: Statistics regarding the perceived application of the management of specified form of knowledge in relation to thetype of Department

Type of Department	Know-how	Know-who	Know-about	Know-with	Know-why	None
Central entity (6)	50%	50%	17%	0%	0%	17%
Squadron (4)	75%	25%	50%	0%	0%	25%
Training institute (3)	100%	33%	67%	33%	33%	0%
Detachment (2)	0%	0%	50%	50%	0%	50%

The following are selected textual responses deemed useful for the analysis and interpretation of results.

From personnel in central entities (original responses):

- (Know-how) *Nel mio ambito, il personale opera con piena consapevolezza dei processi lavorativi di interesse.*
- (Know-how*) Il Know-how in un Reparto Genio è fondamentale per raggiungere gli obiettivi presenti e futuri (puntando sullo stesso per il travaso delle conoscenze/competenze da parte del personale più anziano verso personale più giovane.*
- (Know-how) *Nel contesto del Reparto, la conoscenza procedurale (know-how) assume un'importanza cruciale e va ben oltre la semplice esecuzione di compiti.*
- (Know-who) *La conoscenza delle fonti (know-who) è un asset fondamentale per il Reparto. […] sapere dove reperire dati affidabili e aggiornati è cruciale per prendere decisioni informate e strategiche.*
- (Know-about) *Nel mio ambito, può capitare che venga chiesto di svolgere attività lavorative pur avendo una parziale/incompleta conoscenza su oggetti e fatti.*
- (Know-about) *[…] il Know-about è importante in ogni realtà lavorativa, ma in special modo nel Reparto in cui lavoro, Ente di tecnici soggetti a continua formazione (es.*

master di vari livelli per ingegneri e seminari/corsi a cui partecipa personale di tutti i Ruoli).

- (Know-with) *Nel mio ambito ritengo che tale tipologia di conoscenza non sia adeguatamente gestita, principalmente per una carenza formativa ma anche per l'assenza di attività specifiche che permettano di avere una visione a più ampio respiro su tali tematiche*
- (Know-with) *[…] Nell'ambito del Reparto, questa abilità è cruciale per affrontare le complessità e le incertezze nei vari settori della F.A.*
- (Know-why) *[…] conoscere le cause degli eventi (riferendomi soprattutto a quelli che comportano criticità), inserendole nelle "lezioni apprese" agevola il lavoro futuro in caso di situazioni analoghe.*
- (Know-why) *La conoscenza causale/razionale rappresenta un asset inestimabile valore per il Reparto. Essa va ben oltre la semplice esecuzione di compiti e la comprensione delle procedure.*

From personnel in central entities (English translation):

- (Know-how) *In my field, personnel operate with full awareness of the relevant work processes.*
- (Know-how) *Know-how in an Engineering Unit is essential for achieving both present and future objectives, particularly in facilitating the transfer of knowledge and skills from senior personnel to younger staff.*
- (Know-how) *In the context of the Unit, procedural knowledge (know-how) plays a crucial role and extends far beyond the mere execution of tasks.*
- (Know-who) *Knowledge of sources (know-who) is a fundamental asset for the Unit. […] Knowing where to find reliable and up-to-date data is crucial for making informed and strategic decisions.*
- (Know-about) *In my field, there are instances where I am required to carry out tasks despite having only partial or incomplete knowledge of objects and facts.*
- (Know-about) *[…] Know-about is important in any work environment, but especially in my Unit, a technical entity where continuous training is essential (e.g., various levels of master's programs for engineers and seminars/courses attended by personnel across all roles).*

- (Know-with) *In my field, I believe this type of knowledge is not adequately managed, primarily due to a lack of training but also because of the absence of specific activities that would provide a broader perspective on these topics.*
- (Know-with) *[…] Within the Unit, this ability is crucial for addressing complexities and uncertainties in various sectors of the Air Force.*
- (Know-why) *[…] Understanding the causes of events (especially those that lead to critical issues) and incorporating them into "lessons learned" facilitates future work in similar situations.*
- (Know-why) *Causal/rational knowledge is an invaluable asset for the Unit. It goes far beyond merely executing tasks and understanding procedures.*

From personnel in training institutes (original responses):

- (Know-how) *Le abilità pratiche, possono essere acquisite con delle procedure. Nel mio reparto molte procedure (anche se non tutte) sono standardizzate (anche se non formalizzate), il che aiuta l'acquisizione delle abilità.*

From personnel in training institutes (English translation):

- (Know-how) *Practical skills can be acquired through procedures. In my unit, many procedures (although not all) are standardized (even if not formalized), which helps in acquiring these skills.*

From personnel in Squadrons (original responses):

- (Kow-how) *A livello di Stormo, molta conoscenza trasmessa durante SOCIALIZZAZIONE tacita -esplicita , rappresenta talvolta la modalità più attuata/frequente per trasmettere conoscenza.*
- (Know-with) *[Bisognerebbe] migliorare nel complesso la comunicazione e la gestione dei database, creando delle check list e delle mappe concettuali utili alla comprensione immediata dei vari concetti/ pratiche in maniera di rendere edotto tutto il personale e renderlo istruito su tutto l'operato tecnico/amministrativo/gestionale di reparto/stormo*

in maniera di non lasciare mai buchi nell'organizzazione ed essere continuamente operativi e capaci di affrontare qualsiasi evento/azione.

- (Know-with) *In un ambiente operativo come il nostro Stormo, il know-with, sebbene possa risultare estremamente accrescitivo, talvolta non ha tempo/risorse per essere messo in pratica.*
- (Know-wy) *[Bisognerebbe] migliorare il dialogo e l'analisi delle cause/eventi, aumentare il livello di comunicazione ed empatia nella scala gerarchica.*

From personnel in Squadrons (English translation):

- (Know-how) *At the Wing level, much of the knowledge is transmitted through tacit-to-explicit socialization, which often represents the most commonly used method for knowledge transfer.*
- (Know-with) *[It would be necessary to] improve overall communication and database management by creating checklists and conceptual maps that allow for the immediate understanding of various concepts and practices. This would ensure that all personnel are fully informed and trained on the technical, administrative, and managerial operations of the unit/wing, preventing gaps in organization and ensuring continuous operational readiness and the ability to handle any event or action.*
- (Know-with) *In an operational environment like our Wing, know-with, although potentially highly enriching, sometimes lacks the time or resources to be effectively implemented.*
- (Know-why) *[It would be necessary to] improve dialogue and the analysis of causes and events, while also enhancing communication and empathy within the hierarchical structure.*

From personnel in detached units (original responses):

- (Know-who) *Adeguata, sia per la disciplinata gestione degli archivi che per l'esperienza del personale che opera nei punti chiave che conosce perfettamente dove reperire il materiale.*
- (Know-with) *Scarsa, dovuta alla mancanza di formazione nel settore.*
- (Know-why) *E' adeguata, dettata spesso dall'esperienza del personale che opera nei diversi settori.*

From personnel in detached units (English translation):

- (Know-who) *Adequate, both due to the well-organized management of archives and the experience of key personnel who know exactly where to retrieve the necessary materials.*
- (Know-with) *Limited, due to the lack of training in the field.*
- (Know-why) *Adequate, often driven by the experience of personnel working in various sectors.*

These divergences lead to a deeper investigation into the types of knowledge, distinguishing not only between types of entities but also between work contexts. Some questions of the second round should be aimed at exploring this aspect.

KM Orientation

As can be easily deduced from the following table, the experts agree in identifying the people-oriented KM approach as the most appropriate for both the IAF and their respective departments. However, they perceive the goal-oriented KM approach as the most commonly used in their own departments, while the technology-oriented approach is seen as the most widespread at the IAF level.

Table 30: Results regarding KM orientations

	people oriented KM	**process oriented KM**	**technology oriented KM**	**target oriented KM**
Which do you believe would be most suitable for the Air Force?	6	4	1	4
Which do you believe would be most suitable for your department?	6	4	0	5
Which do you believe is the most widespread in the Air Force?	4	3	6	2
Which do you believe is the most widespread in your department?	1	3	3	8

The following are some statements considered particularly significant.

These come from individuals who support the importance of a people-oriented KM approach.

(Original rensponses)

- *Sebbene tutte le tipologie di orientamento siano adatte per la Forza Armata, quello che ritengo possa essere più efficace e alla base di tutto sia un approccio orientato alle persone tra le quali debba essere trasmessa, in maniera più naturale, esperienza e conoscenza. La tecnologia e i processi debbono considerarsi comunque come ausili essenziali per poi orientare l'insieme agli obiettivi strategici che l'organizzazione vuole raggiungere.*
- *Il personale rappresenta la risorsa fondamentale della nostra organizzazione, spesso custode della conoscenza, delle tradizione e delle procedure. I processi, la tecnologia e gli obiettivi sono orientamenti raggiungibili, più o meno efficacemente, solo se la componente umana è formata a dovere.*

(English translation)

- *Although all types of approaches are suitable for the Armed Forces, I believe that the most effective and fundamental one is a people-oriented approach, where experience and knowledge can be transmitted more naturally among individuals. However, technology and processes should still be considered as essential tools to support and align the overall strategy with the organization's strategic objectives.*
- *Personnel represent the key resource of our organization, often serving as custodians of knowledge, traditions, and procedures. Processes, technology, and objectives are achievable orientations, but their effectiveness largely depends on properly trained and prepared human resources.*

These come from individuals who support the importance of a process-oriented KM approach.

(Original rensponses)

- *Talvolta la carenza di mansionari quanto più specifici e direttivi comporta l'attuazione di processi operativi arbitrari o mutevoli nel tempo, compromettendo standardizzazione e ottimizzazione delle risorse. Bisognerebbe evitare l'arbitrio nell'ideare processi* *operativi diversi in Enti simili, ma puntare tutti a praticare l'unica best practice aziendalmente approvata.*

- *Gestire sistematicamente i flussi di conoscenza e integrarli nelle operazioni lavorative quotidiane darebbe quel successo duratura svincolandolo dall'episodica riuscita per la buona volontà degli individui.*

(English translation)

- *At times, the lack of highly specific and directive job descriptions leads to the implementation of arbitrary or evolving operational processes over time, compromising standardization and resource optimization. It is essential to avoid discretion in designing different operational processes across similar entities and instead ensure that everyone adheres to the single best practice officially approved by the organization.*

Systematically managing knowledge flows and integrating them into daily work operations would ensure lasting success, making it independent from occasional achievements driven solely by individual goodwill.

These come from individuals who support the importance of a technology-oriented KM approach.

(Original rensponses)

- *L'Arma Azzurra notoriamente è la più tecnologica e, con l'avvento dell' Intelligenza Artificiale secondo me è di vitale importanza investire, gestire e stare al passo con i progressi che grazie ad essa si raggiungono.*

(English translation)

- *The Air Force is widely known as the most technologically advanced branch, and with the advent of Artificial Intelligence, I believe it is vital to invest in, manage, and keep up with the progress achieved through its advancements.*

These come from individuals who support the importance of a target-oriented KM approach.

(Original rensponses)

- *KM orientati alle persone, KM orientato ai processi e KM orientato alla tecnologia convogliano insieme verso il KM orientati agli obiettivi. Le PERSONE attraverso PROCESSI tramite la TECNOLOGIA sviluppano OBIETTIVI.*

- *La risposta ideale è un approccio integrato che combini i punti di forza di ciascuno degli orientamenti. Un KM orientato ai processi è fondamentale per garantire la qualità e l'efficienza delle operazioni. Un KM orientato alla tecnologia è necessario per gestire l'enorme quantità di dati generati dai sistemi militari. Un KM orientato agli obiettivi assicura che le attività di KM siano allineate con la strategia dell'organizzazione. Un KM orientato alle persone crea un ambiente collaborativo e facilita lo scambio di conoscenze. In sintesi, si dovrebbe adottare un modello di KM che: sia centrato sull'uomo: Valorizzando il ruolo delle persone nella creazione e nella condivisione della conoscenza. Sia basato sui processi: Ottimizzando i flussi di lavoro e garantendo la qualità delle informazioni. Sia supportato dalla tecnologia: Utilizzando strumenti tecnologici per gestire e condividere la conoscenza in modo efficiente. Sia orientato agli obiettivi: Contribuendo al raggiungimento degli obiettivi strategici dell'organizzazione.*

(English translation)

- *People-oriented KM, process-oriented KM, and technology-oriented KM all converge towards goal-oriented KM. PEOPLE, through PROCESSES, utilizing TECHNOLOGY, develop OBJECTIVES.*
- *The ideal response is an integrated approach that combines the strengths of each orientation. A process-oriented KM is fundamental to ensure the quality and efficiency of operations. A technology-oriented KM is necessary to manage the enormous amount of data generated by military systems. A goal-oriented KM ensures that KM activities are aligned with the organization's strategy.*
  A people-oriented KM creates a collaborative environment and facilitates knowledge exchange. In summary, a KM model should be adopted that: Is human-centered: Valuing the role of people in the creation and sharing of knowledge. Is process-based: Optimizing workflows and ensuring the quality of information. Is technology-supported: Using technological tools to manage and share knowledge efficiently. Is goal-oriented: Contributing to the achievement of the organization's strategic objectives.

