A Framework for Analytical Demands of Alumni Capital

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Abstract: In 2020, in the Brazilian context, the postgraduate regulatory entity introduced new evaluation criteria on former postgraduate students' information for its 4,598 master's and doctoral postgraduate programs. The alumni are perceived as a permanent connection to society and reflect the social impact of their education. Thus, the postgraduate programs sought to gather information about their former students for better results in their strategic plannings as well as their evaluations. Using the Design Science Research (DSR) methodology, this research focused on bibliographic and empirical work, through an integrative literature review, to identify contributions to the construction of an artifact to explore alumni data and knowledge based on the theories of Intellectual Capital, Data Science and Knowledge Engineering. As a result, a framework was created to guide the process of analytical demands for the exploration of the intangible assets related to the postgraduate programs´ former students. The first element of this framework addresses Intellectual Capital management in Higher Education Institutions (HEIs) to identify and measure their intangible assets related to the alumni. The second element relies on Business Intelligence techniques for the creation of reports and dashboards with descriptive analyses. Data Science is the third element which contributes to generating predictive analytics. And, as the last element of the proposed framework, it is expected the use of Knowledge Engineering for the construction of prescriptive analyses. Although there is an extensive literature on tools for alumni management and management of Intellectual Capital in HEIs, it was observed a lack of practical research for the development of workflows for management and monitoring of Alumni Capital in postgraduate programs with descriptive, predictive and prescriptive analyses. Therefore, the proposed framework has the potential to assist these postgraduate programs in their analytical demands for better results in their evaluations. In addition, the data and knowledge about Alumni Capital enable better strategic planning of their actions.

Keywords: Alumni capital, Intellectual capital, Data science, Knowledge engineering, Postgraduate programs

1. Introduction

The Brazilian National Postgraduate System (SNPG) currently comprises 4,598 active postgraduate programs. According to Fernandes *et al.* (2021), these programs are part of a robust system, regulated by Higher Education Personnel Improvement Coordination (CAPES), with over one hundred thousand professors distributed among more than five hundred HEIs, and are the locus of scientific development and a high-quality training environment in Brazil. However, the training of students needs to be even more connected with the demands of professional sectors. The recognition of this successful technical-scientific system must go beyond the academic circuit and be in line with contemporary digital transformation, taking advantage of evolutionary and disruptive technologies. In this context, there is a need to analyze the education obtained from the perspective of the alumni with these technologies, who provide a bridge between the demands of society and professional sectors with postgraduate programs (Hortale *et al.*, 2014; Senger *et al.*, 2018).

Exploring alumni information is not a new topic in the literature. However, several academic studies still point out the need to deepen the exploration of alumni information in postgraduate programs and face a lack of means to carry out such activity (Ribeiro *et al.*, 2021). It is in this context that the theory of Intellectual Capital (IC) in HEIs, Data Science, and Knowledge Engineering can help through new artifacts and knowledge. The study of Intellectual Capital began in the business field, starting with the Skandia Navigator model published in 1994 (Edvinsson, 2013). The initial definition of IC was related to the sum of intangible assets that generated competitive advantage (Dumay, 2016). Over the years, IC has been the subject of great research interest, with currently more than 7,000 studies in the Scopus database. IC is one of the main sources of wealth creation in organizations, and for this reason, scholars have endeavored to create models, methods, and frameworks to identify, measure, and increase these intellectual assets (Pedro, 2018). With this growing interest, the exploration of IC has expanded to different types of organizations, including hospitals, government departments, research organizations, third sector, cultural and heritage organizations, police departments, regional groupings, and, lastly, the focus of this research, HEIs (Secundo *et al.*, 2015).

