Abstract In this paper, a Systematic Literature Review (SLR) on Bodies of Knowledge (BOK) was carried out. Also, the theoretical base to build a model for knowledge representation was created. In addition, it was found that there is a lack of guidelines to describe knowledge representation, because of the dramatically increasing number of requirements to produce a BOK, the difficulty with comparing related BOK contents, and the fact that reusing knowledge description is a very laborious task. In short, this paper can be seeing as a first step in building a model that can be used for describing knowledge description in BOK. Finally, a comparison among BOK, structure, and evolution was conducted. The results of this comparative analysis were satisfactory, allowing to determine the elements with greatest influence in the process of describing a BOK to applied on sustainability educational context and base to improve a curriculum.

Keywords: Body of Knowledge; BOK Description; BOK Model; Curriculum; Education; Systematic Literature Review; Stakeholders

1. Introduction

According to [1], a BOK is a term used to represent the complete set of concepts, terms, and activities that make up a professional domain. It encompasses the core teaching, skills, and research in a field or industry. In addition, a BOK is necessary because it allows to develop the abilities and talents of technical engineers [2]. The goal of knowledge description is to reach a consensus on the core subsets of the knowledge characterizing engineering disciplines [3].

It is a well-known fact that developing a BOK is a complex task. It is done by considering that knowledge can be often represented as interconnected BOK knowledge areas (KAs), Knowledge Units (KUs) and Knowledge Topics (KTs) [3].

The main guide that is used for the description of the necessary knowledge of technical academic disciplines is the Software Engineering Body of Knowledge (SWEBOK V. 3.0) [3]. This guide is taken as a reference for the implementation of Software Engineering in industrial contexts [4-6], in educational contexts [7-10] and in IT governance, where the focus is on how the knowledge is being described [11].

In accordance with [12], from 2000 to 2010 knowledge was represented as a set of core knowledge, skills, and attitudes that were generally accepted and applied by investment professionals worldwide. Furthermore, in [12] it is mentioned that knowledge was often written in a specific language with rules and algorithms that are not compatible with other knowledge-based information technology (KBE-IT) frameworks [13].
In short, articulating a BOK is of paramount importance, because it is an essential step to develop an academic profession [14]. Nevertheless, a set of widely agreed guidelines on how to develop these BOKs and, more specifically, on the way to describe knowledge, are not yet available. The description of knowledge allows to understand both the context of each academic discipline and its relationship with other disciplines, structures, contents, and the necessary capabilities for describe BOK.

The above-mentioned lack of guidelines to describe knowledge may dramatically increase the required effort to produce a BOK, makes it very difficult to compare BOKs addressing closely related disciplines, and makes it even more difficult to reuse knowledge descriptions when necessary.

In order to find a solution to this problem, this paper presents an SLR on different ways in which knowledge can be described, and how it should be structured. As part of the study carried out in this paper, the relevance and usefulness of this novel BOK approach for different communities of stakeholders are also analyzed.

The outline of this paper is as follows: Section 2 is aimed at carrying out the analysis of related research works; Section 3 is devoted to describe the research methodology used in this paper; Section 4 shows the result and discussion; and the conclusions are given in the Section 5.

2. Related works

In the scientific literature, there is a great number of researches works on knowledge description for BOK. For example, in [15] a BOK is built upon published research, [16] describes a BOK that has been modelled for software development, [17] shows representation and scientific reasoning used for the description of knowledge, [18] shows different elements needed to describe a given knowledge in engineering, and [19-21] show the usage of skills, attitudes, abilities, and capabilities to describe knowledge for BOK.

In addition, a conceptual model to describe knowledge is discussed in [22], and a framework for structured knowledge is shown in [23]. The framework created in [23] is aimed at facilitating the design of an adaptive knowledge management system, and the structural knowledge model is combined with processes that are used for ensuring the quality of knowledge acquisition in the framework. Moreover, in [23-24], two kinds of spaces (i.e., knowledge and process spaces) and a knowledge state model are introduced.

Furthermore, [25] carried out the analysis of references for SEBOK, and [6-7], [18], [26]-[27] show an application of two more detailed guidelines structures (i.e., SWEBOK and SE2004) and a taxonomy that is applied in Software Engineering, in order to examine recommendations and suggest an appropriate subset of topic areas for a software engineering service course.