On this aspect, the goal is to achieve greater convergence in order to understand which approach is considered most relevant by the experts. To this end, a question of the second round will presents four statements extracted from the responses obtained in the first round regarding this topic. Each of the four statements will represent a position in favor of one of the four KM orientations.

Potential Implementations

All the proposed topics are considered potentially relevant for KM in the IAF, as shown in the following table.

Table 31: Perceived relevance of the topic in relation to knowledge management in the IAF

Topic	Mean	Mode	Standard Deviation
Integrated digital systems	4,27	5	0,80
Innovation	4,33	5	1,18
Artificial intelligence	3,93	5	1,22
Human resource development	4,80	5	0,56
Organizational capabilities	4,73	5	0,46

The following are some statements considered particularly interesting.

Regarding Integrated Digital Systems:

(Original rensponses)

- *Permettono la condivisione dei dati e delle informazioni tra sistemi differenti, consentendo di instaurare relazioni che possono essere parte fondamentale di un processo decisionale.*
- *Oggi essenziali per una forza armata in continua evoluzione come la nostra. Facilitano i processi, li chiarificano e li semplificano in modo da renderli maggiormente interoperabili e trasferibili.*
- *Creando una VERA integrazione tra tutti i sistemi... una banca dati con accessi alle informazioni per livelli/competenze/necessità, un polo punto di accesso, una sola password e da li si fa tutto. Un esempio positivo è il portale delle Direttive.*
- *Fondamentali, ma per funzionare hanno la necessità di essere corredati da Manuali fruibili e attagliati alla realtà dei Reparti.*

(English translation)

- *They enable the sharing of data and information between different systems, allowing for the establishment of connections that can be a fundamental part of the decision-making process.*
- *Essential today for an armed force in constant evolution like ours. They facilitate, clarify, and simplify processes, making them more interoperable and transferable.*
- *Creating TRUE integration between all systems… a centralized database with access to information based on levels, competencies, and needs, a single access point, one*

password, and from there, everything can be managed. A positive example is the Directives Portal.

- *Fundamental, but to function effectively, they need to be accompanied by accessible manuals tailored to the realities of the Units.*

Regarding the topic of Innovation:

(Original rensponses)

- *Permette di applicare nuove metodologie a processi lavorativi già in essere, fornendo alternative e punti di vista differenti sempre in ottica di miglioramento continuo.*
- *Sempre utile se correttamente "armonizzata" con i sistemi in uso.*
- *SMA, Alti Comandi, SOA di Reparto.*
- *Ciò che fa la differenza non sono le idee o le innovazioni in termini di contenuto/oggetto, la differenza secondo me la fa la mentalità innovativa ovvero la gestione delle idee con la loro implementazione e la messa a sistema nel BAU.*
- *citata più volte fino ad ora, l'INNOVAZIONE è alla base di tutto perché 100 anni li abbiamo passati ma il futuro è in continuo mutamento e vede nuove tecnologie e nuove conoscenze che non possono essere trascurate da nessuno di noi, per quanto riguarda gli aeroplani, per quanto riguarda i radar, per quanto riguarda i missili e per quanto riguarda l'insegnamento e quindi la Knowledge.*

(English translation)

- *It allows for the application of new methodologies to existing work processes, providing alternatives and different perspectives with a focus on continuous improvement.*
- *Always useful if properly "harmonized" with the systems in use.*
- *SMA, High Commands, Unit SOA.*
- *What makes the difference is not just ideas or innovations in terms of content or subject matter; in my opinion, the real difference lies in an innovative mindset—that is, the management of ideas, their implementation, and their integration into the BAU (Business as Usual) system.*
- *Mentioned multiple times so far, INNOVATION is the foundation of everything—we have passed the 100-year mark, but the future is in constant evolution, bringing new technologies and knowledge that none of us can afford to overlook. Whether it's about aircraft, radars, missiles, or teaching and knowledge management, innovation must remain at the core of our approach.*

Regarding the topic of Artificial Inteligence:

(Original rensponses)

- *Ausilio importante che potrà aiutare al raggiungimento degli obiettivi e per la condivisione della conoscenza.*
- *importante ma da usare con moderazione su alcuni ambiti*
- *Di strategica importanza la gestione della stessa per lo sviluppo di e miglioramento di varie fasi e settori, tra cui il KM.*
- *Ancora sconosciuta per molti aspetti. Probabilmente faciliterà molti settori.*
- *Rappresenta il futuro ma non immediato per la nostra organizzazione.*

(English translation)

- *An important tool that can assist in achieving objectives and facilitating knowledge sharing.*
- *Important, but should be used in moderation in certain areas.*
- *Strategically important, as its management plays a key role in the development and improvement of various phases and sectors, including KM.*
- *Still largely unknown in many aspects. It will likely facilitate multiple sectors.*
- *It represents the future, but not an immediate one for our organization.*

Regarding the topic of Human Resource Development:

(Original rensponses)

- *Ritengo la risorsa umana fondamentale in ogni organizzazione. Lo sviluppo, la crescita e l'ampliamento delle conoscenze e competenze un requisito essenziale per il raggiungimento degli obiettivi.*
- *corsi professionali, sviluppo delle competenze, sviluppo del benessere del personale.*
- *Sono anni difficili per il personale, sempre più inadeguato, numericamente, per sostenere lo sforzo del sistema. Occorre investire molto nelle poche risorse, senza tuttavia raggiungere punti di rottura strutturale.*
- *Mediante profili di carriera, non in termini di grado, ma di progressione degli incarichi, accompagnati da momenti formativi ad hoc.*

- *fondamentale la cura delle occasioni di qualifica, upgrade e aggiornamento delle competenze. (es. ci vorrebbero dei cyber guru ah hoc anche per altre tipologie di lavoro comuni a tutti gli Edo di FA).*

(English translation)

- *I consider human resources fundamental in every organization. Development, growth, and the expansion of knowledge and skills are essential requirements for achieving objectives.*
- *Professional courses, skills development, and personnel well-being improvement.*
- *These are challenging years for personnel, who are increasingly insufficient in number to sustain the system's effort. It is necessary to invest heavily in the few available resources, without, however, reaching a point of structural breakdown.*
- *Through career paths, not in terms of rank, but in terms of progression of assignments, accompanied by tailored training programs.*
- *Ensuring opportunities for qualification, upgrading, and skills development is crucial. (e.g., there should be dedicated cyber experts for various types of work common to all Armed Forces units).*

Regarding the topic of Organizational capabilities

(Original rensponses)

- *Importante, pur ritenendolo conseguenziale ad uno sviluppo delle risorse umane di alto livello.*
- *Il KM può senza dubbio contribuire al miglioramento delle capacità organizzative.*
- *Sono necessarie a tutti i livelli dell'organizzazione: dalla leadership che deve tracciare le linee guida al più piccolo dei nuclei che deve potersi organizzare per massimizzare l'efficienza del proiprio operato.*
- *La capacità organizzativa è il risultato di tutti i fattori sopra elencati. Al migliorare della stessa migliora la qualità del lavoro in tutte le fasi.*

(English translation)

- *Important, although I consider it a consequence of the development of high-level human resources.*
- *KM can undoubtedly contribute to improving organizational capabilities.*

- *They are necessary at all levels of the organization: from the leadership, which must set the guidelines, to the smallest units, which must be able to organize themselves to maximize the efficiency of their work.*
- *Organizational capability is the result of all the factors listed above. As it improves, the quality of work at all stages also improves.*

In the second round, the aim is to achieve greater convergence on this aspect. Therefore, in one of the questions, participants will be asked to rank five topics from the most relevant to the least relevant for the future of KM in the Air Force.

KM Tools

Regarding the software indicated by the UIM-005, directive for knowledge management in the IAF, The question "Which digital platforms for managing data, information, and knowledge are most commonly used in your department?" was asked, and the results are presented in the following table.

Table 32: Statistics for regarding Digital Platforms for Data, Information, and Knowledge Management in IAF

Softwares	Mean	Mode	Standard Deviation
Document Management System (SIDPAM)	4,27	5	1,10
Content Management System (SHAREPOINT)	3,93	5	1,10
Lessons Learned Platform	2,27	1	1,39
Incident Reporting System Platform	1,60	1	1,06
Learning Management System (MOODLE)	3,27	4	1,53

In the area focused on tools, their relevance appears to be partially linked to the type of entity and influenced by other factors such as personnel training, the work environment, and familiarity with the tool. The results also show a strong connection to the type of entity. For instance, the LCMS Moodle platform is rated more highly by training institutes and central entities, while the Lessons Learned platform and the Incident Reporting System receive the highest ratings from Squadrons. Conversely, platforms like SharePoint (CMS) and SIDPAM (document management) are widely used across all types of entities. Several questions in the second round will aim to further investigate these aspects.

KM Processes

The KM processes considered most important by the experts are knowledge sharing, knowledge storage/retrieval, and knowledge application.

Table 33: Selection of the most important KM processes

Which KM processes do you consider most important for the Air Force?	Count
Knowledge Creation (KC):	4
Knowledge Storage/Retrieval (KSTR):	8
Knowledge Sharing (KS):	11
Knowledge Application (KAP):	6
Knowledge Transfer (KT):	4
Knowledge Acquisition (KA):	3

From a broader analysis, it is interesting to note that of the four indications regarding Knowledge Transfer (KT) processes, three were provided by personnel from Squadrons. Additionally, out of the four officers from Squadrons, three indicated KT as an important process. In contrast, the Knowledge Creation (KC) process received a preference from personnel across all four different types of entities. The three preferences for Knowledge Application (KA) processes are distributed among personnel from a Squadron, a Central Entity, and a Training Institute.

The following examples were provided in the open responses concerning KM processes:

- **For KC**: Primarily brainstorming activities.
- **For KA**: Information retrieval from external sources and stakeholders, document management systems, bibliographic research, participation in conferences and seminars, collaborations with universities and research centers, consultations with companies working with the organization, and base open days.
- **For KSTR**: Standardizing procedures, document management systems, shared network folders, CMS, and storing information on servers or networks mainly located within the organization. There is a noted need for training in the use of tools and an improvement in the system for searching and retrieving necessary information.

- **For KAP**: The effectiveness depends on the training received, personal inclinations, and work methods, which are not always standardized. Best practices and lessons learned from previous projects should be applied to optimize internal processes and increase efficiency. Support decision-making by providing relevant information and in-depth analysis, implement training and mentoring programs, and use collaborative tools to facilitate the sharing and discussion of ideas via collaboration platforms. Additionally, there is standardization in terms of procedures and their application, also tied to training programs.
- **For KS**: Knowledge tends to be shared across related fields, even if they do not necessarily perform similar activities, maintaining an extremely positive organizational climate that helps approach daily tasks with greater efficiency. Morning briefings and CMS software are used.
- **For KT**: New arrivals are typically paired with experienced personnel who have full command of the relevant work processes. On-Job Training (OJT) is applied in flight maintenance departments. New guides and orientation programs are developed by Flight Groups/Units. Issues highlighted include the lack of young personnel for replacement and a reluctance to share information.

In the second round, the focus needs to shift toward specific approaches and work methods rather than KM processes.

