

A GRAMMAR FOR INFORMATION SYSTEMS AND TECHNOLOGY COMPETENCIES

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ABSTRACT

The description of Information Systems and Technology professional competencies requires the articulation of various concepts in an integrated structure. The definitions for these concepts are not consensual and the instantiations of the concepts are written in non-standard ways. This ambiguity can have a negative impact on the characterization and evaluation of professional attributes. This work carries out an analysis of several competency frameworks and proposes the application of grammatical classes for the concepts that make up the competency structure, aiming at greater transparency and clarity in the use of the concepts. To this end, a Backus-Naur Form grammar is proposed to standardize the writing of concepts. Seeking to validate the competency grammar, Information Systems and Technology professionals reported attributes of their occupations, observing the proposed grammatical rules. Afterwards, the exercise was replicated with practitioners from four other professional areas.

KEYWORDS

Competency; information systems and technology; information systems and technology competency; competency grammar; Backus-Naur Form.

1. INTRODUCTION

Addressing the concept of competency in scientific investigations has been increasingly challenging, as it may be found by the number of scientific publications that refer to this concept. With a proliferation of studies on a topic, it might be expected that the more a concept is referenced, the greater the rigor in its use. However, in what concerns competency, this does not necessarily mean higher levels of maturity or standardization in the employment of the concept. Indeed, Ferrari (2012) notices the existence of a “jargon jungle not easy to breach” (p. 11), Janssen *et al.* (2013) observe that “concrete elaborations [*of digital competence*] vary depending on the context and the particular ‘language’ used,” (p. 473), and Oberländer *et al.* (2020) highlight the prevalence of “many different labels” (p. 4), frequently “used interchangeably, as synonyms, describing the same concept”, but where “definitions and intended meanings are rather imprecise and depend on the context of use.” (p. 4).

This perceived lack of rigor when applying the word “competency” and other terms that are often treated as synonyms for competency, such as, skill, knowledge, ability, and proficiency, or that are closely related to competency, such as, posture, behavior, disposition, and attitude, conveyed the opportunity for this work.

By studying several well-known Information Systems and Technology (IST) competency-focused frameworks in the search for definitions of competency-related concepts, we found that different concepts form the structure of those frameworks. The lack of rigor when applying the concepts related to the competencies of individuals led us to resort to dictionaries, seeking primary definitions for the concepts. In an effort to obtain a unified approach to the variety of concepts addressed in this work, as well as to grasp better ways to formulate (writing) them, we advanced revised definitions for the concepts, based on the reviewed literature. This allowed us to structure the construct of competency in the realm of IST professional area.

In this paper, we argue that one way to distinguish the attributes characterizing professionals' competencies is the way of writing the attributes that compose the competency construct. We advocate that the attributes associated to job competencies, such as, expected actions from a professional, knowledge requirements, individuals' features, or even job-related objects, may have their writing standardized, and that this will assist in their classification in one of the main concepts reviewed in this work. To this end, we propose that Backus-Naur Form (BNF), a meta-syntax notation, can be used to define criteria – a grammar – to govern the writing of concepts that composes the competency construct. Thus, the research question that this work aims to answer is the following: Is a Backus-Naur Form competency grammar able to assist in the identification, classification and writing of IST professional attributes? Aiming to answer the research question, IST professionals were involved in this work, having used the BNF competency grammar to map the responsibilities assigned to them in the workplace in order to meet the daily demands of their job functions.

We delineated the competency-related concepts based on several competency frameworks and grounded in definitions found on dictionaries. In the next section of the paper, we summarize the literature review, briefly describing the competency frameworks, and identifying the dictionaries that provided support material for the definition of concepts. The main concepts are also presented, with BNF being introduced as the notation for specifying the rules of writing the instantiations of the concepts involved. After the literature review, the section on competency grammar sets forth the writing rules for each of the reviewed concepts. Also in that section, we propose a decision tree to aid in the classification of words or sentences related to the practice of professionals. In the final section, conclusions, limitations of the study and ideas for future work are pointed out.

