

New Education Challenges in Profiling Digital Experts for a Digital Economy Era

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Abstract—Nowadays, modern business includes acquisition and storing enormous data volumes, larger than ever before. Such data represent a significant value that an organization or a society can utilize to reach created goals and provide sustainable development. Unfortunately, a daily practice still intensively points out to the problem of a serious gap between the identified needs for knowledge, on one hand, and inability of the disciplines of Computer Science, Software Engineering, Informatics, and Data Science (CSSEIDS, for short), combined with the modern software technologies, to address such needs in an effective way, on the other hand. One of the important causes of such phenomenon is in a lack of strongly educated and interdisciplinary oriented experts showing an appropriate level of knowledge both in CSSEIDS, as well as in the disciplines of Business, Management and Economics, for a specific problem domain. In this paper, we address issues on how to come to more flexible and interdisciplinary oriented study models capable of producing various forms of digital managers and digital engineers, as a new profile of experts, ready to cope with digital economy and digital transformation in a modern society. Massive deployment of such experts is a way to significantly raise the level of organization maturity regarding capabilities for: information management, quality management, business processes, and big data analytics.

Index Terms—Digital Transformation, Education of Digital Experts, Digital Engineer, Digital Manager.

I. INTRODUCTION

NOWADAYS, modern business includes acquisition and storing enormous data volumes. Practically, we are faced with exponential growth in the amount of data collected. In [1], the authors discuss about big data as an emerging phenomenon. They state that “computing systems today are generating 15 petabytes of new information every day—eight times more than the combined information in all the libraries in the U.S.; about 80% of the data generated everyday is textual and unstructured data.” As such, we can state that we are in the Age of Big Data. Current state of data and knowledge management in modern business, characterized by the big data age, is in that the data represents a significant value that an organization or a society can utilize to reach created goals and provide sustainable development.

By [2], Big Data is the next frontier for innovation, competition, and productivity.

By our experience, in well-matured companies, the company management typically shows a clear recognition of needs for generating corporate knowledge from data. To address this need, they are ready to deploy quantitative, analytical methods, with the aim of effective data use in the decision process and various company management activities.

Despite that there is a clear recognition of significant worth ingrained in stored data, unfortunately it is still mostly unexploited. Data is operationally used in a short time frame, and then archived, without further utilization in the process of generating corporate knowledge. Tremendous amounts of data are available, while many institutions fail to make efficient use of the huge amount of data available, or look for patterns. One reason notified in [3] and [4] is that it is because the business appetite for doing so didn't exist, while the survey presented in [5] notifies the main obstacle to use advanced data analytics in the lack of understanding how to apply it.

Hereby we identify a great discrepancy between business needs on one hand side, and Information Technology (IT) capabilities on the other hand side. We notify significant needs for generation of corporate knowledge from data, while we notify inability of modern software products to effectively address these needs, despite that huge amounts of data already exist, and modern IT tools provide excellent technical capabilities. Such phenomenon can be perceived as a new form of Software Crisis introduced even in 1970's. However, it is never ending, present even for decades in various forms. Now, we can call such phenomenon a Big Data Crisis. From the managers' point of view, the phenomenon is perceived as an evident lack of return of investment (ROI) in big data projects in which engineers are unable to satisfy stakeholders' and managers' evident needs. However, from the engineers' point of view it is perceived as managers' and stakeholders' insufficient and unsatisfactory understanding of both IT capabilities, as well as business and decision processes.

However, Big Data Crisis is not just about perceiving factors ‘on the surface’ of the problem. It is to go deep into its causes and address them in a strategic way. We can identify the following main causes of Big Data Crisis, covering both managers’ and engineers’ side of the problem:

- (A) Unsatisfactory level of organization maturity regarding the capacities for: information management; corporate knowledge management; business processes and institutionalization; and quality management;
- (B) Unsatisfactory level of accumulated knowledge in a problem domain; and
- (C) Unsatisfactory level of accumulated knowledge in the domain of computer science, software engineering, informatics, and data science (CSSEIDS), necessary for the development and formal specification of models for software products aimed at generation of company knowledge and decision support.

Addressing the Big Data Crisis causes is a strategic and long-life task. It implies addressing all its significant causes simultaneously.