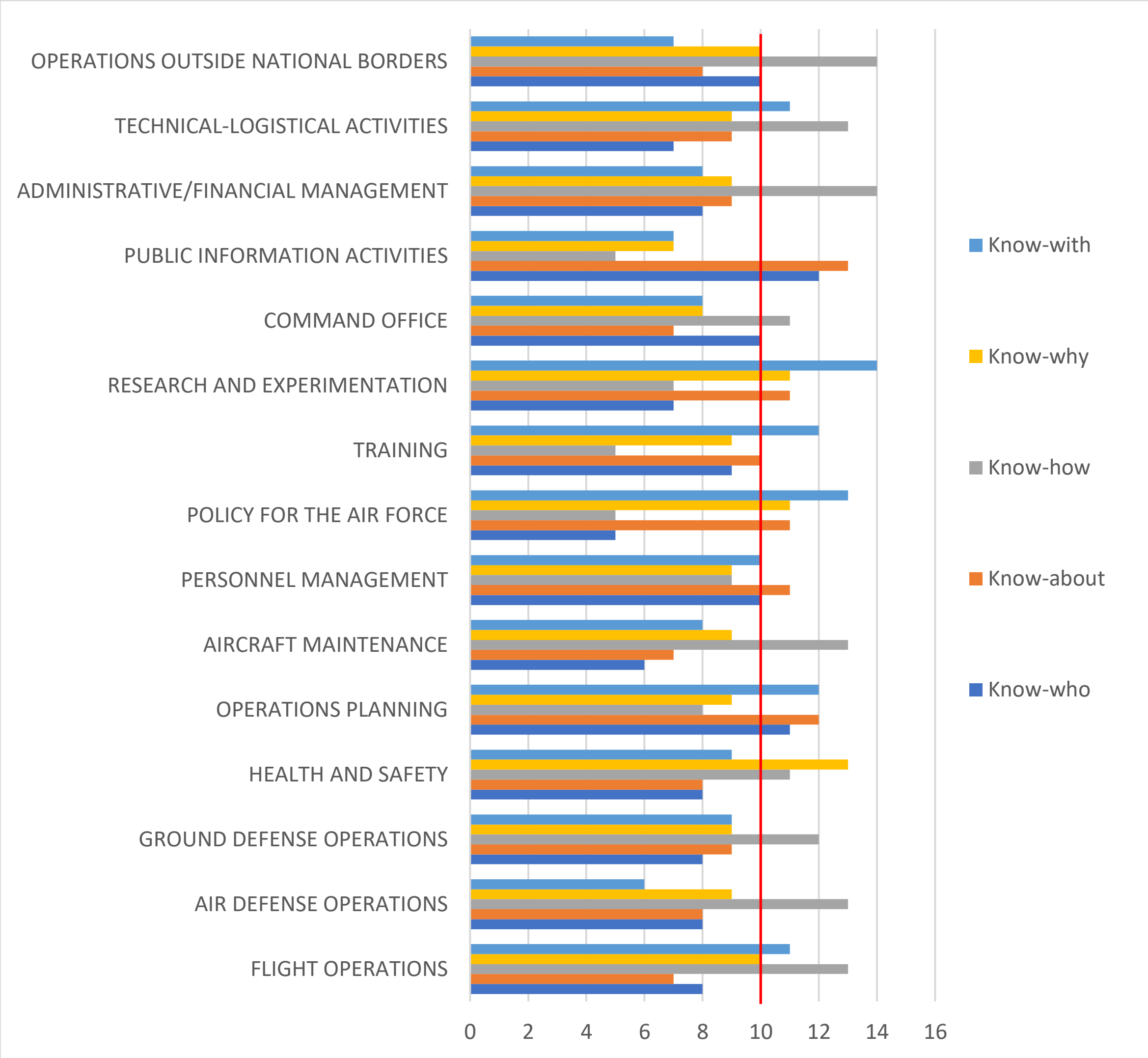
11.6 Results and Findings from Delphi questionaire

The second round was administered in the same manner as the first (explanatory email and questionnaire created on Moodle). The reference sample remained the same (42 officers trained as knowledge managers), allowing those who had not responded to the first round to participate. The explanatory email included a report summarizing the main results from the first round, highlighting areas of major divergence, areas of convergence, and the objectives of each question in the second round.

The questionnaire was available on the platform from September 26, 2024, to October 10, 2024. A reminder was sent to participants on October 5. By October 10, responses from 15 experts had been collected, of whom 8 had responded to the first round, while 7 had not.

Question 1, "Select the types of knowledge you consider to be the most important for each of the following work contexts (multiple selections are allowed)", received the following responses:

Graph 28: Answers to Question 1



The chart highlights the areas where expert opinions converge. We consider convergence to be above 60% when, for each work area, the most important types of knowledge are those that received more than 10 out of 15 preferences (i.e., the bars that exceed the red-highlighted value line). Below are the converging expert opinions regarding Question 1.

- Know-who is considered most important for the following work areas: public information activities, operations planning.

- Know-about is considered most important for the following work areas: public information activities, research and experimentation, policy for the Air Force, personnel management, operations planning.
- Know-how is considered most important for the following work areas: technical-logistical activities, operations outside national borders, administrative/financial management, command office, aircraft maintenance, health and safety, ground defense operations, air defense operations, flight operations.
- Know-why is considered most important for the following work areas: research and experimentation, policy for the Air Force, health and safety.
- Know-with is considered most important for the following work areas: technical-logistical activities, research and experimentation, policy for the Air Force, training, operations planning, flight operations.

Question 2 asked respondents to indicate the work area related to their current primary role.

Question 3 asked respondents to choose, from among four statements, the one that best represents their opinion. The statement on which there was convergence, recording 10 preferences out of 15, is the following:

> *Si dovrebbe adottare un modello di KM che: sia centrato sull'uomo: Valorizzando il ruolo delle persone nella creazione e nella condivisione della conoscenza. Sia basato sui processi: Ottimizzando i flussi di lavoro e garantendo la qualità delle informazioni. Sia supportato dalla tecnologia: Utilizzando strumenti tecnologici per gestire e condividere la conoscenza in modo efficiente. Sia orientato agli obiettivi: Contribuendo al raggiungimento degli obiettivi strategici dell'organizzazione*[20].

[20] *A KM model should be adopted that:*
Is human-centered: Valuing the role of people in the creation and sharing of knowledge.
Is process-based: Optimizing workflows and ensuring the quality of information.
Is supported by technology: Using technological tools to efficiently manage and share knowledge.
Is goal-oriented: Contributing to the achievement of the organization's strategic objectives.

The following table lists all 4 statements and the respective preferences received:

Table 34: Preferences expressed by the experts for each statement

1	*L'Arma Azzurra notoriamente è la più tecnologica e, con l'avvento dell' Intelligenza Artificiale è di vitale importanza investire, gestire e stare al passo con i progressi che grazie ad essa si raggiungono*[21].
10	*Si dovrebbe adottare un modello di KM che: sia centrato sull'uomo: Valorizzando il ruolo delle persone nella creazione e nella condivisione della conoscenza. Sia basato sui processi: Ottimizzando i flussi di lavoro e garantendo la qualità delle informazioni. Sia supportato dalla tecnologia: Utilizzando strumenti tecnologici per gestire e condividere la conoscenza in modo efficiente. Sia orientato agli obiettivi: Contribuendo al raggiungimento degli obiettivi strategici dell'organizzazione.*
2	*Il personale rappresenta la risorsa fondamentale della nostra organizzazione, spesso custode della conoscenza, delle tradizione e delle procedure. I processi, la tecnologia e gli obiettivi sono orientamenti raggiungibili, più o meno efficacemente, solo se la componente umana è formata a dovere*[22].
2	*Gestire sistematicamente i flussi di conoscenza e integrarli nelle operazioni lavorative quotidiane darebbe quel successo duratura svincolandolo dall'episodica riuscita per la buona volontà degli individui*[23].

The results of the second question from the Delphi survey place a clear emphasis on the central role of human resources within the KM model. Experts agree that the success of any knowledge management system ultimately hinges on the people who create, use, and share knowledge. The human-centered approach is considered the cornerstone of effective KM, highlighting the need to prioritize individuals as the primary drivers of knowledge generation and dissemination. In the context of the IAF, this means fostering an environment where interpersonal collaboration, experience sharing, and continuous learning are valued and promoted. Human interactions, trust, and personal expertise are essential to the effective circulation of knowledge within the organization.

While the human factor is the foundation, the other components—processes, technology, and objectives—serve as complementary elements that support and enhance the human-centered

[21] *The Air Force is famously the most technologically advanced, and with the advent of Artificial Intelligence, it is vital to invest, manage, and keep up with the progress achieved thanks to it.*
[22] *The personnel represent the fundamental resource of our organization, often the custodians of knowledge, traditions, and procedures. Processes, technology, and objectives are attainable goals, more or less effectively, only if the human component is properly trained.*

[23] *Systematically managing knowledge flows and integrating them into daily work operations would provide lasting success, freeing it from the occasional success driven by individual goodwill.*

focus. The process-based approach ensures that the valuable knowledge created by individuals is captured, structured, and distributed efficiently. Well-defined workflows allow for smoother interactions and help preserve the integrity and accuracy of knowledge as it moves through the organization. Optimizing processes means that individuals can focus on their expertise while being supported by efficient systems that facilitate knowledge flow.

Technology plays a supportive role, enabling human resources to manage and share knowledge more efficiently. Experts highlight the importance of integrating technology-supported tools to assist individuals in accessing, storing, and disseminating information. In an organization like the IAF, where operations are complex and dispersed, digital tools can break down barriers to communication and foster collaboration across departments, units, and locations. However, the technology should be seen as an enabler rather than the focus, reinforcing the human aspect by facilitating access to knowledge rather than replacing the critical role of personal expertise and experience.

Finally, the goal-oriented dimension ensures that the KM system is aligned with the organization's strategic objectives. While individuals are the drivers of knowledge creation and sharing, the system as a whole must contribute to the larger mission of the IAF. Knowledge management should actively support the organization's goals, ensuring that the knowledge shared is relevant, actionable, and contributes to operational effectiveness.

Question 4 asked respondents to rank the five topics that emerged from the umbrella review presented in Chapter 4 in order of relevance for the future of KM in the IAF, from most to least important. Below are the topics and their rankings based on the experts' opinions:

- Human resource development (ranked as most relevant by 9 experts and least relevant by 2 experts).
- Organizational capabilities (ranked as most relevant by 4 experts and least relevant by 4 experts).
- Integrated digital systems (ranked as most relevant by 2 experts and least relevant by 3 experts).
- Innovation (ranked as most relevant by 1 expert and least relevant by 2 experts)
- Artificial intelligence (ranked as most relevant by 1 expert and least relevant by 6 experts).

Question 5: "Rank the following software based on how important you consider them for your work."

The results presented for this question exclude the responses of one expert who likely did not understand the mechanics of the question, as they assigned the highest importance to a software that is not used in their work area (while giving the same software a low score for functionality in their field in the subsequent question) and assigned the lowest importance to a software that is widely used in their work area (while giving it a high score for functionality in the subsequent question).

The following tables show the results for each software.

Table 35: Responses provided to Question 5 regarding CMS - SharePoint

CMS - SHAREPOINT		
Number of experts	**Work areas**	**Average ranking for each area**
5	Technical-Logistical Activities	1,0
1	Administrative/Financial Management	2,0
1	Flight Operations	2,0
2	Command Office	2,5
1	Research and Experimentation	3,0
3	Training	3,3
1	Air Force Policy	5,0
1	Personnel Management	5,0

Table 36: Responses provided to Question 5 regarding LMS - Moodle

LMS - MOODLE		
Number of experts	**Work areas**	**Average ranking for each area**
1	Personnel Management	2,0
3	Training	2,7
5	Technical-Logistical Activities	2,8
1	Air Force Policy	3,0
1	Flight Operations	3,0
1	Administrative/Financial Management	3,0
2	Command Office	3,5
1	Research and Experimentation	4,0

Table 37: Responses provided to Question 5 regarding the Lessons Learned Platform

LESSONS LEARNED PLATFORM		
Number of experts	**Work areas**	**Average ranking for each area**
1	Air Force Policy	2,0
1	Personnel Management	3,0
5	Technical-Logistical Activities	3,0
3	Training	3,0
1	Flight Operations	4,0
1	Administrative/Financial Management	4,0
2	Command Office	4,5
1	Research and Experimentation	5,0

Table 38: Responses provided to Question 5 regarding the Incident Reporting System Platform

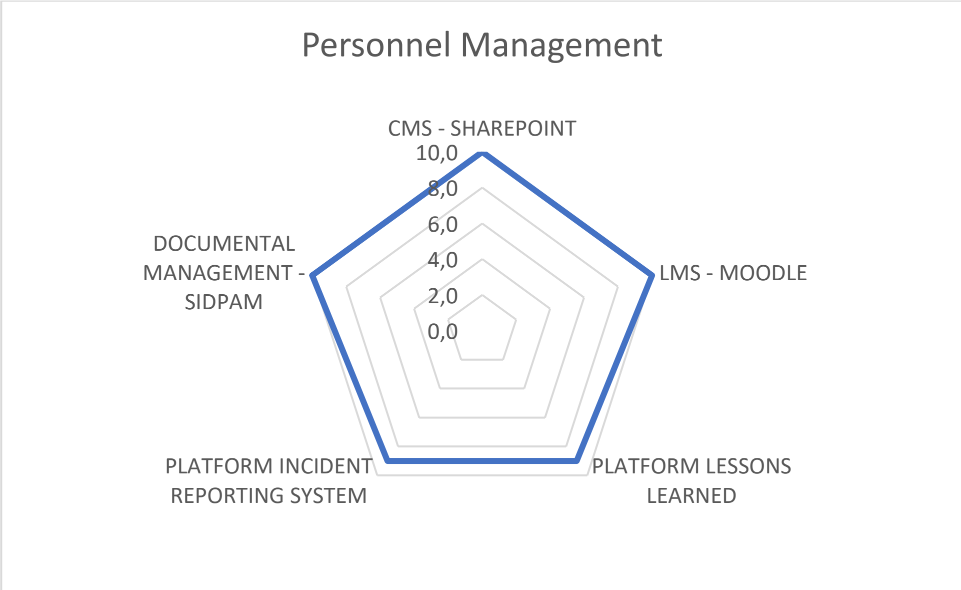
INCIDENT REPORTING SYSTEM PLATFORM		
Number of experts	**Work areas**	**Average ranking for each area**
1	Air Force Policy	1,0
3	Training	3,7
1	Personnel Management	4,0
5	Technical-Logistical Activities	4,0
1	Research and Experimentation	5,0
1	Flight Operations	5,0
2	Command Office	5,0
1	Administrative/Financial Management	5,0