2. LITERATURE REVIEW

The definition of the concepts was considered a requirement to start this work. In what concerns the competency frameworks, it was noted that these references approach the concepts differently, resulting in different definitions for the same concept, as well as different concepts with the same definition. Aiming more consistency to the path that led to the definition of concepts, it was also necessary to use dictionaries, given that the definitions present in these references were not influenced by the specific purposes or central themes that guided the frameworks reviewed.

The following subsection addresses the competency frameworks reviewed in this work, paying special attention to the approach to competency adopted in each framework and to its respective central theme.

2.1 Competency Frameworks

The O*NET framework is supported by the United States Department of Labor (2020), receiving constant updates. This framework has professional occupation as its central theme, but it involves several other concepts that refer to characteristics and attributes expected to be found in professionals. Some complementary concepts are based on the RIASEC concept (Realistic, Investigative, Artistic, Social, Enterprising, and Conventional) proposed by Holland (1997). With similar characteristics, there is the Répertoire Opérationnel des Métiers et des Emplois (ROME) (ETALAB, 2020), provided by the French government. This framework also uses the RIASEC concept, but it constrains the concept addressed to its central theme, namely occupation. Assigning the concept of competency as the central theme of the framework, the European e-Competence Framework (ECF) (European Union, 2016), specifically aimed at the area of IST, sets forty different competencies.

Assuming skill as the central theme, there are the Skill Framework for the Information Age (SFIA) (SFIA Foundation, 2015, 2018) and the i-Competence Dictionary (iCD) (Hayashiguchi, Endou and Impagliazzo, 2018), both specific to IST professional area. The support provided by SFIA is based on the mapping of 112 skills, grouped into 17 subcategories and 6 categories. The iCD, although having skill as its central theme, proposes a different approach that lists the tasks associated to each individual's skill. This framework includes 84 skills, divided into 14 classifications and four categories.

In this work, seven competency frameworks were analyzed, each one composed by different concepts that make up what the authors of the frameworks define as competency. Through the proposal of a definition for the competency construct and an associated set of rules for expressing instances of the component concepts (the grammar), we hope to increase the maturity and rigor with which these matters are dealt with.

In the next subsection, we present the main concepts in the aforementioned frameworks and advance definitions that will be useful for the standardization of the concepts involved in this study.

2.2 Main Concepts

Considering that IST was the main area under study in this work, in the beginning we sought for concepts defined and applied specifically in IST, and the references that initially contributed to the study were ECF and SFIA, and later iCD. Considering the structure of each framework, the definitions for the concepts are contrasting. When comparing SFIA and ECF, for example, a common concept is that of skill, however, its application is different. In ECF, skill is one of the elements that support the existence of a competency, while in SFIA skill is related to a professional area. Also present as central to iCD, the concept of skill is referred as a group of expected functions that the professional performs. Although these frameworks, as mentioned, pertain to the area of IST, the results of the relationship between these frameworks had some commonalities with the structure of broad non-specific frameworks, such as O*NET and ROME.

According to ECF definition, the competency concept can be defined as a demonstrated ability to apply knowledge, skills, and attitudes for achieving observable results. In this definition, some concepts are pointed out that need special attention, such as ability, knowledge, skill, and attitude. The ECF notes that competency is a holistic concept, being related to workplace activities, and incorporating behaviors expressed as embedded attitudes.

In addition to the frameworks mentioned before, we also reviewed the IT2017 (IT2017, 2017) and MSIS2016 (Topi *et al.*, 2017), two curriculum guidelines that provide support in the design of programs at graduate and undergraduate levels for IT and Information Systems (IS), respectively. Building on the concept of competency, both documents lay out professional profiles for the IST area, defining skills, tasks, and levels of difficulty related to the functions performed by IT and IS professionals.