In [28-29], a technical review on software development knowledge area is aligned with an engineering perspective to assess a version of the SWEBOK guide, and [30-32] show how stakeholders use knowledge to describe BOK. These studies symbolize a significant contribution to the Requirements of Engineering Body of Knowledge, and [34] presents solutions in the form of a mobile application that improves performance reporting for the Project Management Bodies of Knowledge (PMBOK) framework.

In [35], within the context of natural resources management, stakeholders use BOK to manage the production and application of knowledge in social settings. Also, in [36-38], stakeholders use BOK to develop academic programs where parameters can be synthetized to describe knowledge. Finally, BOKs such as the ones presented in [39], [40], [41], [42], [43], [44], [45], [46], [47], [48], [49], [50], show further structures and guidelines to describe knowledge.

3. Methodology

In this paper, the Systematic Literature Review (SLR) method was used as the research methodology. In [51], SLR was proposed in Software Engineering Research as a method to report reliable conclusions about a research area while systematically collecting quality evidences in knowledge description for BOK.
3.1. Phases of an SLR

In this paper, review of the state of the art of BOK was carried out by following the guidelines proposed in [52], where three main phases of an SLR were suggested. These phases are the following (see Figure 1):

- **Planning the review.** This phase is aimed at developing the review protocol, which defines the methods to undertake a specific SLR, reducing the possibility of it being driven by research expectations. A detailed explanation of this phase is given in Section 3.1.1.
- **Conducting the review.** This phase is aimed at executing the previous protocol. A detailed explanation of this phase is given in Section 3.1.2.
- **Reporting the review.** This phase is aimed at providing the obtained results for the community. A detailed explanation of this phase is given in Section 3.1.3

**Figure. 1. Phases of the SLR method proposed in [60]**

Planning the review. -This phase is aimed at developing the review protocol, which defines the methods to undertake a specific SLR, reducing the possibility of it being driven by research expectations. A detailed explanation of this phase is given in Section 3.1.1.

Conducting the review. - This phase is aimed at executing the previous protocol. A detailed explanation of this phase is given in Section 3.1.2.

Reporting the review. - This phase is aimed at providing the obtained results for the community. A detailed explanation of this phase is given in Section 3.1.3

3.1.1 Planning the review

In this phase, the steps that were followed to implement the protocol were established. Also, the objectives were reviewed, and the necessary research works to describe BOK were searched for. Then, the following learned lessons were identified: needs, problems, and challenges to determine the elements, structure, and context of an BOK. Next, taking into consideration the above information, the Research Question (RQ) were the following: RQ1: What are the necessary elements needed to describe knowledge in BOK on educational context? [14]

The search strategy for planning the review was, first, to identify the most relevant data bases in order to determine the primary studies (PS). These most relevant data bases are shown in Table 1.

Second, once the previously-mentioned data bases were identified, the searching chains were formed to determine the PS. Third, the relevant documents for answering the RQ were identified, and the criteria for the inclusion and exclusion documents of BOK were established. Finally, a way for extracting these documents was searched for. An automatic search was realized in the scientific electronic databases and validated by SLR protocol [83].
Table 1 Scientific Data bases

<table>
<thead>
<tr>
<th>Database</th>
<th>Retrieved</th>
</tr>
</thead>
<tbody>
<tr>
<td>IEEE Xplore Digital Library</td>
<td>87</td>
</tr>
<tr>
<td>ACM Digital Library</td>
<td>24</td>
</tr>
<tr>
<td>Springer</td>
<td>20</td>
</tr>
<tr>
<td>Web of Science</td>
<td>24</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>155</strong></td>
</tr>
</tbody>
</table>

3.1.2 Conducting the review

Once it was clear what was going to be done in the planning phase, the search for PS was carried out at each database, in order to answer the RQ. To conduct the search for PS, the following key words were used: a) Body of Knowledge, b) Area Breakdown, c) Component, d) Guide, e) Engineer, f) Software, g) Structure, and h) Software Engineering Body of Knowledge. Also, alternative spellings and acronyms for major terms were used, such as: Information Technology BOK, SWEBOK.

