Towards Competency Model in IS Education

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Abstract

First Information Systems (IS) curricula for undergraduate and graduate education were based on knowledge. As now the industry expects more from graduates, there is a need for a transformation from knowledge-based learning to competency-based. The paper discusses the evolution of the competency approach in IS education and notices important aspects that could guide creating new or updating the existing IS programs.

Keywords

Competency model, IS curricula, computing curricula, IS2020, MSIS 2016, CC 2020

1. Introduction

Recent advances in the ICT area increase the role of the IT competencies of professionals in the industry. The fast growth of business digitalization and the need for adequate reaction to this process raises new obstacles to IT professional competencies, which significance is growing. Information Systems (IS) competencies also are recognized as important for increasing the business advantages of organizations. Today, the personal competencies of the employees such as communication and collaboration, critical thinking, creativity, problem-solving ability, and others become as much important as their knowledge, skills of programming, or different technical skills.

To address these challenges, companies and organizations need to adopt the new skill-based approach instead of the traditional job-based in order to be more flexible and prepared for future business needs and to increase the motivation for learning [1], [14]. This also will allow the employees to contribute to the organization's core competencies and corporate advantages with their individual skills to learn, communicate and be more effective in their performance in a job [6].

Information Systems & Grid Technologies: Fifteenth International Conference ISGT'2022, May 27–28, 2022, Sofia, Bulgaria
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This has led university graduate and undergraduate programs to recognize the importance of professional competencies and to find a way to embed them into education at all levels. We can see the reflection of these expectations in the modifications in several new computing curricula guidelines. Instead of providing a set of curriculum recommendations based on a predefined list of courses, MSIS 2016 introduces competencies that students need to obtain during their education in a large number of graduate programs in the Information systems area [13]. The new curricula report IT 2017 and CC 2020 also adopt the competency-based approach for education in computing [10], [3]. These efforts are in line with the industry's efforts to assess employees' skills and make the right selection for the specific type of jobs, as can be seen from the role of the established competence frameworks like the Skills Framework for the Information Age (SFIA) and the European e-Competence Framework (e-CF) [15], [5].

The paper presents several competence frameworks and curricula guidelines (mostly in the IS area) that follow the competency-based approach. The study discusses competency models, that are currently used, as well as the sets of important competencies, outlined in the discussed frameworks and curricula. Some observations and conclusions are summarized, which could be useful for educators to prepare a curriculum for their university IS program, that also meets the expectations of the industry.

2. Competencies in computing curricula and industry frameworks

During the last several decades, the computer and engineering societies Association for Computing Machinery (ACM), the Institute of Electrical and Electronics Engineers (IEEE), and the Association for Information Systems (AIS) have constantly worked on computing curricula. Many working groups in connection with established IT bodies and professionals have been formed. Computer Science, Software Engineering, Information Systems, Information Technology, and Computer Engineering were the first five sub-disciplines, addressed in the produced curricula recommendations. Last, Cybersecurity and Data Science curricula recommendations were announced [3]. Periodically, new curricula were announced for graduate and undergraduate programs.

Traditionally, curricula are created based on the course-based approach, presenting sets of courses, their topics, learning outcomes, etc. The first curricula guidelines focused on disciplines, their content and consistency, and different relations and lenses were discussed. In addition, recourses and examples of best practices were included. The provided information helps universities to adopt these recommendations to the specific needs of their programs. The latest document, "CC2020 Computing Curricula 2020: Paradigms for Global Computing

Education", on the other hand, makes the transition from knowledge-based learning to competency-based learning [3]. The target of this report is the undergraduate programs in all seven mentioned above sub-disciplines.

We can also consider MSIS 2016 and IT 2017 curriculum recommendations, where the competency approach is firstly introduced in computing curricula, before its broad adoption in CC2020. All curricula agree – knowledge, skills, and dispositions must be connected to the competencies.

Knowledge is considered with the understanding of content, concepts, theories, etc. Skills, on the other hand, are connected with the capabilities that are developed during the practice. And finally, disposition comprises social behavior and attitude which motivate the engagement in task execution.