When recurring to some dictionaries, for the term competency or competence, the Oxford (2014) registers “the ability to do something successfully or efficiently”, very close to Collins’ entry “the ability to do something well or effectively” (Collins Dictionary, 2017), but different from Cambridge’s explanation as “an important skill that is needed to do a job” (Cambridge, 2020) or APA’s definition of “one’s developed repertoire of skills, especially as it is applied to a task or set of tasks” (APA Dictionary, 2018). From the competency frameworks, groups of tasks are assigned to a competency, which can be segregated into abilities, which correspond to different levels of proficiency. These levels of proficiency involve a combination of knowledge and skills that will enable the professional to perform the tasks inherent to its abilities. The analysis of the IST frameworks also suggested that professional practice, regardless of the possession of abilities, is conditioned to the professional’s posture, which may be formed by the behavior and disposition elements.

In this work, we consider that competency has two pillars that support it, namely ability and posture. Ability has levels of proficiency, that express the complexity of the knowledge and skill associated to an ability. Since the combination of knowledge and skills indicate a level of complexity for a given ability, there is also the possibility of measuring the complexity to perform a given task, making evident the relevance of the ability element in this competency structure. For each task, there may be a set of tools necessary for its execution. The other pillar that supports competency goes beyond technical factors, addressing personal factors, which are equally relevant to competency. The professional’s posture is something that can be identified through attributes and characteristics observed in the work environment, which are the dispositions that, in turn, support the occurrence of certain behaviors by the professional and that enact his/her competency. The definitions proposed for the competency construct and competency-related concepts are now presented, built upon IST and general competency frameworks, as well as entries from dictionaries:

- Competency: ¹It refers to a combination of abilities and postures at the individual level to solve a given task at a specific time. ²It must be related to a professional area where individuals employ their abilities.

- Ability: ¹It refers to the condition that indicates someone can perform a certain task, having a degree of proficiency in the use of resources, which at the individual level refers to the possession of knowledge and skills. ²It has great proximity to the definition of a position to be held by a professional.

Table 1. Concepts and Their Relationships with Framework

Concept	Related Concepts	Example
Competency	① Dimension 2	Information Systems and Business Strategy Alignment
	② Category	Strategy and architecture
	④ Areas	Business Continuity and Information Assurance
	⑤ Career Pathway	Programming and Software Development
	⑥ Professional Domain	Études et développement Informatique
	⑦ Skill Classification	(Development) System architecting technology
Posture	⑤ Work Values	Achievement; Independence
Disposition	⑤ Interests	RIASEC
	⑥ Personality Type	RIASEC
Behavior	① Behavior	Transforming, making decisions, applying, organizing
Task	③ Essential IT Domains	Use a risk management framework
	⑤ Tasks	Coordinate installation of a software system
Tool	⑤ Tools Used	Computer servers
Ability	② Subcategory	Information strategy
	⑥ Occupation	Software Developers
	⑦ Skill Item	System development management technology
Proficiency	① Dimension 3	Level 1 – Level 5
	② Levels of responsibility	Follow, Assist, Apply, Enable, Ensure, Initiate, Inspire
	④ Levels of competence	Awareness; Novice; Supporting; Independent
	⑦ Skills Proficiency	Level 1 – Level 7
Knowledge	① Dimension 4	Business strategy concepts
	⑥ Savoirs	Algorithmique
Skill	① Dimension 4	Review and analyze the effects of implementations
	④ Foundational Competences	Critical Thinking, Creativity, Leadership
	⑤ Skill	Speaking, Coordination, Monitoring, Writing
	⑥ Savoir-faire	Installer un équipement informatique
	⑦ Skill Item	Software construction technology

- Posture: ¹Classifier of the recurrent behavior observed in the individual. ²It characterizes the moment when the individual responds to a stimulus received, influenced by his/her disposition in the face of an event, which leads to the execution of specific behaviors.

- Disposition: ¹It refers to an inclination or tendency to favor an alternative over other(s), which results in one or more behaviors, supporting an individual's characteristic posture. ²It specifically addresses inclinations, individual preferences.