In this paper, we intend to contribute to addressing (B) and (C) causes. It is an important endeavor related to the education process, and mostly formal academic education process. Our goal is to address issues on how to come to more flexible and interdisciplinary oriented study models capable of producing various forms of digital managers and digital engineers, as a new profile of experts, ready to cope with Digital Economy (DE) and Digital Transformation (DT) in a modern society. We believe that massive deployment of such experts is a way to address in some aspects the (A) cause, i.e. to significantly raise the level of organization maturity regarding capabilities for information management, corporate knowledge management, quality management, business processes, and big data analytics. Let us notify that full addressing of the (A) cause is out of the scope of this paper, and it is a matter of our future research work.

Apart from Introduction and Conclusion, the paper is organized through four sections. The analysis of present research works is given in Section II. In Section III we discuss current findings regarding present education models. Perspectives and requirements about the improved education process are discussed in Section IV, while in Section V we outline a more flexible and interdisciplinary oriented academic education model to cope with Big Data Crisis.

II. RELATED WORK

In recent years, labor markets have experienced significant changes, primarily due to the rapid technological progress introducing new skill requirements for DE. This change resulted in a gap between the skills companies seek and the ones available in the job market. As a result, it is essential to align the education curricula with the industry requirements. Underscoring this point, in [6] it is argued that curricula must be regularly updated to prepare students effectively for the digital landscape. Similarly, in [7] the authors proposed a new framework to measure the alignment between higher

education digital skills and industry requirements, deriving factors for graduate preparedness from a systematic analysis of the relevant literature.

To address the evolving needs of the labor market, the education sector is increasingly compelled to adopt a systematic approach to transformation enabled by digital innovations. The authors of [8] analyzed existing DT frameworks to identify the critical components that educational leaders must consider when developing strategies for effective digital change. This study reviewed contributions from 50 organizations involved in education policy, including research institutions and technology companies providing hardware, software, and digital consulting services, as well as 15 Ministries of Education. The findings highlighted four principal themes: Leadership (94%), People (67%), Technology (56%), and Experience (33%). In [9], the authors investigated whether education is perceived as an essential factor in the broader digital transformation narrative by analyzing scholarly works from diverse scientific fields. The findings suggest that both education and workforce competencies are crucial for advancing digitalization and that many barriers to technology implementation can be mitigated through targeted educational initiatives. Furthermore, in [10], the authors argue for the establishment of interdisciplinary research and education centers that focus on IT skills development through industry partnerships and experiential learning.

In [11], it is proposed a theoretical framework to guide development of study programs that align with job market requirements, addressing the shortage of DT leaders. The authors note that universities often struggle to adapt swiftly due to lengthy bureaucratic procedures and curriculum development cycles. The authors of [12] reported on an educational project from the University of Birmingham. In collaboration with industry partners, the aim of the project was to strengthen students’ personal development in the digital domain and provide exposure to digital systems used across industries. Subsequent evaluations revealed that this initiative enhanced students’ digital competencies, resulting in a 30% improvement in their knowledge of the digital skills covered.

The skills required for the digital economy era cannot be acquired through a single discipline; rather, they demand an interdisciplinary approach that combines academic learning with professional training. Supporting this view, the authors in [13] introduce an educational framework with two components: a Competence Model for identifying essential skills for DT and a Digital Transformation Maturity Model for evaluating both individual and organizational competencies. Similarly, in [14] the authors analyzed the profiles of modern, data-driven companies and identified two groups of skills required for Data Scientist roles: (1) professional and attitude skills and (2) critical thinking, communication, collaboration, organizational awareness, and ethics. Focusing on Brazil’s emerging economy, in [15] the authors identified a misalignment between the skills required by IT companies and those taught in IT-related education programs. Companies’ managers emphasized that non-cognitive or ‘soft’ skills distinguish exceptional IT

professionals. The study concluded that Computer Engineering programs tend to prioritize technical skills over social and emotional competencies, highlighting the need for a more holistic educational approach to produce well-rounded graduates.

In contrast, in [16] the authors examined students' perceptions, where students' population is one of the main groups entering the workforce, regarding studying in digital environments and their consequent preparedness for employment in DE. In a case study conducted in the city of Osijek in Croatia, the results indicated that 35.8% of students considered the traditional education model to be unsatisfactory. Additionally, 71.6% of respondents believed that acquiring knowledge in DE would likely or certainly benefit their future employment or self-employment. Similarly, in [17] it is investigated the impact of Digital Transformation Initiatives (DTIs) on the Future Job Prospects (FJPs) of senior engineering students, demonstrating a direct, empirically measurable relationship between comprehensive digital educational environments and enhanced perceptions of career readiness.