After that, the general search string was formed. This string was the following: ("BOK" OR "Body of Knowledge") AND ("SE" OR "Software Engineering") AND ("Area Breakdown" OR "software engineering body of knowledge" OR "importance of SWEBOK." OR "Component", "OR" Design)) [14]. Moreover, other 27 documents were retrieved from different resources. Then, the total PS and relevant documents increased to 182. Table 2 shows the PS by type.

Table 2 Primary Studies and relevant information in BOK context

<table>
<thead>
<tr>
<th>Type</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Journal</td>
<td>42</td>
</tr>
<tr>
<td>Conference Publications</td>
<td>101</td>
</tr>
<tr>
<td>Report</td>
<td>3</td>
</tr>
<tr>
<td>Web Pages</td>
<td>1</td>
</tr>
<tr>
<td>Special Publications</td>
<td>2</td>
</tr>
<tr>
<td>Documents</td>
<td>2</td>
</tr>
<tr>
<td>Book Chapter</td>
<td>18</td>
</tr>
<tr>
<td>BOKs</td>
<td>8</td>
</tr>
<tr>
<td>Guides</td>
<td>5</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>182</strong></td>
</tr>
</tbody>
</table>
Furthermore, the research work presented in this paper considered the inclusion and exclusion criteria to identify those PS that provided direct evidence to answer the RQ. Additionally, in order to reduce the likelihood of bias, the selection criteria were decided during the protocol definition. Here, the selection of PS was a multi-stage process. Initially, the selection criteria were openly interpreted. Next, these criteria were refined to avoid duplication of information.

SLR require explicit inclusion some exclusion criteria to assess the fitness of the information in each PS to respond the RQ [53].

Inclusion criteria (IC): Scientific materials (i.e., papers, experience reports, summaries of workshops, etc…) written in English and digitally accessible were included. Here, it was also necessary to consider studies framed in contexts of other disciplines but related with the concept of BOK, workshops, and IEEE and ACM meetings [82].

Exclusion criteria (EC): Documents in computer science but not related to Bodies of Knowledge. Documents related to Bodies of Knowledge but not related to the research questions of this study.

Remove false positives. That is, removing documents that were not part of the research in the search string were discarded.

Papers in the form of abstracts, tutorials or talks that did not provide enough detail for the systematic literature review were excluded.

Poor arguments. That is, studies with low relevance according to the research were excluded.

Reduction ad absurdum that is, those studies that did not fulfil the Inclusion Criteria were excluded.

Then, as continuation of the PS selection process, inclusion and exclusion criteria on practical issues were applied.

Examples of these criteria were: language, journal, authors, participants or subjects, research design, sampling method, and date of publication [54].

The criteria to assess the papers for this study are shown in Figure 2.

![Figure 2. Criterias to evaluate PS](image)

In order to interpret the findings in PS, the importance of the scientific quality of the papers under study was determined. The above inclusion and exclusion criteria indicated the credibility of the analyzed PS and identified potential limitations of the current search [55], [56]. The quality criteria were based on what is said in [57], [58]. These criteria were the following: rigor, credibility, and relevance.
Finally, as part of this SLR phase (i.e., Conducting the review) the data extraction strategy allowed to identify the required information to answer the RQ.

3.1.3 Reporting the review

This SLR phase consisted of the following steps:

First, the paper information was extracted. Here, Electronic Sheets, Mendeley, and Atlas TI 8.0 [80], as software tools, were used.

Second, the obtained information was synthesized to understand the BOK context (see Figure 3).

Third, the data extraction forms were developed (see Figure 4).

The synthesis process consisted of organizing the key concepts to enable comparisons across studies and the reciprocal translation of findings into higher-order interpretations.

At this point, it is important to mention that the synthesis strategies are important not only because they include multiple publications of the same data in an SLR, but also because they prevent duplicated reports that could bias the study results. To confirm whether reports refer to the same
study or not, authors may be contacted. In Section IV, the most relevant information to support this research is included. Fig. 5 shows the SLR synthesis process.