- Behavior: ¹It is what can be observed as the result of a stimulus received by the individual, depending on the environment in which he/she is located. ²It is influenced by the beliefs and experiences that the individual has and contributes to the evolution of knowledge at the individual level. ³It is the immediate response to a stimulus.

- Task: ¹Something that can be performed by the individual, in fulfilling a demand or attending to the solution of a problem, requiring the use of one or more abilities and one or more postures for its full fulfillment, as expected. It is possible that, for its execution, it is necessary to use one or more tools. ²It is something that can be fulfilled by employing (posture) the individual's abilities.

- Tool: ¹Auxiliary technological resource that can be used to accomplish a given task. A tool can be involved in different tasks, just as a task can demand different tools for its execution. ²It is something that can be mobilized during the employment (posture) or ability as a support for the completion of a task.

- Proficiency: ¹It indicates the level by which the individual is trained, considering the resources possessed (knowledge and skills) and the results that can be obtained when putting them into practice (posture). ²The proficiency of an individual must indicate the result that he/she must deliver when acting professionally.

- Skill: ¹It is one of the elements that make up the ability of the individual and may be carried by the individual's posture (along with knowledge). ²It refers, in some situations, to the application of knowledge acquired, and in other situations, it refers to the application of natural knowledge, both intending to solve some demand in the professional scope. ³Some skills support the execution of other skills, that is, one skill may depend on another

to be applied. It is important to emphasize that having skills is a necessary condition for the professional to be able to perform tasks.

- Knowledge: ¹It sustains the individual's action in the execution of his/her skills or in the conduct of the professional position he/she holds. ²It is what can be acquired through experience and study; thus, the sources of knowledge acquisition are the practice of the individual's abilities and the individual's participation in training and qualification courses. ³It is considered that knowledge is improved through its practice (posture), forming the beginning or basis of an ability formation process. ⁴There is knowledge that supports the acquisition of another knowledge. This means that for acquiring some specific knowledge it may be necessary the existence of some previous knowledge.

Table 1 covers the concepts, the framework to which they referred to, and how the concept was addressed in that framework. Frameworks are signaled by numbers, identified as ①ECF, ②SFIA, ③IT2017, ④MSIS2016, ⑤O*NET, ⑥ROME, and ⑦iCD. Analyzing the provisions in Table 1, although we have equivalent examples related to the same concept, having different sources, we note the absence of criteria for its writing. Establishing criteria for writing the attributes that make up the competency construct can provide some advantages, such as classifying the element according to the concept; establishing dependencies between competency attributes, indicating an evolutionary path for the professional, and raising the maturity of a particular professional area.

Considering what has been portrayed regarding the difficulties involved in investigating the subject of competency, and avoiding being limited to an isolated research initiative, a step to standardize the application of competency in future studies on the subject is suggested in this work. This possibility concerns the use of BNF as a resource for the definition of writing standards for the concepts related to the competency construct, such as those present in this subsection, considering their definitions and correspondence with other reviewed frameworks. Next, we provide a brief overview of BNF.

2.3 Backus-Naur Form

BNF is one of the most used methods for writing syntax for context-free grammars (McCracken and Reilly 2003). The origin of the name comes from the creators of BNF, John Backus and Peter Naur. The first incarnation of BNF was used to describe the syntax of the programming language ALGOL 60, in 1960. In the following years, updates to the BNF notation were made.

In this proposal, we will use BNF, because we believe is the form that allows a better understanding of the writing pattern, even for non-IST professionals. According to Sebesta (2011), there are three advantages when opting for the use of BNF: clarity and conciseness of the BNF description; the possibility to use BNF as a basis for a parser; and the BNF-based implementations being relatively easy to maintain due to their modularity.

From a standardization point of view, it is desirable that meta-syntaxes, such as BNF and its variants, possess a set of characteristics (ISO, 1996), like: conciseness, precision, formality, naturality, generality, simplicity, self-describing, and linearity. In practical terms, considering BNF as a standard for writing, we can define transparent delimitations and rules, that mitigate the mishmash associated to definitions of competency.