From almost all related works analyzed it follows that having deep digital skills will be more and more important factor of better employability in the future job market. A review of scholarly work on this topic highlights the need to revise higher education curricula to provide learning opportunities across diverse domains. Universities must foster stronger connections with industry, as these partnerships can co-create authentic learning opportunities and provide insights into evolving labor market demands. In response to this need, we propose fundamentals of a new education model that introduces the digital expert profiles of a Digital Manager and Digital Engineer. Such model emphasizes the importance of interdisciplinary knowledge, integrating technical competencies such as mathematics, statistics, and engineering with business, economics, social sciences, and soft skills, thereby producing graduates who are not only technically proficient, but also adaptable, collaborative, and prepared to lead in the DE era.

III. INITIAL FINDINGS

One of the hot issues in creating Computing, Computer Science (CS), Informatics (I), or Software Engineering (SE) curricula in academic education is in what extent they are to be characterized as: (i) "self-contained", (ii) interdisciplinary oriented, or (iii) applied, and how to properly adjust a level of overlapping with other disciplines. It is not always easy to constitute high quality study programs that will properly meet the balance between those three characteristics, and to satisfy current and future needs of industry, at the same time.

As discussed in [18], in software industry of well-developed economies, we can notify a strong fitting between the skill and education requirements for specific job positions, and the level of education and experience of software engineers or IT experts being hired at those positions. Also, such software engineers typically show a higher level of specialization in some disciplines or problem domains. On the con-

trary, in underdeveloped or even developing economies, fitting between the required skills and education level for the job positions, on one hand side, and the level of education and experience of software engineers on the other hand side, is often not appropriate, and we can notice hiring overqualified or underqualified experts at some positions, to a wider extent. The level of specialization depth of software engineers to some disciplines or problem domains is not as strong, as in well-developed economies. However, it seems that a common characteristic of the Human Resource (HR) market in both cases is that interdisciplinary oriented professionals are always welcomed and better positioned, particularly as the requirements for such profiled experts are typically much over the HR market capacities.

In [15] the authors advocate about significant changes in the technology-related job market over recent years, mainly due to technological advances. It pushes industry toward new demands for skilled professionals, and it is a crucial factor to consider the future industry needs for HR experts. The authors notify: (i) a gap between industry needs and professional profiles available in the job market; and (ii) difficulties in finding employees who meet the required profile. All that results in financial loss and extra training expenses.

Absence of almost any academic education strategy leads to total leaving the academy to the operational market laws. Consequently, it comes to the two paradoxes [18]:

- (P1) More interdisciplinary oriented experts, capable of covering a wide range of tasks, knowledge and skills are always significantly better positioned in the software industry HR market, while academic institutions offer study programs that are rather self-contained, i.e. oriented to a narrower knowledge scope; and
- (P2) Students or young software engineers believe that they will be better positioned in software industry HR market just as they are good IT experts, i.e. programmers, while employers rather expect experts capable of recognizing and resolving their interdisciplinary oriented and complex requirements.

In [19], it is stated that the culture of interdisciplinary orientation of education is usually poorly developed, while interdisciplinary education is most likely in experiment phase. Even more, there is no consensus on how to evaluate the outcome of interdisciplinary education.

If we say here that academic institutions motivate, often 'in silence', education of 'more specialized experts', that means experts that are pure software or informatics engineers, mathematicians, business administration managers, or various domain experts.

Traditional taxonomy of education and research areas that is commonly applied in the academic accreditation process in some countries (e.g. in Serbia) is very rigid and comes to the disciplines of (a) science and mathematics; (b) engineering and technology; (c) social science and humanities; and (d) medicine. We identify study programs of the three categories, covering in some extent disciplines of CSSEIDS. Those are: (1) Specific study programs in Computer Science, Software

Engineering, or Informatics (CSSEI); (2) Study programs in (Applied) Mathematics (AM); and (3) Study programs in Economics, Business Administration and Management (EBAM). Many universities traditionally provide study programs in all three categories, for decades. A common belief among university education staff is that such traditional disciplines are quite enough to satisfy the needs of future HR market in the DE era.

By our long-term education experience, we identify the typical students' and even teachers' behavioral patterns of all three study program categories, as follows [18].

(1) Students from specific CSSEI study programs are predominantly technology oriented. Often, they express their animosity to the mathematical, and even more organizational, managerial or economics disciplines, with a belief that this knowledge is not necessary to them, and that someone else is to possess it. Study programs of this category often provide just a modest level of knowledge from mathematics and business administration. On the other hand, such students express their strong interest in learning a typical technology knowledge in IT.