Table 39: Responses provided to Question 5 regarding DMS - SIDPAM

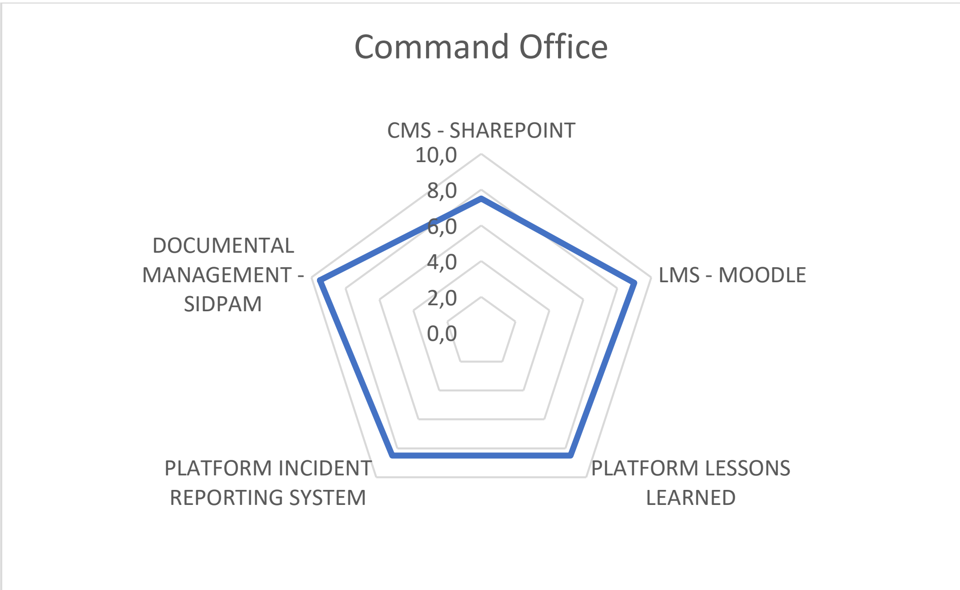
DOCUMENTAL MANAGEMENT - SIDPAM		
Number of experts	**Work areas**	**Average ranking for each area**
1	Administrative/Financial Management	1,0
1	Personnel Management	1,0
1	Flight Operations	1,0
1	Research and Experimentation	2,0
3	Training	2,0
2	Command Office	2,5
1	Air Force Policy	4,0
5	Technical-Logistical Activities	4,2

Question 6: "Rate each software on a scale from 1 to 10 based on how functional you find it for achieving your work objectives”. Below are graphical representations of the average scores assigned to the functionality of each tool across different work areas.

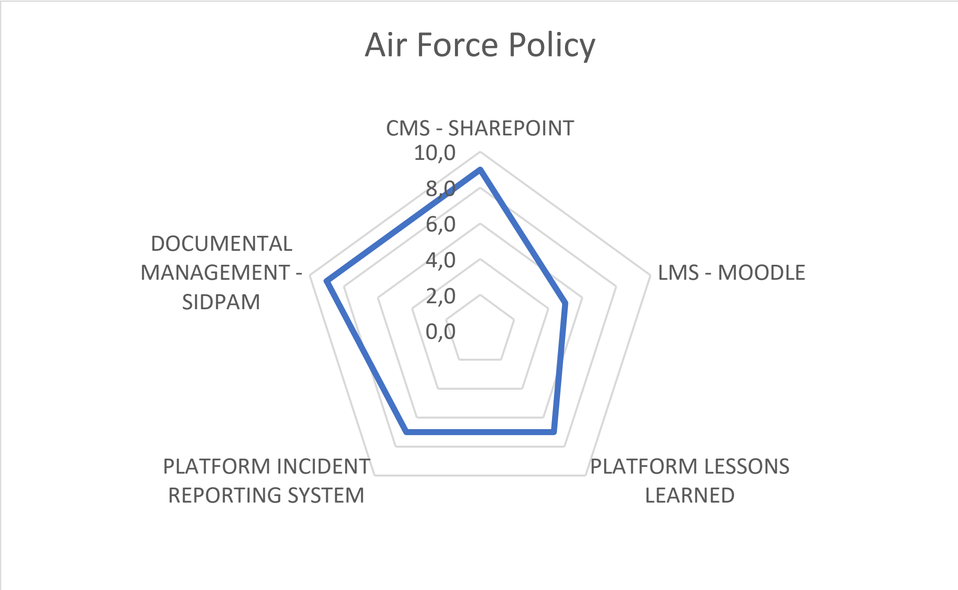
Graph 29: Average scores assigned by experts from Personnel Management area to the functionality of each software



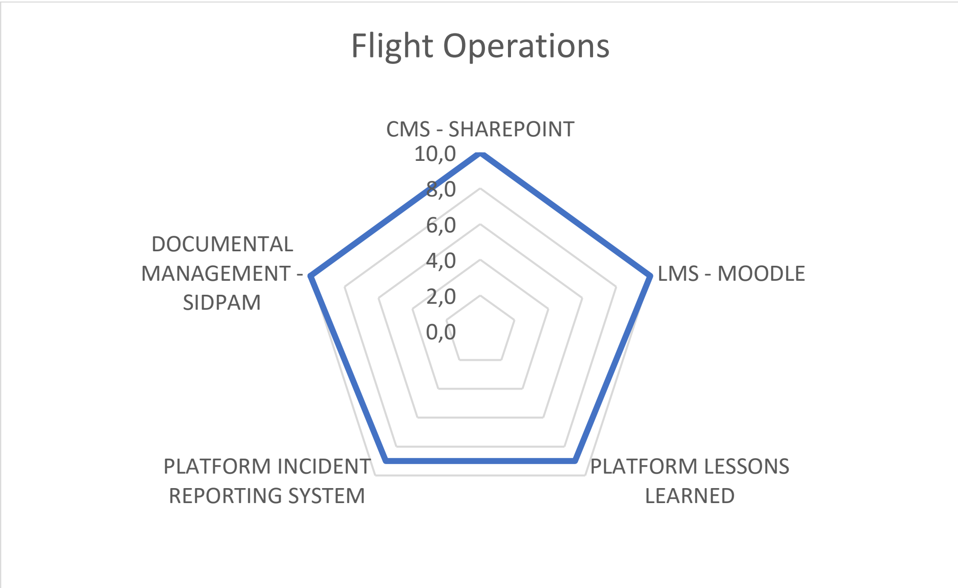
Graph 30: Average scores assigned by experts from Command Office area to the functionality of each software



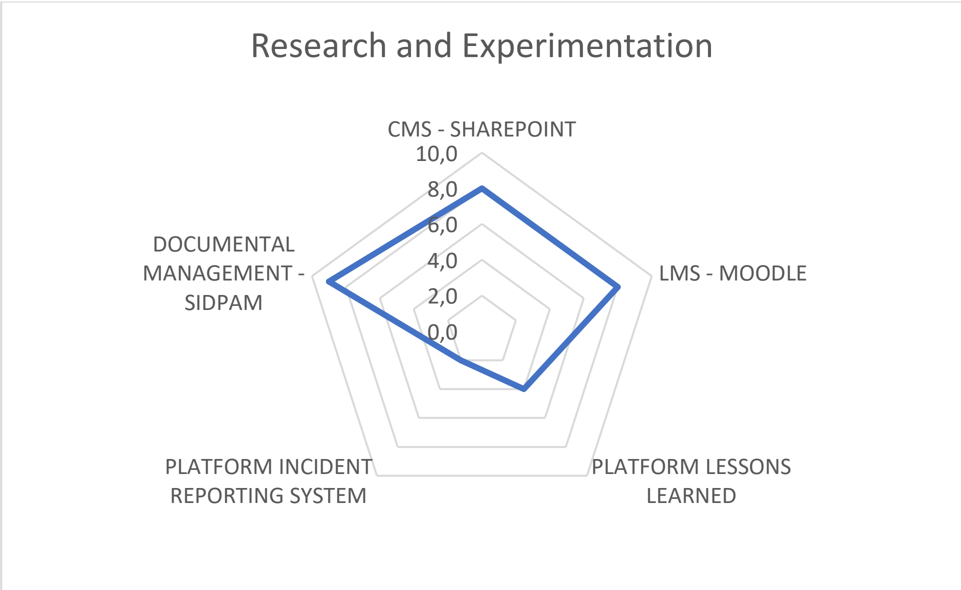
Graph 31: Average scores assigned by experts from Air orce Policy area to the functionality of each software



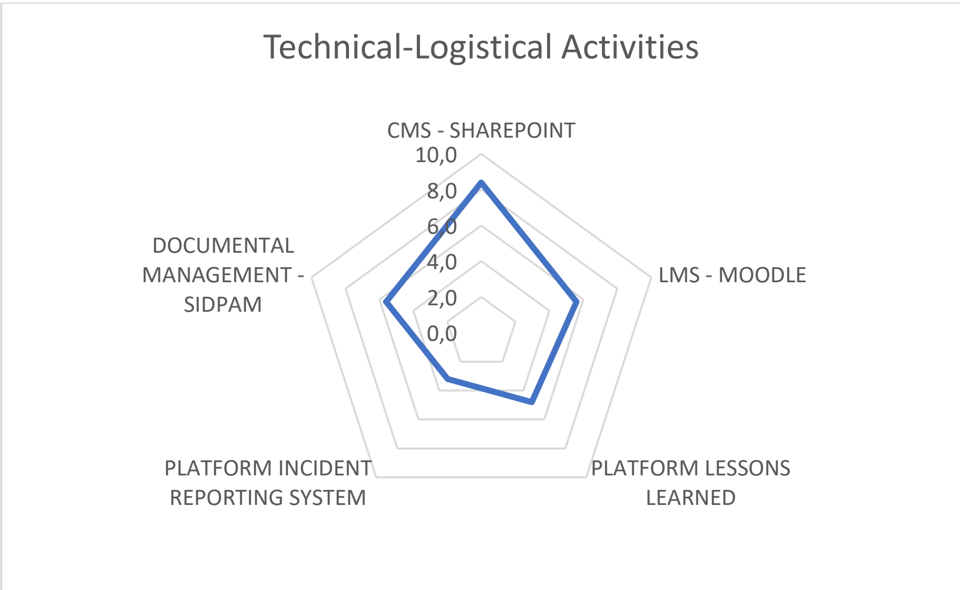
Graph 32: Average scores assigned by experts from Flight Operations area to the functionality of each software



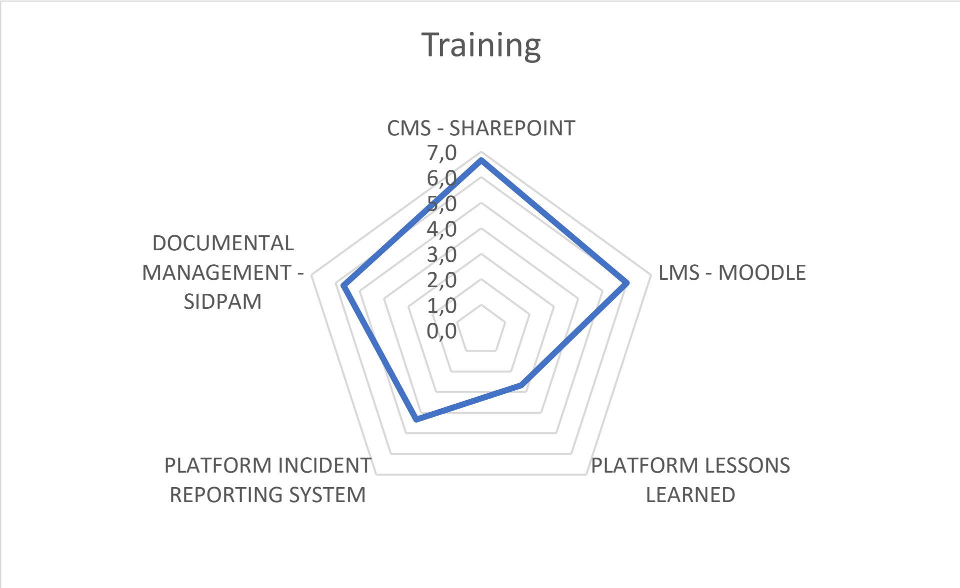
Graph 33: Average scores assigned by experts from Research and Experimentation area to the functionality of each software



Graph 34: Average scores assigned by experts from Technical-Logistical Activities area to the functionality of each software



Graph 35: Average scores assigned by experts from Training area to the functionality of each software



Question 7: "Indicate your level of knowledge on each of the listed platforms" is structured using a 5-level knowledge scale, with the results presented in Table 37.