Several studies address the measurement and disclosure of IC in HEIs (Ramírez and Gordillo, 2014; Bisogno *et al.*, 2018). It is understood that there is a great convergence and complementarity between the metrics of the IC measurement models in HEIs and the indicators used by the evaluation areas of postgraduate programs by CAPES. Therefore, the various studies on IC in HEIs, especially in European HEIs, can be useful for postgraduate programs, helping them to be more comparable, competitive, dynamic, transparent, and focused on society's demands. Alumni are the subject of these IC studies in HEIs, and their analysis is mainly reflected in the components of Human Capital (HC) and Relational Capital (RC) (Pedro, 2018; Secundo *et al.*, 2018; Aversano *et al.*, 2020). In addition to these components, there is a specific one for alumni in IC, called Alumni Capital (AC), proposed by Liu (2007), which explores the relationship between educational institutions and their alumni.

While Fernandes *et al.* (2021) suggest the use of Data Science and Data Intelligence to assist in the challenging task of CAPES evaluation process in the SNPG, Dabić *et al.* (2020) suggest the creation of new interdisciplinary research projects to connect computer scientists with business management scholars in exploring IC in organizations. Therefore, Data Science and Knowledge Engineering can assist in exploring data and information from the postgraduate programs for CAPES evaluations, as well as in the study and expansion of Capital Alumni related to IC in HEIs. The triad of Intellectual Capital, Data Science and Knowledge Engineering, complements each other and allows the study of IC, through AC, to impact the postgraduate programs in exploring data and information about postgraduate students, in such a way that Data Science and Knowledge Engineering support this activity, providing appropriate technology and methodologies for supporting this analytical process. This analytical process can be understood as activities for exploring data and information from alumni through the collection, mining, and use of technology to measure, identify patterns and trends. However, as observed in the literature reviews, especially in the integrative review that addressed these themes together, there is a lack of specialized artifacts in Data Science and Knowledge Engineering to guide these analytical demands for information from the Alumni Capital in the context of postgraduate programs. This includes models, methods, technological architectures, and frameworks that enable efficient and effective management of alumni, providing postgraduate programs coordinators with relevant information without creating exhaustive demands on teachers and postgraduate students themselves.

The next section presents the theoretical framework that discusses the existing literature on these topics. Section 3 discusses the proposed methodology used for the study. Results and discussion are captured in section 4, while section 5 presents the conclusion of the study.

2. Theoretical Background

2.1 Intellectual Capital

According to Magrassi (2002), Intellectual Capital is related to the resources and potential that determine the value and competitiveness of an organization. The concept of IC has been associated with organizational knowledge and intangible resources. The term is widely discussed and a vast array of studies, across various disciplines, have created a series of definitions, properties, and attributes that can be considered as part of Intellectual Capital and intangible assets (Choong, 2008). In the context of HEIs, Gradim *et al.* (2022) discuss the importance of managing IC in HEIs and highlight that HEIs are important sources of intangible resources. The components of Intellectual Capital in HEIs follow the most common elements in the literature: Human Capital, Structural Capital, and Relational Capital (Pedro, Leitão and Alves, 2018). According to Secundo (2015), Human Capital in HEIs refers to the intangible value that lies in individual competencies, covering the experience, knowledge, and life experiences of researchers, professors, technical staff, students, and administrative employees. For Pedro (2018), in general, organizational HC is formed by the knowledge, competencies, attitudes, and intellectual agility of all members who are part of the organization. Structural Capital (SC) in HEIs consists of the organization's explicit knowledge, which is shared and disseminated internally, and can be part of the management of scientific and technical knowledge (Pedro, 2018). This knowledge can be derived from the interaction between research, management, and process organization, as well as organizational routines, corporate culture, values, development of internal procedures, software, technologies, and other technical resources available, such as bibliography, archives, licenses, databases, among others. The Relational Capital is composed of intangible resources and capabilities that generate value from the internal and external relationships of the university. These relationships include partnerships with public and private organizations, position and image in networks, academic prestige, brand, partnerships with the business sector and regional governments, involvement with nonprofit organizations and civil society in general, as well as collaborations with national and international organizations, research centers, networks, and alliances (Secundo *et al.*, 2015).