The transition to a competency-based approach in education in informatics and related fields can be seen in the industry, too.

Professional organizations in the IT area also are interested in the technical competencies and skills of individuals and how they can be assessed. Several industry-based frameworks were adopted from organizations in many countries in Europe and around the world.

The Skills Framework for the Information Age (SFIA) is used for more than 30 years by ICT practitioners to provide clear guidelines for their competence progress [15]. The framework is available in different languages – English, German, Japanese, Arabic, etc., and is now used by two hundred organizations.

The framework addresses the need of organizations to seek Professional Skills, Behaviors, Knowledge, Qualifications, and Certifications for their employees. On the other hand, every employee obtains specific skills. To measure them, SFIA defines seven Generic "Levels of Responsibility" (from 1 to 7) that specify IT professional competencies and about a hundred IT skills definitions (Specific Skill Level Definitions) which try to cover the broad set of IT professional roles. An IT professional role (or job) usually combines several skills at similar levels. The specific skills are defined at each of the same seven levels of responsibility – Follow, Assist, Apply, Enable, Ensure/advise, Initiate/influence, Set strategy/inspire/mobilize. In this way, the framework can measure the progress of a practitioner from his entry-level position (Follow) to the highest level (Set strategy/inspire/mobilize) where he takes the responsibility for significant organizational decisions, including policy making. The levels of responsibility are described in terms of *Autonomy*, *Influence*, *Complexity* and *Business Skills* [15]. An IT professional role (or job) usually combines several skills at similar levels.

The European e-Competence Framework (e-CF) applies the term "competence" defined as "a demonstrated ability to apply knowledge, skills, and attitudes to achieving observable results" [5]. The European ICT workplace determines 40 competences that are based on stakeholders' input.

The framework is structured into four dimensions:

- *Dimension 1* proposes five e-Competence areas – *Plan, Build, Run, Enable*, and *Manage* that follow the classical IT lifecycle view;
- *Dimension 2* gives a general description of the competences;
- *Dimension 3* describes five e-CF proficiency levels (from 1 to 5) for each competence.

To add value and context, *Dimension 4* presents knowledge and skills examples, which are related to the described in Dimensions 2 competencies.

Considering the large number of discussed complex topics, it is not expected for graduates to cover all these competencies. The framework could be used for undergraduate computing programs such as computer science and software engineering [7]. For these programs, the list of competencies from the *Build* area will be particularly useful.

3. IS curricula recommendations and the competency models

In this section, we'll emphasize some specific changes in the latest IS curricula guidelines and how they relate to competency-based education.

The first Information systems curriculum is the curriculum recommendation for a master's degree in Information systems, presented in 1972 by ACM. It focuses mostly on courses and programs in six categories – people, models, systems, computers, organizations, and society. Ten years later new recommendations for both undergraduate and graduate IS programs were announced. In 2000, ACM and AIS started a joint project, which resulted in MSIS 2000. It introduced three basic categories of individual skills: „ communication, interpersonal, and team skills; analytical and critical thinking skills; and career development skills" (MCIS 2000) and for the first time in university education introduces career tracks in IS area. MSIS 2006 made some reconfigurations on the set of courses. The most recent MSIS 2016 addressed much more issues.

3.1. MSIS 2016 global competency model

Following the definition given in [11]: "Competencies represent a dynamic combination of cognitive and meta-cognitive skills, demonstration of knowledge and understanding, interpersonal, intellectual and practical skills, and ethical values", MSIS 2016 is the first IS curriculum that introduces a competency model instead of upgrading the list of courses, needed for the education of IS master students.

MSIS 2016 structure is based not on traditional *knowledge area/ knowledge unit/ topic* hierarchy. Instead – *competency area/ competency category/ competency* categorization is introduced. The report classifies core competencies, that should be developed, into three realms:

- Information Systems Competencies;
- Individual Foundational Competencies;
- Domain Competencies.