1 = I have never seen it in use

2 = I have seen it in use, but I am not familiar with its functionalities

3 = I am familiar with its functionalities, and my collaborators use it

4 = I directly use the basic functionalities of the tool

5 = I directly use the more advanced functionalities of the tool

Table 40: Results from Question 7

	CMS - SHAREPOINT	LMS - MOODLE	LESSONS LEARNED PLATFORM	INCIDENT REPORTING SYSTEM PLATFORM	DOCUMENT MANAGEMENT SYSTEM - SIDPAM
Administrative/Financial Management	4,0	3,0	2,0	1,0	5,0
Air Force Policy	4,0	4,0	1,0	1,0	5,0
Command Office	3,5	4,0	1,5	1,0	5,0
Flight Operations	5,0	5,0	2,0	1,0	4,0
Personnel Management	3,0	5,0	2,0	1,0	5,0
Research and Experimentation	4,0	4,0	4,0	1,0	5,0
Technical-Logistical Activities	4,6	3,0	2,2	1,6	4,4
Training	4,3	4,0	2,0	1,3	4,0
AVERAGE LEVEL OF KNOWLEDGE	**4,1**	**4,0**	**2,1**	**1,1**	**4,7**

In particular, looking at the table, it is easy to notice that among the KM tools listed in the UIM-005 directive, the ones that are most widely known and for which personnel are trained are the Document Management System SIDPAM, the CMS SharePoint, and the LMS Moodle. The Lessons Learned platform is more familiar to the Research and Experimentation sector, while the Incident Reporting System platform is largely unknown, even to the Flight Operations and Command Office sectors.

The analysis of the responses to Question 8, which asked for opinions regarding personnel training on the mentioned tools, reveals several key insights:

SharePoint: Respondents emphasized the need to improve its usability through dedicated training courses for personnel (potentially via the Moodle platform) or by implementing an official directive/manual that establishes usage policies. Enhancing the system's search functionality and accessibility was also recommended. Some respondents believe it is essential to ensure all personnel, even those outside their specific job categories, have at least a basic understanding of platforms like "Lessons Learned" and the "Incident Reporting System."

Training Gaps: Many respondents pointed out the lack of widespread knowledge or training on most of the listed applications. Training is often insufficient, with many staff members being self-taught or relying on colleagues for guidance. There is a call for more structured, formal training to ensure broader, more effective use of these tools.

On-the-job Learning: Several responses indicate that training on these tools is often done informally, on the job, or through peer-to-peer learning rather than through formalized processes.

Dependence on Roles: The use and familiarity with these tools seem to be strongly linked to specific roles or assignments, with some systems being more relevant or better known in certain sectors, such as "Lessons Learned" for continuous improvement.

Tool-Specific Feedback: SharePoint was generally viewed positively, though there is a strong desire for further development to improve operator accessibility. SIDPAM is seen as useful for bureaucratic processes but not necessarily for achieving objectives or sharing knowledge. Moodle is regarded as a good training platform with room for improvement in terms of usability. Other tools, such as Incident Reporting System, are less well-known or utilized.

Lack of Standardization: Some respondents noted a lack of standardization and guidance in training, with few resources or manuals available to help users fully understand the systems' functionalities. There is also a general sense that the full potential of these tools is not being realized due to insufficient awareness and training.

In summary, the open-ended question highlights the need for more formalized, accessible training programs, greater awareness of the tools available, and improved usability of platforms like SharePoint and SIDPAM. A stronger focus on standardizing guidance and ensuring personnel at all levels are equipped to use the tools would help enhance their effectiveness.

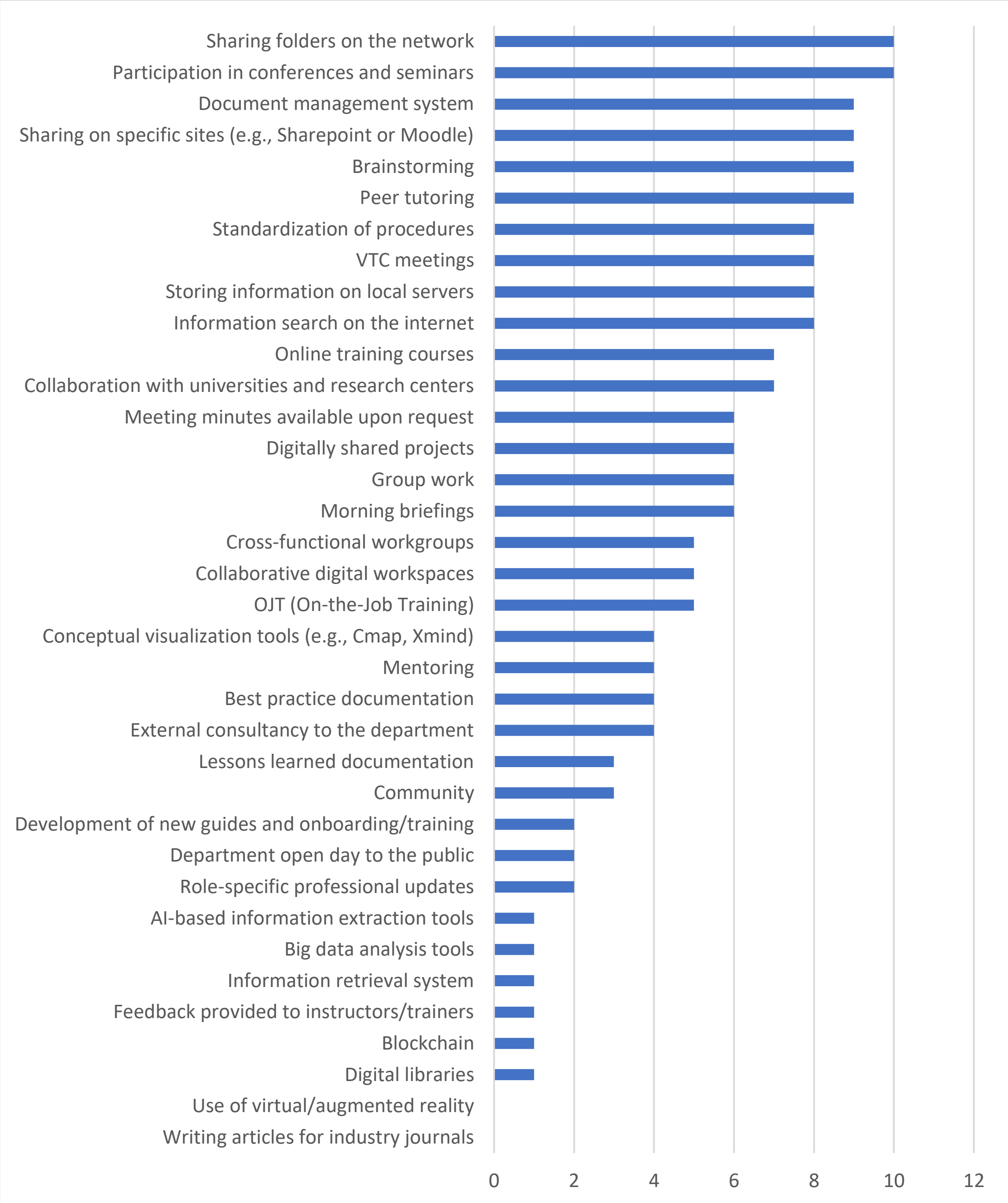
For Question 9, respondents were asked: "Which of the following practices are used in your work environment?"

- Brainstorming
- Morning briefings
- File sharing on the network
- OJT (On-the-Job Training)
- Participation in conferences and seminars
- Internet information search
- Peer tutoring
- Role-specific professional updates
- Collaborative digital work environments
- Local server-based information storage
- Digital libraries
- Blockchain
- Collaboration with universities and research centers
- Community
- Sharing on specific platforms (e.g., SharePoint or Moodle)
- External consultancy to the department
- Best practice documentation
- Lessons learned documentation
- Feedback provided to instructors/trainers
- Cross-functional workgroups

- Group work
- Mentoring
- Department open day to the public
- Participation in conferences and seminars
- Online training courses
- Digitally shared projects
- Internet information search
- VTC meetings
- Information retrieval system
- Document management system
- Standardization of procedures
- Big data analysis tools
- AI-based information extraction tools
- Conceptual visualization tools (e.g., Cmap, Xmind)
- Development of new guides and onboarding/training
- Meeting minutes available upon request

The following chart shows the recorded results.

Graph 36: Results from Question 9



The following table presents the previous results distributed by work area.

Table 41: Results from Question 9 distributed by work area

Work area (number of respondents)	Indicated tools	Number of preferences
Technical-Logistical Activities (5 respondents)	Brainstorming	4
	Document management system	4
	File sharing on the network	4
	Group work	4
	Local server-based information storage	4
	Sharing on specific platforms (e.g., SharePoint or Moodle)	4
	Standardization of procedures	4
	VTC meetings	4
	Collaboration with universities and research centers	3
	Internet information search	3
	Morning briefings	3
	OJT (On-the-Job Training)	3
	Online training courses	3
	Participation in conferences and seminars	3
	Best practice documentation	2
	Collaborative digital work environments	2
	Conceptual visualization tools (e.g., Cmap, Xmind)	2
	Cross-functional workgroups	2
	Department open day to the public	2
	Peer tutoring	2
	AI-based information extraction tools	1
	Big data analysis tools	1
	Development of new guides and onboarding/training	1
	Digital libraries	1
	Digitally shared projects	1
	External consultancy to the department	1
	Information retrieval system	1
	Lessons learned documentation	1
Flight Operations (1 respondent)	Brainstorming	1
	Community	1
	Digitally shared projects	1
	Document management system	1
	File sharing on the network	1
	Local server-based information storage	1
	Mentoring	1
	Online training courses	1
	Peer tutoring	1

	Sharing on specific platforms (e.g., SharePoint or Moodle)	1
	Standardization of procedures	1
Command Office (2 respondent)	File sharing on the network	2
	Local server-based information storage	2
	Peer tutoring	2
	Digitally shared projects	1
	Document management system	1
	Internet information search	1
	Meeting minutes available upon request	1
	Morning briefings	1
	Online training courses	1
	Participation in conferences and seminars	1
Training (3 respondent)	Brainstorming	3
	Mentoring	3
	Participation in conferences and seminars	3
	VTC meetings	3
	Best practice documentation	2
	Collaboration with universities and research centers	2
	Community	2
	Conceptual visualization tools (e.g., Cmap, Xmind)	2
	External consultancy to the department	2
	Group work	2
	Internet information search	2
	Lessons learned documentation	2
	Peer tutoring	2
	Sharing on specific platforms (e.g., SharePoint or Moodle)	2
	Standardization of procedures	2
	Collaborative digital work environments	1
	Cross-functional workgroups	1
	Development of new guides and onboarding/training	1
	Digitally shared projects	1
	Document management system	1
	Feedback provided to instructors/trainers	1
	File sharing on the network	1
	Local server-based information storage	1
	Meeting minutes available upon request	1
	Morning briefings	1
	OJT (On-the-Job Training)	1
	Online training courses	1
	Role-specific professional updates	1
Air Force Policy (1 respondent)	Brainstorming	1
	Collaboration with universities and research centers	1
	Collaborative digital work environments	1

	Cross-functional workgroups	1
	External consultancy to the department	1
	Internet information search	1
	Meeting minutes available upon request	1
	Morning briefings	1
	Participation in conferences and seminars	1
Administrative/Financial Management (1 respondent)	Document management system	1
	File sharing on the network	1
	Internet information search	1
	OJT (On-the-Job Training)	1
	Peer tutoring	1
Research and Experimentation (1 respondent)	Collaboration with universities and research centers	1
	Cross-functional workgroups	1
	Digitally shared projects	1
	Document management system	1
	Meeting minutes available upon request	1
	Participation in conferences and seminars	1
	Peer mentoring	1
	Role-specific professional updates	1
	Sharing on specific platforms (e.g., SharePoint or Moodle)	1
	Standardization of procedures	1
	VTC meetings	1
Personnel management (1 respondent)	Blockchain	1
	Collaborative digital work environments	1
	Digitally shared projects	1
	File sharing on the network	1
	Online training courses	1
	Sharing on specific platforms (e.g., SharePoint or Moodle)	1

In conclusion, the second round of the Delphi survey reinforced several key findings. First, there is a strong consensus among experts on the importance of a human-centered approach to KM, recognizing personnel as the cornerstone of effective KM practices. The convergence of opinions highlighted the critical role of individuals in creating, sharing, and managing knowledge within the organization.

While processes, technology, and objectives are also necessary components, their effectiveness relies heavily on the proper training and engagement of personnel. The data points to gaps in formal training, with many respondents noting that on-the-job learning and informal peer support are common. This suggests a need for standardized training programs and guidance to improve the overall functionality and adoption of KM tools.

Specific tools, such as SharePoint, SIDPAM, and Moodle, received attention for their widespread use, although respondents emphasized the need for improvements in usability, accessibility, and structured training. Conversely, less-known tools, like the Incident Reporting System, remain underutilized, particularly in areas where they could have a significant impact.

Additionally, the ranking of the most relevant KM topics for the future of the Air Force—human resource development, organizational capabilities, and integrated digital systems—further emphasizes the need for investment in personnel and digital infrastructures to support KM initiatives.

Overall, the findings suggest that the success of KM in the IAF will depend on a balanced approach that prioritizes human resources, supported by efficient processes and technologies, and aligned with strategic organizational goals.

11.7 Comparison with other similar studies

It is interesting to note that other studies on KM perception in military contexts yield results similar to those presented in this chapter. Ismail & Abdullah (2011) conducted a study involving 363 officers, analyzing the influence of demographic variables such as type of service, rank, academic background, and work experience on knowledge creation and application. Their findings indicate that while KM perceptions remain consistent across different military services, they vary significantly based on rank, academic background, and work experience. Additionally, technology was identified as a key enabler in KM processes and knowledge creation. The study concludes that successful KM implementation in the Armed Forces requires strong leadership support and an increased awareness and understanding of KM among personnel.