Figure 5 SLR synthesis process

Figure 6 shows the process to establish the Knowledge Description for Bodies of Knowledge, and Table 3 shows the elements to describe BOK. The reporting the review phase was supported by the quality analysis that was performed for each primary study. The validity of the elements needed to describe BOK is presented in Table 3 and Table 4.

Figure 6. Process to obtain the knowledge description for BOK

<table>
<thead>
<tr>
<th>Body of Knowledge Name</th>
<th>Structure</th>
<th>Evolution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B1</td>
<td>Body of knowledge for medical practice management [39].</td>
<td>The Structure of the BOK has been outlined to identify the various knowledge, and skills required by today’s medical practice executive. Competencies are woven among eight distinct knowledge areas or domains. Within each domain are tasks or statements detailing the responsibilities that comprise that knowledge area. Tasks are further delineated as specific skill statements [39], [59].</td>
</tr>
<tr>
<td>B2</td>
<td>Usability Body of Knowledge (Bloomingdale) [40]</td>
<td>The Usability BOK is constructed around “Topics” – each page on the site is a stand-alone topic, with relationships to other topics [60].</td>
</tr>
<tr>
<td>B3</td>
<td>The Personal Software Process (PSP) Body of Knowledge [41]</td>
<td>The Body of Knowledge is organized in an architectural hierarchy in which the concepts and skills of the PSP are described and decomposed into three levels of abstraction. [41].</td>
</tr>
<tr>
<td>B4</td>
<td>SCAMPI Lead Appraiser Body of Knowledge (SLA BOK) [42].</td>
<td>The SLA BOK is organized by competency clusters and knowledge areas. Individual competencies (CMP) include skills, related competencies, examples and high maturity skills [42].</td>
</tr>
<tr>
<td>B5</td>
<td>The Guide to the Software Engineering of Knowledge (SWEBOK) [43], [61]</td>
<td>The KAs’ descriptions are structured as follows: Introduction. Breakdown of topics in each KA constitutes the core of the KA description, decomposing the KA into subareas, topics, and subtopics. The reference material is chosen because it is considered to constitute the best presentation of the knowledge relative to the topic. A Matrix links the topics to the reference material. References [61].</td>
</tr>
<tr>
<td>B6</td>
<td>A Guide to the Project Management Body of Knowledge [44].</td>
<td>Hierarchical structure using different levels of topics.</td>
</tr>
</tbody>
</table>
Table 4: Elements of BOK

<table>
<thead>
<tr>
<th>Element</th>
<th>Association</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>B8: WEBOK [49].</td>
<td>Hierarchical structure using different levels of topics [29].</td>
<td>Unique version [49].</td>
</tr>
<tr>
<td>B9: IT Body of Knowledge [46].</td>
<td>The IT BOK is structured as a hierarchy, with knowledge areas at the highest level. It breaks down each knowledge area into units, which then further divide into topics. The top level consists of the 13 knowledge areas [46].</td>
<td>Unique version [46].</td>
</tr>
<tr>
<td>B10: SEBOK [47].</td>
<td>The SEBOK is divided into seven parts, the first six of which focus on domain-independent knowledge, and the seventh part devoted to implementation examples [47].</td>
<td>SEBOK has versions 1.0 to 1.4 with very small changes in between. [47].</td>
</tr>
<tr>
<td>B11. BKCASE [50].</td>
<td>The BKCASE project is of courses structured similarly as the SEBOK itself [50].</td>
<td>BKCASE has three versions [50].</td>
</tr>
</tbody>
</table>
• C2.2.1.3.1.2 Knowledge Subtopic

C3. Knowledge Representation

• C3.1 Concepts
• C3.2 Supporting Tools
• C3.3 Ontology
• C3.3.1 Models
• C3.3.2 Vocabulary
• C3.4. Skills
• C3.4.1.1 Instructional Skills
• C3.4.1.1.1 Types of Skills
• C3.4.1.1.1.1 Technical
• C3.4.1.1.1.2 Pedagogical
• C3.4.1.2 Capacities
• C3.4.1.3 Capabilities

An essential part of Knowledge. An ability and capacity acquired through deliberate, systematic, and sustained effort to smoothly and adaptively carry out complex activities or job functions involving skills.