To write a grammar in BNF, one uses the set of symbols from the BNF notation. The symbols needed to understand the competency grammar that will be presented in the next section are now addressed.

The symbols "<" and ">", respectively used before and after a word, define BNF classes, allowing values to be assigned to the class. The value is assigned by using the symbol "=" followed by the value one wants to assign, forming an expression such as: <class> = "xpto".

The symbol "+" serves to complement information that will be assigned to a class, such as: <class> = "xpto" + 123. In this example, "<class>" will have the assigned value "xpto123".

Another important symbol is "|", which is equivalent to the logical operator "or". It means that the <class> may have one or another value, such as: <class> = "xpto" | "123"

When using BNF notation, classes can be assigned to the values of another class. The next example, which contains five lines, consists of a sequence of value assignments. The value that "<mainclass>" may have is either "XPTO" or "xpto" or "1234".

```
<mainclass> = <text> | <number> + "4"  
<text> = <capital> | <tiny>  
<capital> = "XPTO"  
<tiny> = "xpto"  
<number> = "123"
```

In BNF notation, there are so-called terminals and non-terminals. Non-terminals will always be between “<” and “>”, while terminals are those that never appear on the left side of the “=” symbol.

3. COMPETENCY GRAMMAR

In view of the scenario described for the concept of competency, we propose a BNF grammar that establishes the syntactic rules for writing competencies, as well as the elements that make up its structure. These rules aim to prevent the undisciplined use of competency related concepts, by reducing the variations in the application of these elements and, therefore, heading towards a more mature state in approaching the competency construct. For each component of the construct, a syntax with specific rules to its writing is proposed, so that to maintain and strengthen the writing pattern proposed.

```
<competency> = <expr>
<posture> = <adjective>
<disposition> = <action verb>
<behavior> = <action verb> + <expr>
<ability> = <expr>
<task> = <action verb> + <expr>
<tool> = <expr>
<proficiency> = "1" | "2" | "3" | "4" | "5"
<skill> = <expr>
<knowledge> = <substantive> + <expr>
<expr> = <part> | <expr> + <part>
<part> = <substantive> | <preposition> | <article>
<adjective> = TEXT
<action verb> = TEXT
<substantive> = TEXT
<preposition> = TEXT
<article> = TEXT
```

Figure 1: Syntactic structure of Competency Grammar

The main goal is that different people involved in a professional occupation, such as trainers, contractors, and workers, may “speak the same language”. This makes the competency approach more direct, accurate, and independent on interpretations among those involved in the professional environment to determine requirements for a profession or specialty. Once the composition of competency has been defined, a set of specific knowledge and skills is established, which may form the requirements for the professional to exhibit that competency. Through this set of requirements, it is possible to identify the sources that may provide the opportunities for professionals to acquire a certain competency, such as training courses or experiences to which the professionals need to be exposed. The syntactic structure proposed for the way of writing the elements that make up the competency construct is shown in Figure 1.