Finally, an important component of IC for this work and marginally explored in the literature is the Alumni Capital which is related to the intangible assets of alumni in an HEI. One of the first definitions in the HEIs´ context was created by Liu (2007) who defines Alumni Capital as: "the relationship between educational institutions and their alumni. According to that definition, Alumni Capital includes the achievement of alumni, their donations, cohesion, employment, and recurring education". Based on Liu's definition, we expand the definition of AC to: the intangible value that resides in the relationships with its alumni, such as satisfaction with the education received and with their financial achievement, awards and distinctions received after graduation, intellectual and technical production carried out together, the representativeness of positions held in academia, private or public sector, recurrent education at the educational institution, participation in committees, councils or research groups, donation or sponsorship of actions, and other relationships that build ties with former students.

2.2 Data Science

Data Science is a field of evidence seeking that combines data with domain information to generate new knowledge (Yu and Kumbier, 2020). Cao (2017) states that Data Science is a new field of science that emerged from pragmatic issues based on the need of companies and organizations to improve their efficiency with a focus on data. In this context, every organization needs a decision-making process and suggests that data analysis tools should be used for a better decision-making process, thus improving efficiency and effectiveness in their business production processes. According to Cao (2017), the term Data Science has been attracting more and more attention in the literature. In the author's view, Data Science develops relevant methodologies, theories, technologies, and applications for data exploration. Data Science, as a scientific field, explores everything from data capture, creation, representation, storage, search, sharing, privacy, security, modeling, analysis, learning, presentation, and visualization to the integration of complex and interdependent heterogeneous resources for real-time decision making (Provost and Fawcett, 2013; Cao, 2017; Kampakis, 2020; Yu and Kumbier, 2020). Additionally, Data Science enables collaboration, value creation, and decision-making support.

2.3 Knowledge Engineering

The Knowledge Engineering emerged from Artificial Intelligence as a subfield dedicated to the design, development, and implementation of Knowledge-Based Systems (KBS) (Studer, Benjamins and Fensel, 1998; Schreiber, 2008). Knowledge Engineering is the academic area responsible for developing models, methods, and basic technologies for knowledge representation and processing, as well as for constructing Artificial Intelligence applications (Kasabov, 1997). In the so-called Classical Knowledge Engineering, researchers aimed to "transfer" or "extract" the knowledge of the expert to a knowledge base. In this process, knowledge was extracted from experts through interviews and encoded through heuristic rules and rapid prototyping. This generated difficulty in developing large, commercial, and more complex systems, and maintenance became difficult and costly (Studer, Benjamins and Fensel, 1998). Similarly to the software crisis in the late 1960s, which culminated in the creation of the Software Engineering discipline, dissatisfaction with building KBSs led to the need for the creation of methodological approaches, resulting in the new Knowledge Engineering (KE) (Studer, Benjamins and Fensel, 1998; Schreiber, 2008). This new KE focused on "modeling knowledge" rather than "transferring knowledge" became a landmark for creating second-generation expert systems. In this new period of KE, the construction of second-generation KBSs is supported by knowledge modeling methodologies such as MIKE, VITAL, COMMET, PROTÈGÈ-II, EXPECT, and CommonKADS (Schreiber, 2008). In addition to these methodologies for knowledge modeling, ontology has gained a prominent role in KE, assisting KBSs with the domain knowledge model and with knowledge for problem-solving (inference).

3. Methodology

The Design Science Research Methodology (DSRM) was utilized for the development of this research. DSRM is a research approach that focuses on creating artifacts or practical solutions to real problems in a particular context (Peffers *et al.*, 2007). This methodology was chosen due to its process that guides researchers in initiating, developing, and measuring the impact of an artifact for solving a particular problem. The artifact created in this process must be evaluated to ensure its applicability as a new research contribution, designed to improve the effectiveness, efficiency, quality, or usefulness of an existing system, process, or service, or to create something entirely new. The rigor of the research is central to DSRM, which includes a process and a supporting knowledge base. The DSRM framework proposed by Peffers *et al*. (2007) consists of six activities, which are listed below.