Nine *competency areas* are defined at the highest level of categorization for the IS competencies. These areas are specific to IS education. They are presented with a name, a short description of the area, and several (3 to 5) high-level dimensions, also briefly discussed [13]:

1. Competencies in the area of Business Continuity and Information Assurance (BCIA)
2. Competencies in the area of Data, Information, and Content Management (DATA)
3. Competencies in the area of Enterprise Architecture (EARC)
4. Competencies in the area of Ethics, Impacts and Sustainability (ETIS)
5. Competencies in the area of Innovation, Organizational Change, and Entrepreneurship (IOCE)
6. Competencies in the area of IS Management and Operations (ISMO)
7. Competencies in the area of IS Strategy and Governance (ISSG)
8. Competencies in the area of IT Infrastructure (INFR)
9. Competencies in the area of Systems Development and Deployment (SDAD).

Individual foundational competencies and domain competencies are more general and are used in other programs, too. Several essential areas of individual competencies are noticed in the report – Critical Thinking, Creativity, Collaboration and Teamwork, Ethical Analysis, Intercultural Competency, Leadership, Mathematical and Statistical Competencies, Negotiation, Oral Communication, Problem Solving, and Written Communication.

Not specific competencies are noticed for domains of human activities such as government, business, law, and healthcare, but IS curricula always underline the role of the domain of practice in order to be delivered software solutions of high quality [8]. This report presents two examples – for business and healthcare domains.

Further, lists of competency categories for each competency area in the IS realm are specified. Each category specifies the actual competencies. Both categories and competencies are specified with their names and a short description.

It is not expected for all IS graduate programs to prepare their students at the same level – there could be variations for the different profiles. To measure different degrees, four levels for the attainment of competency category are defined – from *Awareness*, where the graduates know this competency exists, through *Novice* and *Supporting (role),* to *Independent (contributor) level*, where the graduates have obtained knowledge and skills that allow them to could produce the needed results without continuous supervision.

3.2. Computing Curricula 2020 (CC 2020) and competency-based computing education

The Computing curricula report CC2005 introduced consolidated guidelines for the five existed in 2005 undergraduate computing programs – computer engineering, computer science, information systems, information technology, and software engineering [2]. During the next 15 years, many changes were made in the graduate and undergraduate curricula guidelines that reflected the changes in the five computing areas. Meanwhile, new programs like cybersecurity and data science were developed. The next report – CC2020 covers all seven mentioned above undergraduate programs in order to provide a useful pathway during the next 10 years – until 2030 [4]. The most important change from the previous edition is the transition "from knowledge-based learning to competency-based learning" [3].

CC2020 identifies *competency* as a composition of knowledge, skills, and dispositions, observed through a task accomplishment (Figure 1).

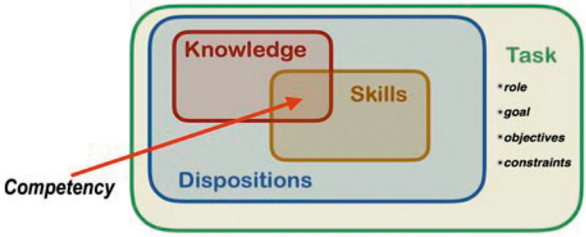

Figure 1: Conceptual structure of the CC2020 competency model. Source: CC2020 [3]

The report complements Knowledge-Skill-Disposition (K-S-D) framework, introduced in [10]. In addition to the knowledge component, which concerns the concepts essential to the discipline of study, the skills are connected to the ability to apply the knowledge to accomplish the task. On the other side, the disposition component refers to how skills and knowledge are used by an individual doing the right activities in a particular context. This concern his attitude, behavior, and social skills.