C4. Knowledge Management

• C4.1. BOK Areas
• C4.2. BOK Details

Structure of BOKs, where topics are thoroughly detailed (in subtopics).

C5. Knowledge Acquisition

• C5.1 Types of Standards
• C5.2 Application of Standards

Ways to acquire Knowledge.

C6. Evolution of BOKs

• C6.1 Consensus
• C6.2 BOK Objective
• C6.2.1 Scope of BOK
• C6.3 Type of BOK
• C6.4 Knowledge Acquisition
• C6.4.1 Lessons Learned
• C6.4.2 Material

Any process of formation, growth or development in the BOK context.

C7. Knowledge Resources

• C7.1 Guides
• C7.2 Communities
• C7.3 Standards

Resources about the BOK.

C8. Knowledge Education

• C8.1 Education
• C8.1.1 Profile
• C8.1.2 Guidelines for Profiles
• C8.1.3 Educational Institution
• C8.1.4 Educational Training
• C8.1.4.1 University Curricula
• C8.1.4.1.1 Curriculum
• C8.1.4.1.1.1 Curriculum Process
• C8.1.4.1.1.2 Curriculum Develop
• C8.1.4.1.1.3 Curriculum Resources
• C8.1.4.1.1.4 Curriculum Architecture
• C8.1.4.1.1.5 Code of Ethics
• C8.1.4.2 BOK Accreditation
• C8.1.5 Professional Certification

A set of characteristics that identify a knowledge within the educational context.
Figure 7. This validity is seen as the relevance of the BOK in different KA. Moreover, to develop the quality analysis, Atlas TI was set to use 8 codecs and 78 subcodecs, which were established based on the density and importance of each concept, and their relationship with the family of concepts.

Figure 7. Initial Codes of BOK

Figure 8 shows this initial network of concepts for knowledge description in the BOK context.
In the network shown in Figure 9 the relation of each concept is presented. Also, the codes, quotation, and neighbours of one PS are shown in Figure 9. In Figure 9, codes are represented by squares, quotations are represented by small boxes, and the relationships are lines between elements.

Aligned with [78], the next step to building the knowledge model was to use the thematic synthesis to represent the BOK representation problem. In order to obtain the concept networks, the iterative cycle was designed. Then, the concept networks were grouped into categories. After that, for each category, iterations were created, and representations schemes were created as well. Next, a narrative synthesis was made to establish the relationship among concepts. Finally, the description model for BOK was created.
This section is devoted to show the main results and discussion of the research work on the context, elements, and structure of BOK that allowed to establish a correct representation of knowledge.

First, BOK is used by those who are interested in expanding their skills and professional training in different areas of knowledge. For the scientific community, BOK allow to widen the spectrum of research fields based on consensus and highlight similarities between disciplines. For example, BOK highlight techniques used in materials science that are common between chemistry and physics [63][70]. Regarding the knowledge levels of a BOK, the amount of knowledge that will be offered within an educational program is defined [82]. BOK have a specific structure according to the area of engineering or science in which they are applied.

Second, according to [36], [64], to establish the description of the BOK, it is necessary to consider the core book (CB) and context-domain (CD) of the BOK study area. In the same way, BOK must establish their respective KAs. Each description of KAs should use the following structure: Acronyms, Introduction, Breakdown of topics, Matrix of themes vs. Reference material, List of additional readings, and References [36], [64].

Also, as part of this second finding, it can be said that each knowledge area is divided into smaller divisions called Knowledge Units (KU) [33], [36], [64], which represent individual thematic modules within a knowledge area. Each KU is subdivided into a set of topics, which are the lowest level of the hierarchy. The themes depend on the evolution and context of the KAs and the discipline [36].

Third, in the BOK context, it is also necessary to standardize a knowledge updating process according to how advanced the discipline is and the existing needs of the communities. In general, BOK have different committees, organizations, and collaborative groups that develop and update their contexts considering the progress of science and its areas of knowledge.

Fourth, in order to formulate BOK with a bottom-up approach (Knowledge Sweep), researchers must take into account the ‘materials’ from which the knowledge is extracted by the discipline-directed. When analyzing these materials, it is assumed that a certain degree of knowledge could be obtained and used to formulate a BOK. The reference materials will be the scientifically agreed information [2-3], [9-10], and the matrix of topics is divided into details in order to establish its relationship with the respective materials [2].