- Identification and motivation of the problem: In this activity, the researcher identifies the practical problem to be solved and presents the motivation for its resolution.
- Definition of objectives for a solution: In this activity, objectives are defined to guide the process of creating the artifact. The objectives should be clear, measurable, and relevant to the identified problem.
- Design and development: The artifact is designed and developed based on a conceptual model that describes the functions and characteristics of the artifact and how it can solve the identified problem.
- Demonstration of the artifact: The artifact is demonstrated in a controlled environment to evaluate its effectiveness and usability.
- Evaluation of the artifact: The artifact is evaluated for its effectiveness, efficiency, quality, and utility in relation to the defined objectives. The evaluation can be conducted through experiments, simulations, or other evaluation techniques.
- Communication of results: The research results are communicated to relevant stakeholders, including those who can use the artifact, those involved in its creation, and researchers who may benefit from the results.

The execution of these DSRM activities in the research are described as follows. Except for the communication activity, which refers to presenting the work to researchers and interested audiences about the problem addressed.

3.1 Identification and Motivation

For this activity, an exploratory research was carried out in the literature to identify the importance of the topic of postgraduate students in postgraduate programs. This first search for works that address the topic of postgraduate students and their trajectories resulted in 20 documents, dated between 1991 and 2021. The Google Scholar® tool was used. The explored documents were scientific articles and research project reports. Works related to the exploration of profiles from public data sources and exploration of LinkedIn® data were also observed. Those works were analyzed and compiled into a) benefits of keeping postgraduate students´ information, b) how to monitor and search for postgraduate students´ information, and c) requested information. In addition, the alumni community portals of the 15 largest institutions in Brazil were analyzed according to their number of postgraduate programs. Based on the analysis of existing solutions in the context of CAPES evaluation regarding the theme of postgraduate students, and the analysis of works related to the exploratory search, a possible solution was reached: the construction of a method for defining indicators aimed at postgraduate program coordinators, adapted to the context of information to be observed about Human Capital and Relational Capital. After the exploratory literature review, a new review was carried out on Intellectual Capital in the context of HEIs. From this review, 18 documents were classified and used in the studies, including three that consisted of systematic literature reviews. These works helped to create the theoretical foundation of the research and assisted in the activity of defining the objectives of the solution, which is described below.

3.2 Definition of Objectives for a Solution

After the two exploratory literature reviews, it was decided to conduct a structured literature analysis using the integrative literature review method. The method was chosen for using systematic procedures and allowing the inclusion of studies with different methods (experimental and non-experimental, theoretical, and empirical), thus providing greater breadth in the literature review. The steps of this integrative review consist of: identifying the theme and selecting the research question; defining the inclusion and exclusion criteria for studies; identifying the pre-selected and selected studies; characterizing the selected studies; analyzing and interpreting the results; and synthesizing the knowledge or presenting the review.

The chosen databases for the study were Scopus, Web of Science (WoS), and the Brazilian Digital Library of Theses and Dissertations (BDTD). During this review, 9 studies out of 71 were selected that jointly addressed the theory of IC, Data Science, or Knowledge Engineering, and Alumni. The studies were classified and described into categories: a) concepts about Intellectual Capital and/or Knowledge Management; b) Management or mapping of IC in HEIs or postgraduate programs; c) systematic or integrative review, bibliometric analysis, or extensive exploration of existing literature; d) data collection instrument, indicators, or metrics about Intellectual Capital; e) technologies related to Data Science and/or Knowledge Engineering. At the end of the reviews, three objectives were established for the proposed solution:

- Define an analytical approach for managing the Alumni Capital of postgraduate programs, based on the theories of Intellectual Capital, Data Science, and Knowledge Engineering.
- Develop a framework to guide the activities of collecting and processing data, information, and knowledge to support analytical demands for Alumni Capital management.
- Instantiate the proposed framework and evaluate it from the perspective of knowledge contribution of Design Science Research.