Further, the reports suggest elements of these three categories:

- *Computing Disciplinary knowledge* – Users and Organizations, Systems Modeling, Systems Architecture and Infrastructure, Software Development, Software Fundamentals, Hardware;
- *Foundational and Professional Knowledge* – Analytical and Critical Thinking, Collaboration and Teamwork, Ethical and Intercultural Perspectives, Mathematics and Statistics, Multi-Task Prioritization and Manage-

ment, Oral Communication and Presentation, Problem Solving and Trouble Shooting, Project and Task Organization and Planning, Quality Assurance/ Control, Relationship Management, Research and Self-Starter/Learner, Time Management, Written Communication;

- Application Domain Knowledge – the most common to computing are engineering, business, medicine, etc.

To evaluate skills, CC2020 applies a six levels scale that correlates with Bloom's taxonomy: B-I Remembering, B-II Understanding, B-III Applying, B-IV Analyzing, B-V Evaluating, and B-VI Creating [12]. Each level is associated with a set of verbs, that suggest appropriate actions or possible practices.

The disposition refers to socio-emotional skills, behavior, and attitudes that determine the attitude to perform tasks and commitment to these tasks. As an essential third dimension of the competency model, dispositions are closely related both to professional and learning activities. The outlined prospective elements of dispositions such as *adaptable, collaborative, intentive*, *meticulous, passionate, proactive, professional, purpose driven, responsible, responsive,* and self-*directed* should be demonstrated in the behavior of graduates in the computing area [3].

The report proposes a number of examples of draft competency statements. They are presented in a template that includes at least a brief competency description, knowledge elements, skill levels, and dispositions.

The report also recommends lists of draft competencies for computer engineering, computer science, information systems, and software engineering completed.

3.3. IS 2020

The IS2020 is the latest curriculum that provides guidelines for IS undergraduate programs. This report still relies on the core requirements, defined in the previous curricula recommendations. In addition to the concepts of knowledge areas, knowledge units, and learning objectives, it adopted the competency approach, too. Moreover, the model integrates both the traditional view based on program, courses, and their learning outcomes with the competency hierarchy: "competency realms, areas, competency knowledge-skill pairs, and dispositions"[9].

The IS2020 understanding of competency is consistent with the one, discussed in MSIS2016 and CC2020: "A competency is the graduate's ability to apply knowledge, skills, and dispositions (called attitudes in MSIS2016 and dispositions in CC2020) to effectively complete tasks"[9].

For the IS 2020 competency's description, (K-S-D) structure – Knowledge, Skill, Disposition and their association with the task is accepted from CC2020 and also MSIS 2016 hierarchical structure. The high-level competency realms are still IS competencies, individual foundational competencies, and domain compe-

tencies as the previous curricula IS2010 and MSIS2016 emphasized the important role of the last two groups.

The immediate IS competencies are organized into six broad competency realms. Nineteen competency areas are established – ten mandatory and nine – elective (see Table 1). Two of the presented IS competency realms do not recommend elective courses, the other list several options for these courses. We can see the continuity from the previous IS2010 curriculum, almost all courses are now transformed into competency areas.

The Foundations competency realm represents information systems "as a whole" [9]. The Data/Information management competency realm concerns data processing in organizations and tools and techniques that support this processing at different levels. It is mostly oriented to building and using databases. On the other side, the Development realm is oriented to the application lifecycle, focusing on analysis and design and application development and programming. It is complemented by several optional competency areas, which present the newest paradigm in application development. The Technology realm covers different aspects of IT infrastructure – assets, architecture, and applications. The Organizational realm directs to issues connected to the strategic management of information technologies in organizations, including ethical and societal issues. As digitalization in the last years has had a big impact on the business and society, a Digital Innovation optional competency area is considered here in addition to the traditional Business process management competency area. At the end of the education, the Integration realm combines knowledge and skills acquired by the student in the program in a practical application – a project, where students usually work as a team and apply the paradigm studied.

To merge the concepts of the course-based model and competency-based model, a two-level curriculum architecture is proposed to provide accordance between competency and learning outcomes, courses and competency areas, and program learning outcome and competency realm [9].