Similarly, Karbasi & Alave (2023), using a mixed-methods approach, analyzed quantitative data via SPSS and applied content analysis to documents and interviews. Their findings highlight 10 key components essential for KM in military organizations: 1) Management & Leadership, 2) ICT, 3) Human Resources, 4) Organizational Structure, 5) Culture, 6) Implementation, 7) Training, 8) Oriented Pillars, 9) Knowledge Fields, and 10) KM Cycle. These studies collectively reinforce the importance of a structured and multi-faceted approach to KM in military environments.

Chapter 12 - Beyond the Gaps: Rethinking Knowledge Management for the Italian Air Force

Recalling the words of Alfred Korzybski, "the map is not the territory", a model is always an attempt to simplify reality, with the consequent limitations. However, a model allows "practitioners" (and all stakeholders in general) to become aware of the elements that must necessarily be taken into consideration when operating within a specific area, just as a map allows us to reach the destination we desire in reality.

In Chapter 3, we reviewed the most well-established KM models in the literature. Each of these models has specific characteristics that could make them applicable in the context of the IAF. The following table highlights the potential opportunities for application within the IAF context.

Table 42: Applicability of existent models to the IAF

Model	Applicability to the Italian Air Force
Meyer and Zack	- Suitable for the management and refinement of information Management - Suitable for the Lessons Learned System - - Useful for maintaining continuity of technical skills - Can support personnel turnover and transfers
Bukowitz and Williams	- Suitable for learning and innovation processes - Useful for evaluating and improving intellectual capital - Can support competence management and long-term strategic planning
Wiig	- Suitable for practical application of knowledge - Useful for decision-making and operational processes - Can support operational continuity and technical skill improvement
Boisot I-Space	- Useful for managing complex and contextual knowledge - Supports knowledge sharing in complex contexts - Potential to improve organizational learning and decision-making
ICAS	- Suitable for addressing complex and changing environments - Useful for improving innovation and adaptation capabilities - Includes knowledge management in unforeseen situations
SECI	- Suitable for improving knowledge creation and transfer - Useful for promoting innovation through social interaction - Can support continuous training and skill development

Although these models offer strong theoretical foundations, they do not provide concrete guidance on choosing the appropriate tools and methodologies to address the specific challenges of knowledge management. This gap is particularly critical in military settings, where effective knowledge management must integrate security, structured processes, and operational efficiency to support mission success.

Moreover, it is crucial to acknowledge that none of these models were originally designed or specifically tailored to meet the unique requirements of the IAF. Their frameworks, while robust in general KM theory, do not inherently address the classified nature of military knowledge, the rigid hierarchical command structures, or the dynamic and unpredictable nature of military operations.

That said, each of the KM models analyzed in this thesis presents elements that could be useful within the IAF's organizational framework. However, the complexity and diversity of organizational scenarios within the Air Force require a holistic approach that enables IAF Knowledge Managers (KM) to effectively address a wide range of KM challenges. A one-size-fits-all model is insufficient in such a multifaceted and mission-driven environment.

For this reason, it is critical to equip IAF Knowledge Managers with practical tools and frameworks that allow them to determine, on a case-by-case basis, the most appropriate approach to adopt. This tailored approach should be concrete and adaptable, ensuring the effective management of all knowledge types, including:

- Know-who (identifying key knowledge holders)
- Know-about (general awareness and conceptual understanding)
- Know-why (understanding principles and reasoning)
- Know-how (practical application and expertise)
- Know-with (integrating values, experience, and cognition for decision-making.)

Given the findings from the doctoral research conducted over the past years and the insights gained from the literature review and case studies presented in this thesis, the following sections aim to introduce models that are more specifically adapted to the IAF context. These models will be analyzed with a focus on their practical applicability, adaptability to military constraints, and alignment with the IAF's strategic and operational objectives, ensuring a more effective and mission-driven approach to knowledge management.

12.1 Limitations of Existing Approaches to Knowledge Management in Military Contexts

The existing literature on KM in military organizations highlights the partial effectiveness of traditional KM models when applied to complex and dynamic military environments. While numerous studies have explored KM implementation, findings suggest that military organizations often require alternative solutions beyond those proposed in academic research to accommodate their unique operational demands and structural challenges.

For instance, studies such as Bartczak & England (2008) and Karbasi & Alave (2023) emphasize the necessity of tailoring KM strategies to address the large-scale, mission-critical, and geographically dispersed nature of military operations. Similarly, Niazmand et al. (2022) highlight that organizational culture, technological capabilities, and strategic alignment play crucial roles in determining KM effectiveness within military settings, reinforcing the idea that context-specific adaptations are essential. However, these studies often focus on isolated aspects of KM—whether technological, procedural, or cultural—rather than adopting a holistic, integrated approach that considers the interplay between tacit and explicit knowledge, human factors, and institutional frameworks.

In this regard, Schulte and Sample (2006) explore the efficiencies gained from implementing KM technologies within military enterprises. Their findings underscore the importance of leveraging knowledge-based systems to enhance decision-making, operational efficiency, and strategic advantage. The integration of such technologies is particularly crucial in modern military operations, where rapid information processing and dissemination play a vital role in mission success.

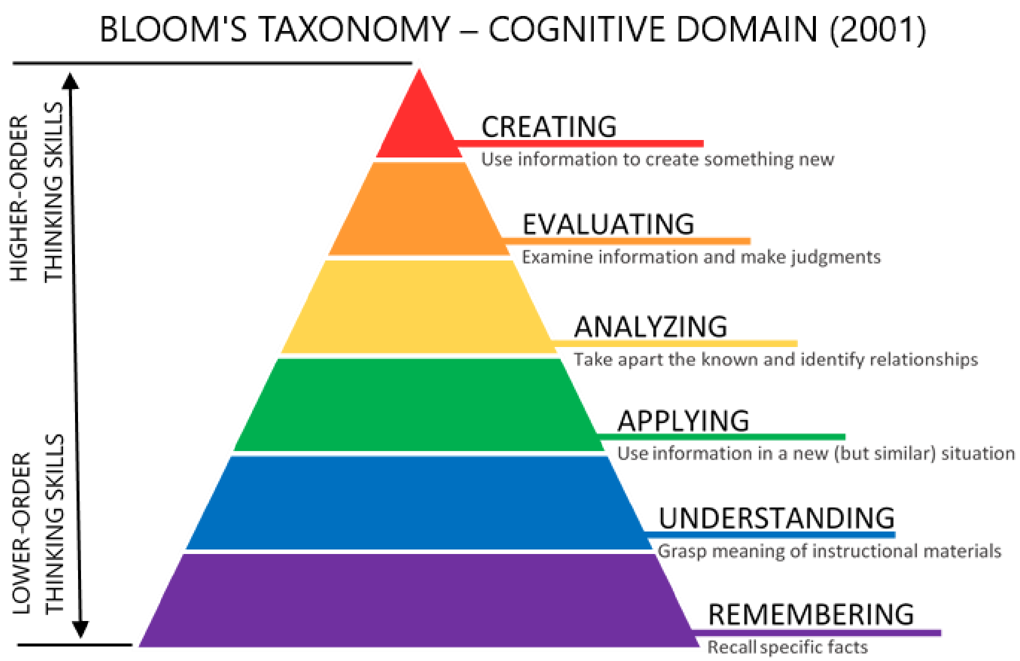
Additionally, research by Singh and Gupta (2021) and Zahedi et al. (2020) identifies key knowledge loss risks and barriers to KM adoption in military organizations, such as hierarchical resistance, lack of awareness, inadequate time and resources, and technical constraints. While these studies contribute valuable insights, they often lack a comprehensive framework that unifies knowledge creation, sharing, storage, and application across different operational levels.

Ultimately, these fragmented approaches underscore the need for a systemic perspective that integrates various dimensions of KM in military organizations. The complexity of military knowledge ecosystems demands a multifaceted strategy that aligns organizational structures, technological enablers, leadership support, and cultural adaptation. In the following sections, this study aims to theorize a model that addresses the gaps identified in current research and proposes a cohesive, adaptable framework for effective KM implementation in military settings.

12.2 Taxonomy of Knowledge Types for the Organization

The literature presents various taxonomies related to the concept of knowledge, each outlining a distinct hierarchical structure. These taxonomies (two of which have already been mentioned) are characterized by the specific perspective of the scholar who proposed them. Bloom's taxonomy, simplified by Krathwohl and Anderson (Krathwohl, 2002), for example, reflects the viewpoint of educational psychologists and has been widely used to define the stages of learning, structure the educational process, and establish the learning objectives to be pursued. This taxonomy remains highly useful today for instructional designers in determining the complexity of training pathways, defining the types of instructional interventions, and setting up the evaluation system to be implemented. Even in educational institutions with an andragogical focus, such as those of the IAF, Bloom's taxonomy serves as a guiding tool for designing and assessing educational programs (Comando Scuole A.M./3^ R.A., 2015).

Figure 29: Source[24]: University of Florida - Center for Instructional Technology and Training

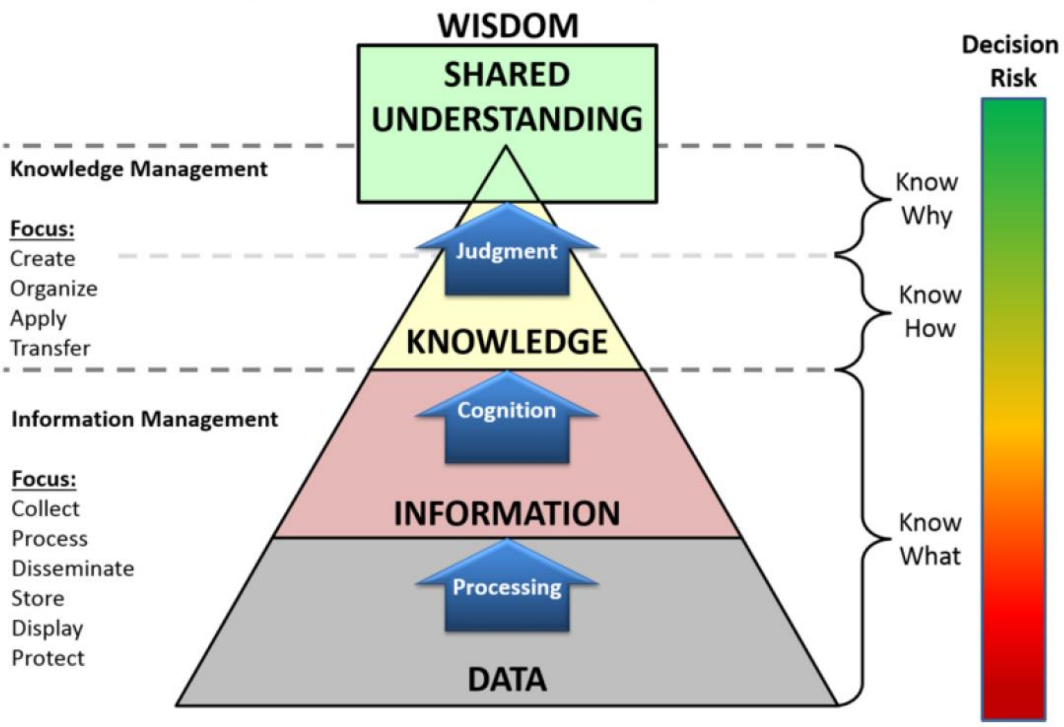


Another taxonomy of interest, already discussed in Chapter 1, is the DIKW model. This hierarchy of the concepts of data, information, knowledge, and wisdom, while initially attributed to the poet T. S. Eliot, has been revisited by several scholars who have offered their own interpretations and perspectives, resulting in various versions of the pyramid. In 1987, Czechoslovakia-born educator Milan Zeleny mapped the elements of the hierarchy to different forms of knowledge: know-nothing, know-what, know-how, and know-why (Zeleny, 1987).

In 1989, Bell Labs veteran Robert W. Lucky discussed the four-tier "information hierarchy" in the form of a pyramid in his book Silicon Dreams (Lucky, 1989). An interesting version for my research is undoubtedly the one proposed by computer scientist Marcia Bates (2005), which also appears to have been adopted by the United States Department of Defense[25]. This version attempts to illustrate the progression from data to information, then to knowledge, and finally to wisdom, facilitating effective decision-making. It also highlights the activities involved in creating shared understanding across the organization and managing decision risks, as outlined below.