3.3 Design and Development

The project and development of an analytical approach to explore information related to the Alumni Capital was elaborated based on the solution objectives defined during the DSRM execution. The approach resulted in the creation of a theoretical solution and subsequently, a framework that guides the construction of analytical solutions for managing the Intellectual Capital related to alumni in postgraduate programs. Both the theoretical solution and the framework use the theories of Intellectual Capital, Data Science, and Knowledge Engineering to present a complete cycle for managing and constructing solutions that measure the Alumni Capital and enable advanced analysis of this IC component. From this proposed theoretical solution, the framework development began, which defines and guides the management (planning, evaluation, and communication) and engineering (measurement and analysis) processes for constructing analyses that provide a complete view of the postgraduate programs Alumni Capital. This framework, called Alumni Capital Data and Knowledge (ACDK), has four pillars described in the proposed theoretical solution: management, measurement, projection, and prescription.

3.4 Demonstration

The proposed ACDK framework was instantiated for demonstration purposes in a postgraduate program in Brazil. The chosen program provided a strategic planning regarding the actions related to its alumni. Regarding the demonstration of the processes, the measurement and analysis of the postgraduate program included data sources from the CV Lattes and LinkedIn®. The sources were used for conducting descriptive and prescriptive analyses.

3.5 Evaluation of the Artifact

Using the theoretical framework of Design Science Research, the descriptive method of artifact evaluation proposed by Hevner (2004) was used to evaluate the contribution of the results with argumentation and scenarios. Regarding the argumentation for the relevance of the proposed framework, the following section presents the results obtained in the planning, measurement, and analysis processes of the ACDK execution in the proposed context. The presented results are promising and demonstrate that the use of the ACDK framework by postgraduate programs allows for direct action in the management of Alumni Capital. Thus, resulting in instruments to respond more effectively and efficiently to the evaluation criteria of CAPES.

4. Results

The research resulted in two artifacts. The first is part of the theoretical solution, where the pillars for the proposed framework are established. The proposed solution seeks to improve the state of the art by integrating the theories of Intellectual Capital, Data Science, and Knowledge Engineering for managing and exploring data, information, and knowledge in analytical demands of Alumni Capital. The pillars presented guide the construction of the proposed framework, allowing for a complete cycle of analytical demands of Alumni Capital in postgraduate programs, from management to recommendation of actions based on evidence through descriptive, predictive, and prescriptive analyses. Below we present a detailed explanation of each pillar of the solution and an overview of the proposed theoretical solution in Figure 1.

- Management: This pillar is the basis for the other proposed pillars. Supported by the theory of Intellectual Capital, it seeks to identify and map the intangible assets related to Alumni Capital in a postgraduate program.
- Measurement: The second pillar of this theoretical solution is supported by the knowledge base of Data Science, which proposes to measure the intangible assets related to Alumni Capital. The measurement plan provides indicators that must be objectively answered, with reports and

dashboards. This pillar recommends the construction of results comparable to traditional Business Intelligence systems.

- Projection: In the third pillar of this theoretical solution, the application of predictive analysis is done with the support of the knowledge base of Data Science. Predictive analysis aims to determine what is likely to happen in the future and why it can happen based on historical data and information.
- Prescription: In the fourth pillar of the theoretical solution, the use of prescriptive analysis is made with the support of the knowledge base of Knowledge Engineering. Prescriptive analysis focuses on providing recommendations as decision support to achieve specific objectives. Essentially, it involves the use of an analytical model to help guide decision-makers with recommendations or to automate parts of the decision-making process.