Table 1
IS competency realms

Competency realm	Required Competency Area	Optional Competency Area
Foundations	Information Systems Foundation	
Data	Data and Information Management	Data and Business Analytics
		Data and Information Visualization
Technology	IT Infrastructure	Emerging Technologies
	Secure Computing	
Development	System Analysis and Design	Object-Oriented Paradigm
	Application Development/ Programming	Web Programming
		Mobile Programming
		User Interface Design
Organizational Domain	Ethics, use and implication for society	Digital Innovations
	IS Management & Strategy	Business Process Management
Integration	IS Project management	
	IS Practicum	

4. Findings and discussion

The review of different initiatives and documents from the previous sections reveals the competency-based approach is broadly accessed. Although some variety in competency definitions and competency modeling has been noted, the efforts are focused on building competency models as a collection of knowledge, skills, abilities, and other characteristics instead of describing different job positions. The research and observations made can be summarized in several directions as it is noted below.

4.1. Implementing a competency-based approach for building IS curricula

Although the competency is not a new idea focusing on competencies in IS programs requires reorganization of program development and teaching processes.

Competency-based approach is not used only for education in the Information Systems area

Different computing curricula use the competency-based approach. Thanks to the effort of ACM, IEEE, and AIS workforce the last computing curricula apply

a united approach to the competency-based education in computer engineering, computer science, cybersecurity, information systems, information technology, software engineering, and data science. As CC2020 concerns only undergraduate programs, MSIS 2016 is not only the first curriculum, using competency modeling, but is still the only one for graduate degree programs.

Competency areas and sets

Different competency levels and hierarchies of competencies are presented in curricula recommendations for different undergraduate programs. The competency realms can differ also for graduate and undergraduate levels. In this case, continuity in education should be considered, as well as the profile of the IS programs.

IS undergraduate and graduate programs

There is good coherence between the areas of competencies in the recommendations of MSIS 2016 and IS2020. The competency areas required as a prerequisite for graduate level – foundational understanding of information systems, data management, system development, and IT infrastructure are covered through the competency realms of IS 2020.

Undergraduate programs are mostly focused on software development and we see the reflection of this topic in the Application Development and Programming competency realms in IS 2020. The design of the master IS programs can focus more on different career tracks or professional profiles, as it is discussed in MS 2016.

4.2. Educational context

Focus on the students

Competency-based approach is more concentrated on the needs of students to learn instead of educators' needs of teaching. In addition, it allows more effective communication between graduates and other stakeholders about the expectations from the learning process.

The requirements for teachers are increasing, as they need to invent and apply new teaching strategies in order to develop different types of competencies.

Focus on outcomes

Defining curriculum outcomes that can be identified or related to competencies would make it easier for students the transition from an academic to a professional environment.

Competency fostering

Students should be encouraged to apply for elective courses that represent additional areas to their IS education, where they could apply not only their technical expertise but also train other skills such as studying foreign languages, practicing business-related and communications activities, etc. The students could

also apply for short-time education at other universities in other countries and obtain abroad experience.

4.3. The industry role

Industry and university frameworks

There are differences between industry and university frameworks. Mapping curricula competencies to the skills, defined by the industry, facilitate the definition of different career paths. A good partnership between universities and industry will help student competencies improvement and give graduates more opportunities for successful professional realization.

Identifying appropriate domain clusters in the programs and connecting each domain scope with the appropriate competencies, achieved by students, will better prepare students for their professional careers.

Industry engagement

The industry and government could contribute to developing students' competencies in many ways – establishing strong lines of communication with educational institutions, providing training materials and appropriate project topics, and mentoring students working on projects.

5. Conclusion

It is essential for IS specialists to understand the important role of information systems as an instrument that successfully transforms organizations. The students need to understand information systems they will develop will have a broader impact on organizations and users than just software tools that solve problems and increase productivity.

The education in IS area, based on the recent MSIS 2016 and IS2020 curricula, will help achieve these goals while directing and assisting not only in the acquisition of in-depth knowledge but also in building the relevant skills for its application.

6. Acknowledgments

This work was supported by the project BG05M2OP001-1.001-0004 (UNITe) funded by Operational Program Science and Education for Smart Growth co-funded by European Regional Development Fund.

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