[24] https://citt.ufl.edu/resources/the-learning-process/designing-the-learning-experience/blooms-taxonomy/blooms-taxonomy-graphic-description/
[25] https://commons.wikimedia.org/wiki/File:US_DoD_KM_Pyramid.jpg

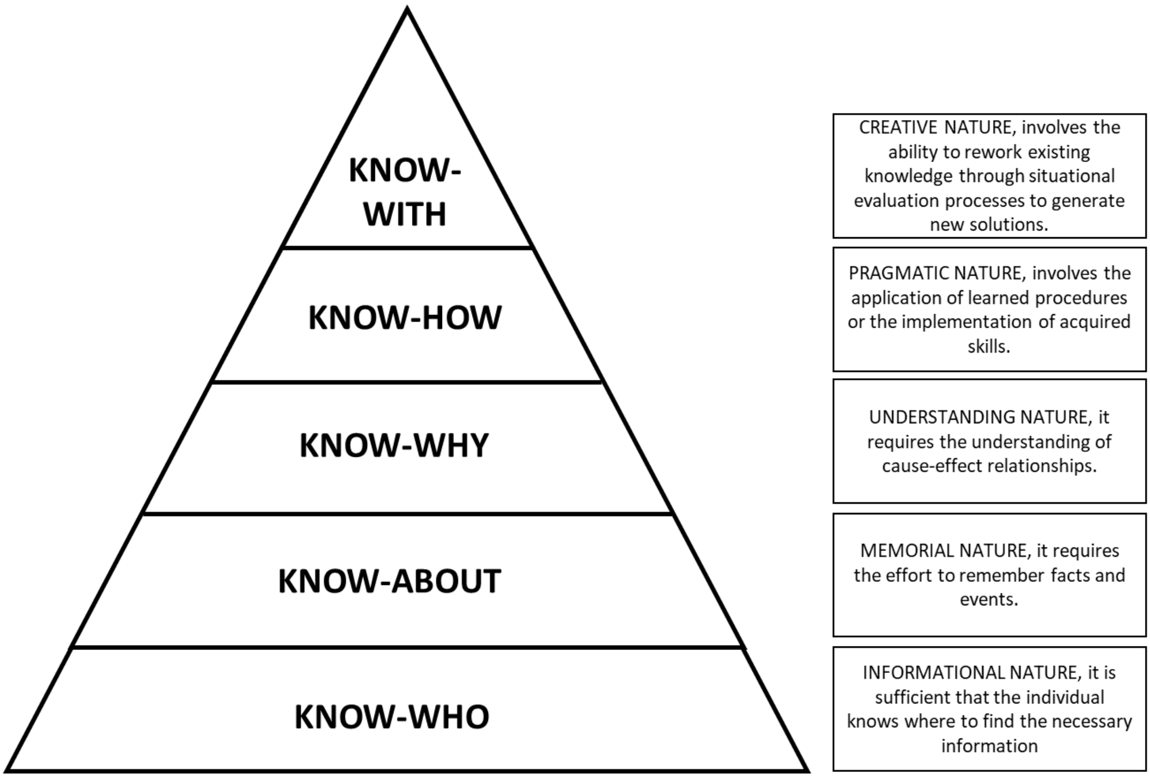
Figure 30: Source[26]: ARCH D4.4 Knowledge Information Management System for Decision Support



Given this premise, intuition may lead us to believe that a hierarchy of the types of knowledge presented in this thesis could serve as a useful tool for knowledge managers when determining which strategies to adopt within their respective organizations. Indeed, there is a notable analogy between the descriptions of the five types of knowledge, the six levels of Bloom's taxonomy, and the four levels of the DIKW model. The logical steps of these analogies are depicted in the following graphic representation.

26 https://www.researchgate.net/publication/366866477_ARCH_D44_Knowledge_Information_Management_System_for_Decision_Support

Figure 31: Taxonomy of Knowledge Types Proposed by the Author of the Thesis



The pyramidal model proposed in this thesis suggests that there is a hierarchical relationship among the five types of knowledge, as described below:

Know-who (knowledge of sources) is informational knowledge, tied to the ability to know and recall the sources that provide access to the necessary data or information. This may be used for decision-making, evaluating a situation, following a procedure that hasn't been performed before, or expanding one's know-about. This level is crucial within the hierarchy because having know-who in a particular area is often more useful (or at least sufficient), whereas lacking know-who can become a critical aspect of the decision-making process. Knowledge managers in organizations should not underestimate the importance of this level of knowledge and should ensure that personnel are informed about the relevant know-who. When know-who pertains to information that can be provided on request, we are clearly dealing with explicit knowledge, as it is well codified for transmission.

Know-about requires greater memory effort. In this case, the individual must recall the information, fact, or description themselves, as they are directly responsible for making a decision or using that knowledge. The person must have stored these pieces of information in their own memory and be able to retrieve them without relying on external sources. Although still considered explicit knowledge, the data or information must be internalized—

stored in the individual’s long-term memory rather than in a database or external source. This represents an increased level of internalization.

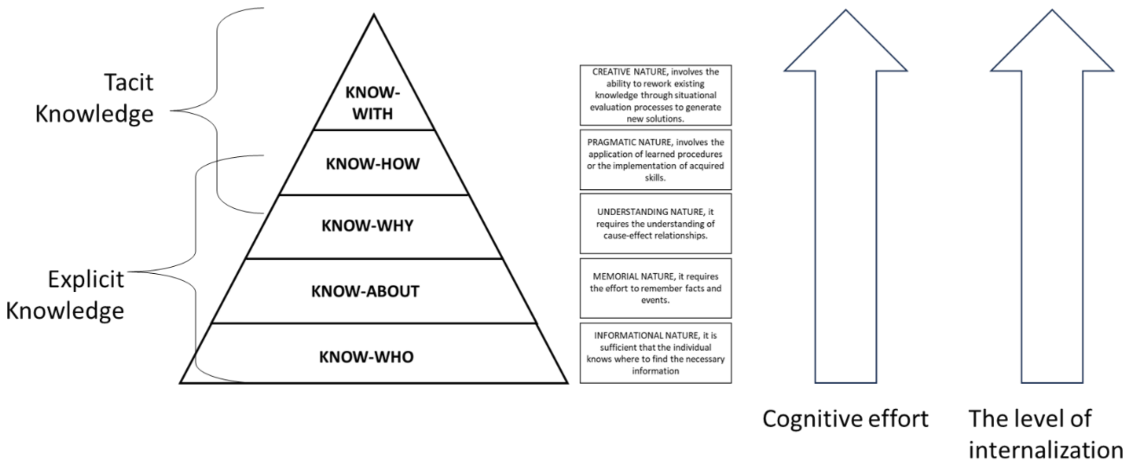
Know-why extends beyond the ability to store and retrieve information, involving an understanding of cause-and-effect relationships between the facts or information retrieved from memory. It would be incorrect to categorize this knowledge entirely as explicit. In some cases, cause-effect relationships are codified, and the individual has understood well-established causal laws shared by the broader community. However, in other cases, the recognized relationships are a result of personal experience or unconscious processing. For instance, an individual might interpret non-verbal cues unconsciously and respond effectively without being able to explain the rationale behind the response.

Know-how refers to knowledge that the individual has fully internalized and can not only recall but also apply. The amount of information the individual must access is substantial, as they possess the skills and competencies to act independently within their domain without relying on external sources. They are capable of managing causal relationships based on the specific situation at hand. In this case, much of the knowledge comes from direct experience and can be both explicit (as the individual might formalize the procedures they apply) and tacit (since not every procedural detail can be codified, nor can the individual always explain how they would act in a new, previously unencountered situation).

Know-with encompasses the individual's entire value system. It refers to the ability to integrate their knowledge background and act in novel situations that have not been previously faced and are not codified. The individual must evaluate the new context and make decisions. The cognitive effort required to reflect, systematize knowledge, and deal with the emotions triggered by the situation is a complex process carried out by the brain. While lessons learned can reduce the level of uncertainty in new contexts, each individual has their own unique value system and personal experience, which will influence the specifics of their behavior. The level of internalization of this type of knowledge is the highest, and it falls within the realm of tacit knowledge.

The hierarchical structure described above is illustrated in the following figure.

Figure 32: In-depth Analysis of the Taxonomy Proposed by the Author of the Thesis



This approach, which considers various types of knowledge, is particularly well-suited to the organization of the IAF, and likely to many other types of organizations, because:

- KM in IAF Includes the sharing of knowledge catalogs (for example, on SharePoint, where all personnel can access directives organized by High Command and by subject). These catalogs provide access to information sources for every member of the military. Furthermore, personnel are distinguished not only by their rank but, in the specific case of officers, also by their Role (e.g., Pilots, Arms, Commissary, Engineering), a category (e.g., Logistics or Operations), and a specific area of expertise (e.g., Human Resources Management, Telecommunications, Logistics). Their professional training and career profile development are based on these roles (Stato Maggiore dell'Aeronautica – 1° Reparto, 2022). The fact that the branch of service is visually represented next to the rank facilitates the identification of potentially knowledgeable personnel in specific fields (know-who) within newly configured operational contexts.
- The specialty, and consequently the sphere of competence of the military personnel, indicates the field in which they are expected to have the most professional know-about. This knowledge often translates into know-how for professionals operating in highly technological or complex environments (such as pilots, air traffic controllers, or aircraft maintenance personnel). Optimizing the transfer of know-how is a strategically necessary choice to maintain the value of the highly qualified human capital within the IAF.
- Every member of the military may find themselves in a situation where leadership unexpectedly changes, and they may suddenly need to assume responsibility for leading a group of lower-ranked personnel. Therefore, every military member should aim to develop a robust know-with, which not only encompasses a high level of practical and

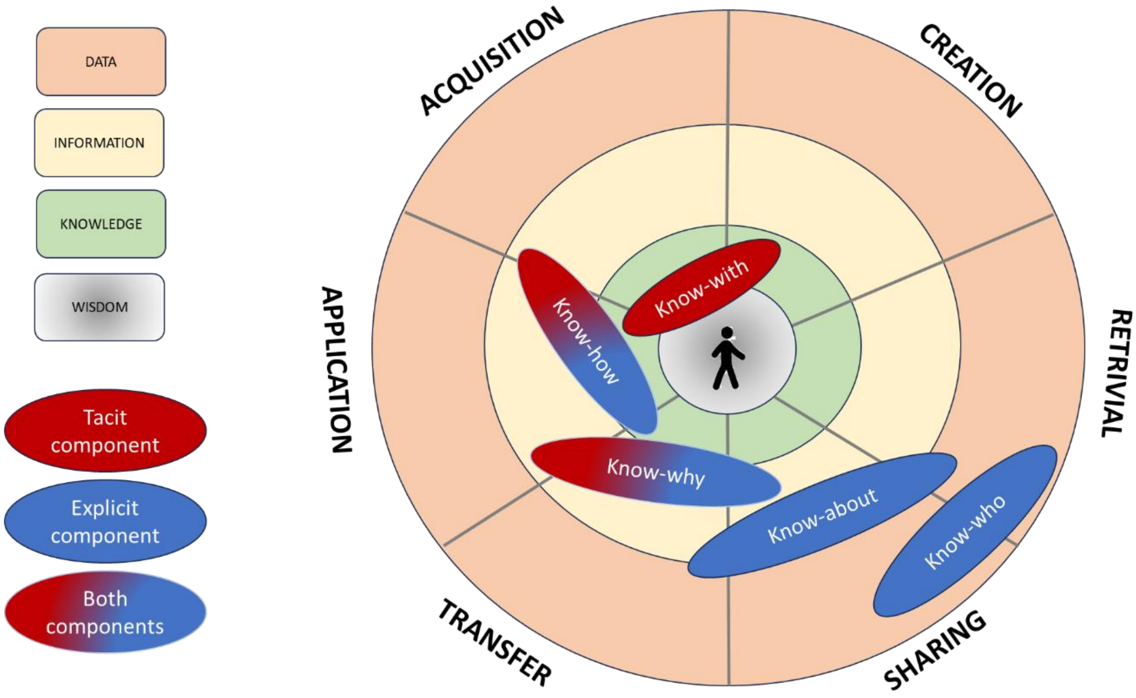
theoretical competence in their field of expertise (know-how and know-why), but also a deeply rooted value system aligned with the vision and mission of the IAF. The transmission of values such as excellence, respect, exemplarity, dedication, and (moral) integrity (which are reflected in the acronym "EREDI," taught to cadets at the Air Force Academy) should be considered an integral part of a KM system that strives for excellence and the development of human capital.

12.3 Anthropocentric model and framework for identifying the relevant KM processes

If we consider that the higher levels of the pyramid involve a greater degree of internalization, we can conceptualize a model with an anthropocentric approach, placing the individual—specifically, the military personnel or the single resource that forms part of the overall human capital—at the center. The model illustrated below transforms the pyramid into a radial model, where wisdom, fully internalized within the individual, is positioned at the center, with the individual at the core. Moving outward from the center, we encounter knowledge, information, and finally data.

In this model, the six key KM processes discussed in this study are integrated, and, considering the reflections discussed earlier, we can position the five types of knowledge in relation to their degree of internalization, as previously explained. This is also done in relation to the knowledge element type (data, information, knowledge, wisdom) and the corresponding KM process that may be involved.

Figure 33: Model Proposed by the Author of the Thesis for Identifying Processes to Implement/Strengthen



This anthropocentric model is designed to support the knowledge manager in choosing the strategies they can implement. Specifically, it is proposed that the knowledge manager follows the framework outlined below and completes the table provided.