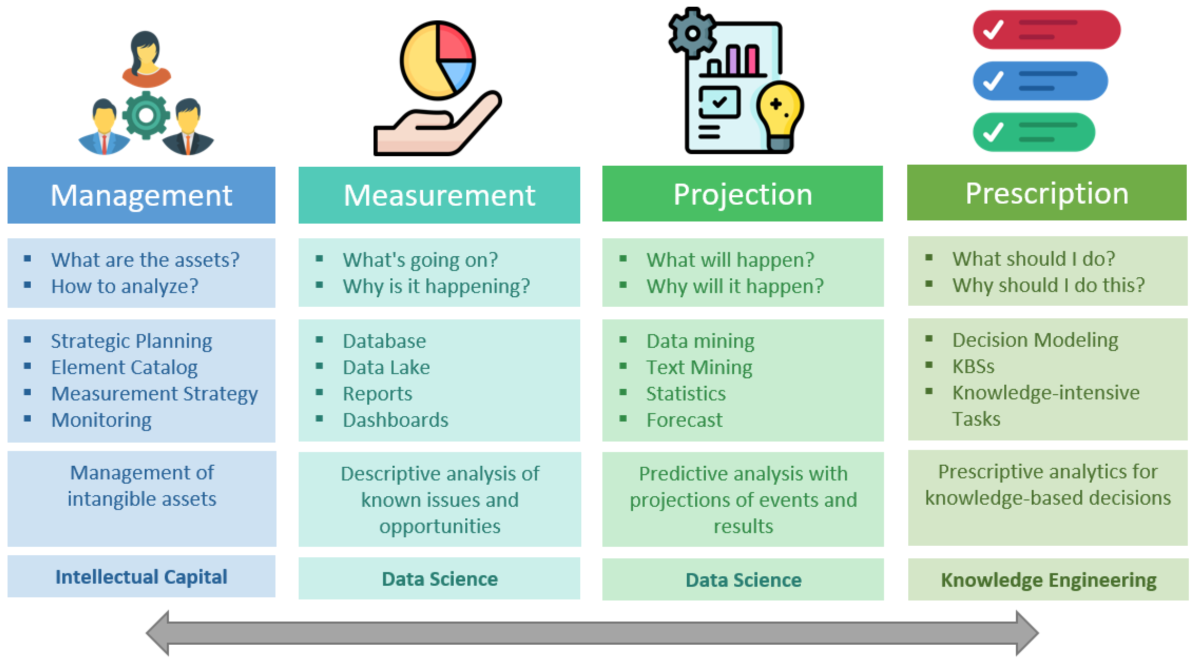

Figure 1: Vision of the Theoretical Solution of the Proposed Framework

Based on the constructs of the theoretical solution, we present the proposed framework. The ACDK guides the planning, measurement, analysis, evaluation, and communication activities related to the Capital Alumni of the postgraduate program. The common step to start the activities supported by the framework is the planning process. In addition, the standard sequence would be executed in the measurement, analysis, evaluation, and communication processes, with the communication process being the last one executed. However, the framework allows different processes to be triggered as needed. The interactive use of these processes is envisaged, without necessarily having an end. Below we present the processes of ACDK with Figure 2 showing the overview of the framework in sequence.

- Planning: directs actions effectively and focused on tangible and measurable results related to the Alumni Capital of postgraduate programs. It is necessary to think about objective actions to measure the intangible assets related to alumni, which assets should be measured, which indicators and resources (e.g., reports with list of alumni) should be proposed, which relevant sources of information should be studied, and what will be the allocation of resources to ensure these objectives.
- Measurement: corresponds to the processes of data acquisition and transformation that respond to analytical demands related to the Alumni Capital of postgraduate programs. It is necessary to verify if the information sources thought in the planning phase are adequate, think about the task of collecting, preparing, and transforming data, creating analytical repositories, and generating reports.
- Analysis: allows for a deeper understanding of the collected and measured data. The result of the analysis should be able to generate valuable insights for decision-making and improvement of Alumni Capital management strategies. Tasks are oriented towards the creation of descriptive, predictive, and prescriptive analyses from the database or data lake generated in the measurement process.