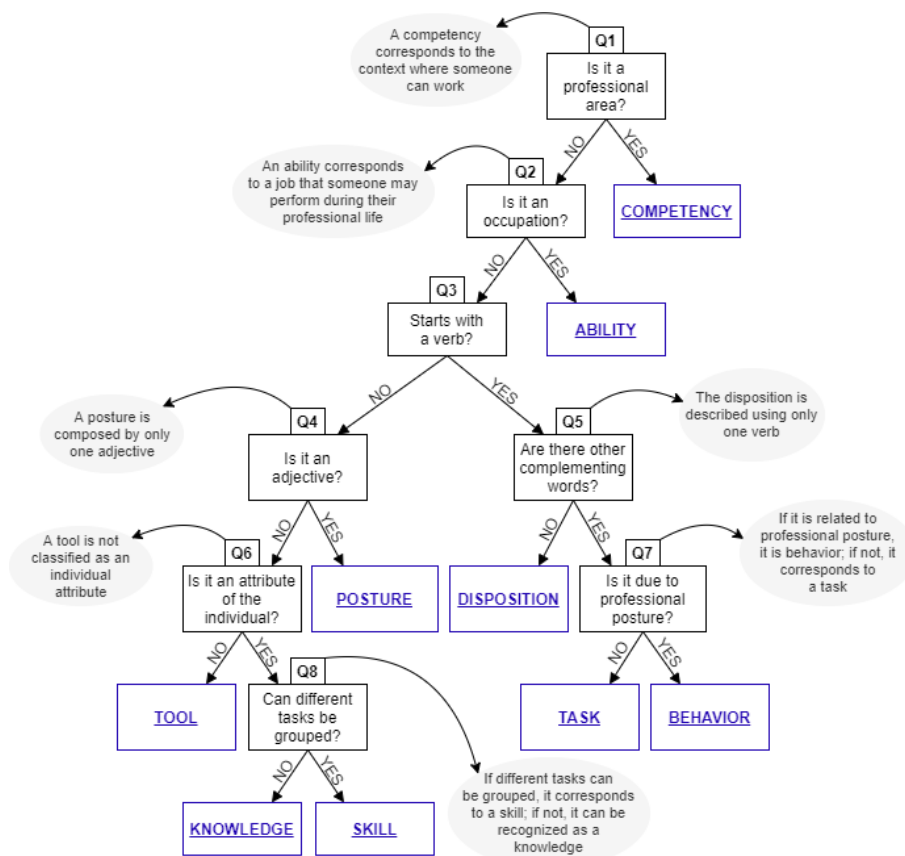


Figure 2. Decision Tree to Concepts Classification

In order to assist in the classification of the attributes of a professional area according to the structure of the competency construct, we designed an instrument in the form of a decision tree. This instrument starts with a single node (root), dividing into possible results, following a sequence of questions. These questions create branches with possible answers. The tree includes eight questions (Q), positioned in the nodes that build the branch of the decision tree. The initial node corresponds to Q1, while the following decision nodes address the other issues. The branches that connect the nodes carry the values that guide the user of the decision support mechanism, based on the issues present in the internal nodes. These questions lead the user of the decision tree to classify the word or phrase according to the concept under analysis. The paths that lead to the classification of any word or sentence related to the competency construct are shown in Figure 2. The tree also includes brief explanations to the eight questions. The concept of proficiency is not part of the scheme; since it does not have a script that can be interpreted (we propose the scale 1–2–3–4–5 to capture the values of proficiency levels).

When using this instrument to support the classification of a sentence or word that is related to the context of a profession, it is expected that the user will be able to classify it in one of the concepts covered by the competency construct, bearing in mind the definition proposed for the concepts. Afterwards, the sentence formulating the professional attribute must be written according to the proposed BNF rule.

4. VALIDATING THE COMPETENCE GRAMMAR

Seeking to validate the rules of writing the competency related concepts, eight IST professionals of three different abilities (“Software Developer”, “Tester”, and “Data Engineer”) were asked to indicate attributes that they consider necessary in their current occupation, given the demands inherent to the environment in which they operate. The respondents had between five and seven years of experience in the IST job market, attending

to the role they currently perform; six (75%) were graduated in Information Systems (Bachelor), and two (25%) were graduated in Computer Engineering (Licensed).