Framework

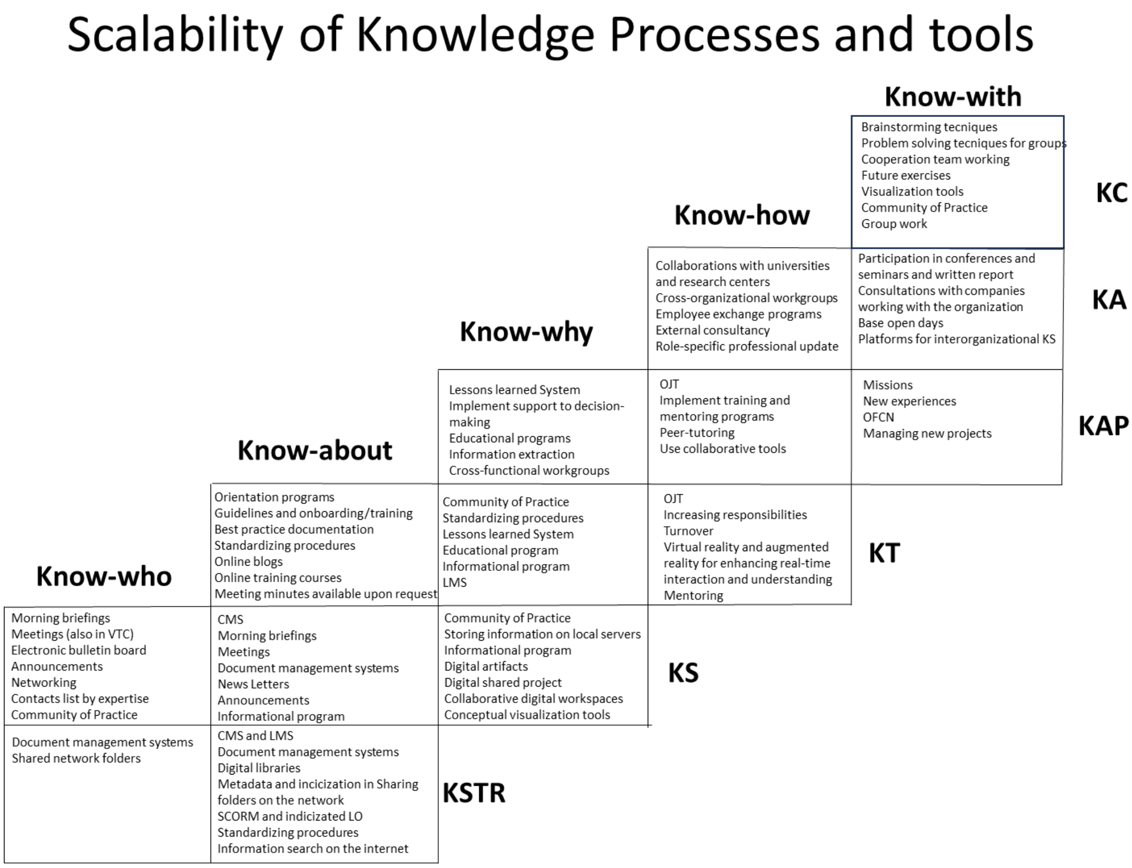
1. Define the knowledge problem to be addressed.
2. Identify the relevant type of knowledge.
3. Derive the KM processes that can be implemented from the anthropocentric model.
4. Use the Reference Scale to identify the tools available within the IAF that can be applied to a specific KM process related to the given type of knowledge.
5. Define the strategy, outlining the sequence of activities intended to resolve the problem.
6. Identify performance measures that will help the manager monitor the effectiveness and efficiency of the strategy once implemented.

Figure 34: Table for the Application of the Framework Proposed by the Author of the Thesis

Problem	Type of Knowledge Involved	Processes involved	Tools	Strategy	Performance measurement

The reference scale provided by the framework is shown in Figure 35 and links all the tools indicated by at least two experts in the Delphi questionnaire with the KM processes and types of knowledge identified as relevant to the issue.

Figure 35: Reference scale, proposed by the author of the thesis, for selecting an appropriate tool



This approach can be considered as a fractal within the organization, meaning it is applicable at all levels of the organization. It is valid from the central level, where KM strategies for the entire IAF are established, to the intermediate level, and down to the peripheral level, where the knowledge managers of individual entities determine the best strategies for knowledge management within their specific organizational context.

12.4 Implementing VCoPs for effective KM in the IAF: Key Principles and Considerations

As previously seen, OVCoPs represent a widely applicable and potentially effective knowledge management strategy, particularly for enhancing processes such as Knowledge Sharing, Knowledge Retrieval, Knowledge Creation and Knowledge Transfer within the Italian Air Force. The existing software applications (SharePoint and Moodle) and the infostructure in the IAF are sufficiently mature, providing fertile ground for the extensive use of OVCoPs and the significant benefits this strategy can bring to the organization.

According to the model proposed in this thesis, an OVCoP should be established only if its purpose falls within one (or more) of the following areas:

1. Improving Business as Usual (BAU) processes
2. Fostering innovation and creativity
3. Problem-solving and decision-making
4. Facilitating external relations with other departments

When effectively implemented, OVCoPs can ensure optimal knowledge sharing among participants, fostering the dissemination of best practices, continuous staff development (upskilling), and ultimately contributing to the development of the organization's human capital by increasing motivation and efficiency within professional contexts.

However, the successful implementation and management of OVCoPs require adherence to key principles identified in this study:

1. Communities should include personnel with a common role or professional background.
2. The primary objective of OVCoPs is to support the development of human resources in a specific field, encouraging the sharing of individual knowledge.

3. OVCoPs should be overseen by senior management, which must remain informed of the community's activities through an annual report detailing:
    - The number of interventions
    - A summary of interventions that have provided valuable contributions
4. For specific professional roles, communities may be populated by participants following a qualification course.
5. Each community must have a designated leader responsible for maintaining the community's activity. The leader’s responsibilities include:
    - Sharing relevant material and promoting member contributions
    - Ensuring diverse engagement methods (not just written texts but also videos, interactive resources, and initiatives, even from outside the IAF)
    - Organizing periodic synchronous update meetings (preferably in-person but also via VTC)
    - Collaborating with a co-moderator to ensure community continuity during relocations or overseas operations
    - Fostering a trusting, non-judgmental environment to facilitate open knowledge sharing
    - Filtering non-constructive interventions and engaging in one-on-one communication before publishing misleading contributions, ensuring they align with community objectives
    - Recognizing valuable contributions and reporting them to the relevant hierarchical chain, as it is essential to acknowledge and promote professional contributions to prevent underappreciation of talent, which can lead to disengagement or departure.

Additionally, Lessons Learned officers should be integrated into this OVCoP category to encourage active population of the LL platform.

Each community should include a SCORM package that outlines all essential aspects of the role, enabling professionals to quickly retrieve necessary materials through indexed searches (Knowledge Retrieval process). Participants are encouraged to share challenges and uncertainties, potentially leading to innovative solutions not previously explored (Knowledge Creation process).

If a preliminary analysis indicates that these principles cannot be guaranteed, the CoP should not be established.

Chapter 13 - Conclusions

In conclusion, this doctoral thesis has extensively explored Knowledge Management (KM) within the complex and dynamic environment of the Italian Air Force (IAF). By integrating theoretical perspectives with practical applications, the research highlights the necessity of developing KM models specifically tailored to the unique challenges of military organizations, particularly those operating in volatile, uncertain, complex, and rapidly changing contexts.

A key finding is that while many KM models exist, none fully address the specific needs of the IAF. The organization's intricate structure, demanding operational requirements, and distinct culture call for a customized approach, especially in areas like knowledge retention, just-in-time training, and the management of knowledge in fast-evolving operational settings. One major challenge identified is Knowledge Retention, as the anticipated retirement of experienced personnel, particularly from the "baby boomer" generation, threatens to erode the IAF’s institutional memory. Preserving tacit knowledge is vital to ensure continuity and safeguard critical expertise.

Additionally, the unpredictable nature of military operations reinforces the need for Just-in-Time Training, requiring a KM system capable of rapidly delivering relevant knowledge and training, particularly in high-pressure or emergency situations. Addressing these challenges demands more than the mere introduction of technological solutions; it necessitates the thorough integration of technology into the organizational culture and processes, alongside fostering collaboration, learning, and knowledge sharing to ensure that KM tools are not only functional but also aligned with the IAF’s operational needs, where success relies heavily on human capital and adaptability.

To address these issues, the study identified several KM strategies suited to the IAF’s needs, including Organizational Virtual Communities of Practice (OVCoP), an efficient Lessons Learned system, and the use of Artificial Intelligence (AI) in training, particularly for non-formal education. Three in-depth case studies from the defense sector demonstrated how these approaches could effectively support the IAF’s operational requirements. While these tools have shown potential, they require further refinement to overcome issues such as bureaucracy, hierarchical structures, and maintaining community engagement. The use of AI in defense training offers promising opportunities to enhance KM through lifelong learning and real-time skill development.

Thus, the ultimate objective of this research was to theorize new KM models designed to cultivate a culture of continuous learning and knowledge sharing within the IAF. By promoting adaptability and preparedness, these models aim to help the organization remain responsive to the ever-changing operational landscape.

The research was driven by several key questions: What are the most crucial aspects of KM for an organization like the IAF? Which KM approaches are most effective in this context? How are KM processes currently managed, and how can they be improved? What KM tools are being used, and how can their effectiveness be optimized? Lastly, what practical models and solutions can be recommended to improve KM processes and ensure long-term organizational success?

Through a comprehensive review of the literature, systematic analyses, case studies within the defense sector, and internal document analysis, a Delphi questionnaire was administered to KM experts within the IAF. This led to the identification of a KM approach fundamentally oriented towards people. Additionally, five types of knowledge were identified through the literature and reclassified into a hierarchical taxonomy to better facilitate the identification of relevant KM processes. Six KM processes were identified, and a comprehensive model was developed to link KM tools with these processes and knowledge types.

Building on these findings, the research proposed a framework to assist KM professionals within the IAF in addressing knowledge-related challenges specific to their organizational context. This flexible framework, designed with fractal-like adaptability, can be applied at all levels of the organization, from peripheral units to central entities. Additionally, a set of principles and guidelines was proposed to ensure the successful implementation of an Organizational Virtual Community of Practice (OVCoP), further enhancing knowledge sharing and management throughout the organization.

By employing a mix of qualitative and quantitative methods—such as case studies, literature reviews, and expert interviews using the Delphi technique—this research offers practical KM models specifically tailored to the IAF. These models emphasize an integrated approach that places human resources at the heart of KM initiatives, ensuring that they align with the broader strategic goals of the organization.

13.1 Limitations

While this research provides practical models and tools designed to support managers working in the intricate areas of human capital and knowledge management, it also opens new questions for future exploration. For instance, it would be valuable to investigate how these models can be adapted to diverse organizational contexts or to the specific challenges posed by different knowledge domains.

Moreover, as emphasized throughout this thesis, all models inherently represent a simplified view of reality, often unable to capture the full complexity of the systems they describe. This is a limitation that must be acknowledged when applying any model, including those presented in this study. Careful consideration is necessary to ensure that the models are applied with an understanding of their limitations, particularly when navigating the complex and dynamic environments characteristic of modern organizations.

Furthermore, the small sample size of experts who responded to the Delphi questionnaire does not allow us to answer certain questions, which could be interesting for future studies. For example: Is there a relationship between the work area and the type of tool used for knowledge management?

Lastly, The theorized models have not yet been tested in the field. To validate the effectiveness of these models, it would be essential to implement them and conduct a thorough analysis of the resulting outcomes.

13.2 Future developments

A significant outcome of this study is the development of a framework tailored to managing Online Virtual Communities of Practice (OVCoP) within the IAF. These communities involve professionals who are defined by Armed Forces directives and who, after receiving formal training in essential competencies, continue their development within their respective units. In this context, the OVCoP becomes an invaluable platform for informal learning, complementing the formal training process.

The application of the proposed framework for enhancing OVCoPs will be carried out within a project led by the Department for Educational and Managerial Training (Reparto per la

Formazione Didattica e Manageriale). This project aims to establish a community for professionals trained in managerial roles, such as:

- Project Managers
- Quality Managers
- Auditors
- Knowledge Managers

The community will focus on cross-functional managerial topics, relevant to all these professional roles. In line with the model, the objectives for the Knowledge Manager overseeing the community will include:

- Enhancing process efficiency
- Promoting creativity and innovation
- Facilitating problem-solving and decision-making processes
- Strengthening professional relationships across different units

The expected outcome, and the overarching goal, is the continuous development of human resources within the organization.

Additionally, the formalized models presented in this thesis will be made available to the General Office for Managerial Innovation. This office will have the opportunity to assess these models and consider potential updates to the UIM-005 directive on Knowledge Management within the IAF. Such updates would help ensure that the directive remains current and responsive to the evolving needs of the organization.

Studies to test the validity of the framework designed for OVCoPs are currently underway, while the validation of the proposed models will be carried out through expert consultations and, if feasible, the gradual implementation of some of the highlighted principles. The findings from these studies, expected to be conducted within the IAF organizational context, will be presented to the scientific community through publications in specialized journals and presentations at thematic conferences.

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