- Evaluation: allows ensuring the quality of the information and knowledge generated throughout the planning, measurement, and analysis processes. A careful evaluation of the results obtained from the measurement plan is performed, verifying if all the steps were executed correctly and if the measurements performed are in accordance with expectations.
- Communication: the objective is to clearly present the results generated from the analysis, evaluation, measurement, and planning processes related to the postgraduate programs Alumni Capital so that everyone can understand the results.

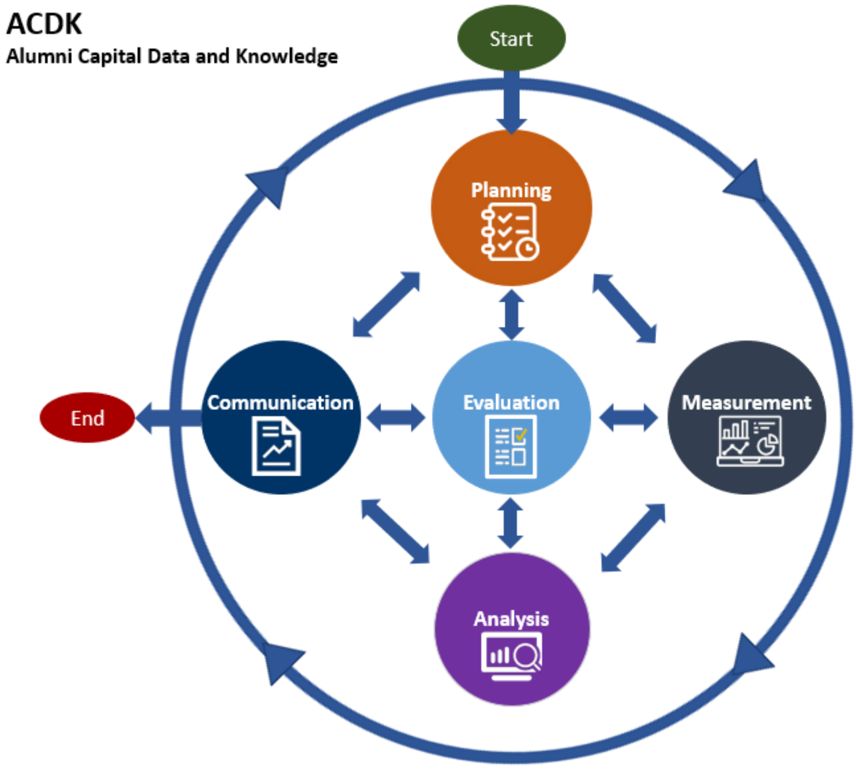

Figure 2: Vision of the Processes of the ACDK Framework

Next, we will discuss the results of the proposed framework and the conclusion of this study.

5. Discussion and Conclusion

As a result of this research, a framework proposal was created to guide the process of managing analytical demands related to Capital Alumni in postgraduate programs. The instantiation of the framework brings important contributions. The first is related to the knowledge of intangible assets related to the Alumni Capital of the analyzed program. The instantiation of the framework brought insights that can be presented to the postgraduate program and can be worked on with more data sources for a better analysis. Regarding the theoretical foundation of the literature, this research integrates different theories and proposes a common path for managing Alumni Capital. This concept of AC is also expanded in this research with elements of postgraduate education, which also allows the expansion of literature related to Intellectual Capital. Additionally, this research presents Data Science as an emerging theory that can contribute to Knowledge Engineering to understand and analyze real-world phenomena with domain data and information to generate new knowledge. This combination of Data Science and Knowledge Engineering enables the creation of intelligent systems.

5.1 Limitations and Future Research

The processes of ACDK can be treated in a generic way to adapt this framework to the management of Intellectual Capital in HEIs, in a broader context. To achieve this generalization, it is suggested to use indicators from the context of HEIs and to present examples related to this new context. This work provided a detailed description of the ACDK in different processes that will be further developed in future works. Lastly, the instantiation of the proposed framework should be detailed in further works to demonstrate the benefits of using the ACDK.

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