Table 2. Synthesis of Collected Data

Concept	Collected	Reclassification							Correct	Repeated	Separated	Final
		Skill	Knowledge	Task	Tool	Posture	Disposition	Behavior				
Skill	62 (17%)	62	7	13	0	0	0	16	22	6	6	26 (10%)
Knowledge	51 (14%)	3	51	0	0	0	0	0	46	11	0	43 (16%)
Task	55 (15%)	1	1	53	0	0	0	1	60	7	5	66 (24%)
Tool	73 (20%)	0	0	0	73	0	0	0	64	11	0	59 (22%)
Posture	34 (9%)	0	0	0	0	34	0	0	28	12	0	18 (7%)
Disposition	35 (10%)	0	0	0	0	0	35	0	29	11	0	18 (7%)
Behavior	51 (14%)	0	0	5	0	0	0	46	53	14	0	43 (16%)

As shown in Table 2, 361 attributes were informed by eight respondents about their professional occupation. After reclassification, changes in writing, identification of duplicates, and the separation of some that added more than one attribute in just one sentence, 273 records remained. Respondents justified such changes, stating they considered behavior to be “behavioral skills”. However, the authors argued that considering the existence of the behavior concept in the proposal, the skill concept refers to the means for the application of knowledge, such as system documentation, or functionality implementation, each of which will group a set of associated tasks. At the end of the interviews, after the analysis performed, the respondents reviewed all the records and endorsed the classifications.

Considering that the study also looked at frameworks related to other areas of professional activity, the opportunity to test the rules and standards in different areas was seized. Thus, five professionals from other professional areas (Biology, Human Resource Management, Psychology, and Veterinarian) performed the procedure of filling out the forms with attributes inherent to their current professional occupations. Afterwards, a process for the collection, analysis, and validation of data similar to the one applied to IST professionals was conducted. In the end, 184 attributes were obtained, properly classified in the concepts addressed in this work.

5. CONCLUSION & FUTURE WORKS

In an attempt to standardize the approach to the notion of competency and related concepts, some challenges were faced. These challenges, for the most part, related to the perceived low rigor in the application of the concepts. Hence, in an initial phase of this study, adjustments in the definition of the concepts were made by the authors, in an attempt to clarify and support the differentiation of professional attributes among the range of concepts involved.

There is a variety of frameworks related to the theme of competency, specifically focused on IST, which organize professional attributes. This variety may be related to the pace of growth of the IST area, where a myriad of different activity sectors employs IST professionals. Since IST play an important role in all professional areas that require the use of information processing of any nature, IST professionals are required to operate in diverse environments. This gives rise to a number of IST job specificities, according to particular contexts of activity, such as health, logistics, education, government, and business. The pervasiveness of the IST profession and the need to broaden the perspective on competency, justified the analysis of general competency frameworks to find out their approach to the topic of competency, in comparison to the IST frameworks.

However, it is necessary to consider the limitations of this work. One refers to the number of participating IST professionals. Our test sample involved a small group of IST professionals, and we strongly believe that extending the process with different professionals in future works would put the grammar to a stress test, eventually revealing the need for adjustments in the rules of the grammar. A second limitation regards the type

of individuals that participated in this study, namely IST professionals. It also makes sense to involve IST recruiters and IST leaders to validate the professional attributes informed by the respondents, making this inquiry a new phase of the grammar validation process. Along the same line, the participation of IST educators and trainers would provide further indications on the validity and usefulness of the grammar. Although laborious, these are essential steps for the refinement of the competency grammar and for increasing the confidence in its practical application.

To improve and supplement the data on IST competencies, structured according to the competency construct and formulate observing the competency grammar, more work is required. Besides enhancing the characterization of the IST competencies versed in this work, there is a need to start collecting and organizing attributes pertaining to other IST competencies. After reaching a certain level of maturity in the description of an IST competency, or even in an ability, it becomes possible to move on to the next stage. This stage would involve the definition of the degree of difficulty of the ability, mapping it to the levels of proficiency proposed in this study, as well as pointing out dependencies between professional attributes. To this end, it is deemed necessary to engage professionals, both to define the degree of difficulty and to point out the dependencies. This work would provide guidance of great relevance for professionals who wish to evolve in their careers.

The generalization of this proposal is envisaged as a future endeavor. The idea is to involve researchers from different professional areas to collaborate in the data collection, analysis, and validation of the process for defining competency profiles, using the same set of rules—the competency grammar—presented in this work.

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