Moreover, a list of readings should be considered to complement the information of the proposed KAs. In the same context, when we develop BOK knowledge, it is necessary to establish the origin of the information.

Fifth, it was found that there exist structures, elements, descriptions, and learned lessons of the BOK evolution. In order to show the evolution of BOK this paper provides a learned lesson synthesized in Table 3.

Sixth, another finding of this paper is the establishment of a general structure of a BOK in engineering. This structure begins with the set of KAs, continues with units, and ends with topics according to the research area. The elements that are necessary to describe BOK knowledge were shown in Fig. 7.

Seventh, BOK provide the foundation for curriculum development and maintenance, in addition to supporting professional development and current and future certification systems. BOK promote integrations and connections with other related disciplines.
Eighth, at the level of professional education in engineering contexts BOK, should provide the following detail levels [68]:

1. To know the basic concepts and the main areas of application.
2. To know the basic technologies and their relationship with basic concepts. Beyond this, professionals need additional dimensions of awareness and critical thinking.
3. To know both authorized and unauthorized sources of information, and how to evaluate the quality of the information.
4. To have the ability to work with standards.
5. To have the ability to critically evaluate and filter information.

Furthermore, as part of this finding, educational programs in engineering and engineering technology have been developed to address many aspects associated with computer science [69]. For example, the BOK of Computer Science Technology, the SWEBOK, and the IT BOK are based on inputs provided from various perspectives, including industry demand, previous works in the creation of computer BOKs and institutional factors. In the same context, ASCE BOK [74] highlights the need for engineers to understand the impact of their solutions with respect to society, culture, and industry. A BOK is normally used for certification, education, and training [71-72], [84]. Knowledge should reflect current best practices, which inevitably change over time. However, updates cannot be carried out in an uncontrolled manner, since associated conferences and other educational materials must be kept in line with the BOK [36].

Finally, other important factors to consider in BOK are the Stakeholders [9], which are people, groups, companies, and either organizational or gubernamental entities that have an interest in educational programs. All interested parties must be identified as well as their responsibilities towards educational programs based on BOK. RapSEEM suggests defining responsibilities for four groups [73] (Figure 10).

Figure 10. RaPSEEM groups for BOK
4. Conclusions

One result of this paper showed the criteria to develop the general structure and contents of the BOK in the field of engineering. The proposal of the way of how to elaborate a BOK permitted to understand the real context of the Knowledge Areas. BOK provides the basis for curriculum development and professional development and current and future certification schemas. Lastly, it promotes integration and connections with related disciplines.

In this paper, an SLR was carried out to determine the structure, elements, and learned lessons to describe knowledge for BOK. Here, it was established the general structure to develop a model to describe BOK, and the relationship between BOK and other scientific disciplines was established, as well.

The knowledge description for BOK presented in this paper defined a set of knowledge, skills, concepts, and behaviour that stakeholders and the related disciplines need for the correct consensus. Also, this knowledge description for BOK allowed to have a validated classification of the boundaries of the disciplines that will support BOK. The BOKs described in this paper showed the hierarchical structure of the content of each knowledge area.

As a result of this research, a BOK generally uses a tree structure to represent knowledge that provide the classification and detailed explanation of each knowledge area. In addition, each knowledge area presents the relationship between BOK and scientific disciplines, which allows to add new structure, concepts, and learned lessons to improve the perspective and projection of the BOK in the industry and science.

Another result of this research is that the definition of Knowledge Description Model for BOK help to determine the training needs of future professionals, allowing them to acquire strong competences in social, business, educational, and industrial fields.

One more result of this paper was that it was found that the Knowledge Description of BOK can be used as a guide to assess and improve disciplines or scientific areas.

Another additional result of this research, is that learned lessons can be generalized to comparable courses that are taught at many academic institutions. Furthermore, it can be said that BOK provide the basis for curriculum development and maintenance and support professional development as a continuous improvement of BOK certification.

Finally, in this paper a general structure of a BOK for engineering was established. This structure consisted of sets of KAs that contain KU, KTs, and KSs.
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