(2) Students from AM study programs are predominantly formally oriented. They believe that technology knowledge is of a lower-level value. Also, they are not aware of the necessity of having a knowledge from business administration, management, or economics. Development of skills aimed at practical application of adopted knowledge in various application domains is often underestimated or even neglected. Students from this category believe that complexity of things is just of a logical nature – the things are more complex, just if they are logically complex, while other forms of complexity that evidently exist in engineering and science are rather neglected. Study programs of this category often provide a modest level of CSSEI knowledge, as well as business administration knowledge.

(3) Students from EBAM study programs show a strong awareness about the importance of having the CSSEI and AM knowledge in resolving the complex problems in organization systems. However, in a lack of formal knowledge from these disciplines, they believe that someone else is to resolve such problems, while their task is just to rent high quality CSSEI and AM experts to resolve the problems. Study programs from this category motivate learning a highly formalized knowledge from CSSEI and AM rarely.

Literally, we may say that the three identified behavioral patterns form “a universe of not joinable worlds” [18].

As such, a question arises: who will maintain the ‘interfaces’ between various disciplines? We need to systematically educate interdisciplinary oriented professionals capable of creating interconnections between various disciplines with a satisfactory deep level of knowledge of details. Our personal view is that academic education in CSSEIDS shows best chances to address this issue successfully, both in the areas of business and organization systems and scientific computations.

To perform some form of a test of our assumption, we consulted ChatGPT (June 2024). The findings are that “education in CSSEI can be closely related to digital manager skills in several ways. Strong technical foundation and problem-solving mindset are crucial for effective digital management. By aligning the technical expertise from CSSEI education with the strategic and operational skills required for digital management, professionals can effectively lead DT initiatives and drive organizational success in the digital age. By evolving the classical education approaches in CSSEI, we come to ability to (i) better prepare graduates for the multifaceted role of digital managers in modern companies; and (ii) equip them with business acumen, and leadership skills required to drive DT and innovation.”

Despite that we identified the three behavioral patterns while developing data science curricula as discussed in [18], the patterns are general and should be strongly considered in creating new study programs in support of DE. DT as a movement to DE is driven by changes in: (a) business models; (b) culture; (c) behavior of individuals; and (d) how technology is driving and is driven by these changes [20]. It is much more driven by the first three factors, supported by IT, than has been driven by advancements in technologies themselves. As stated in [20], strategy, but not a technology drives DT. We can say that it should be strongly considered as an important assumption in creating any education program in support of DE and DT.

IV. NEW EDUCATION PERSPECTIVES

To provide a movement to DE by deployment of DT principles, an organization must create power for organization transformations that are predominantly disruptive by its nature. It means that the incremental model of improvements is considered too slow and inefficient in most cases. DT strongly implies a faster model of discontinuity with a full reconsideration of the company business model and acceleration of company management in better understanding of the transformation process. DT must provide scaling from digital experiments and pilots to digital best practices [21]. An enterprise ecosystem in DE is organized through five layers, i.e. digital platforms (given here from bottom to top): 1. IT Infrastructure Platform; 2. Delivery Platform; 3. Talent Platform; 4. Leadership Platform; and 5. Business Model Platform. The main characteristics of the digital platform layers are that they should be designed as multidisciplinary oriented, dynamically coupled with a possibility of easy adaptation, with evident capabilities for learning and reconfiguration, and easily extensible with porous borders. A strong requirement to apply DT principles successfully and transform organization into a DE enterprise ecosystem is to develop those new digital platforms. The development process of digital platforms is considered as a unique venture in each organization. There is no silver bullet, no way to buy it anywhere – it must be designed and implemented in the organization. Common requirements for such process are integration of business and IT needs and requirements; and establishing a clear collective vision of the

company management, with the main purpose to provide company growth, as the main business priority [21].

A strong prerequisite for initiating a DT endeavor is to provide enough DE experts with a new profile, capable of high-quality support of the DT process. By [22], workforce skills are the most difficult barrier for building organizational capabilities for DT. We are faced with an evident lack of well-educated digital experts ready to support DT process. This phenomenon is called Digital Talent Gap [22], [23].

Academic education is not an exception. It should be subjected to the DT process, to come to the strategic goals necessary to support movement to DE and effective production of digital experts, and by this contribute to overcoming the Digital Talent Gap problem. As such, academic education is also to be transformed in a way to reach the new digital 5-layered platform. In [24], the authors propose adjusted priorities of academic education and training of teachers with a goal to come to well-educated specialists capable of managing and using digital technologies.

By our viewpoint, academic education is always the first-class entity for profiling DE experts – Digital Managers and Digital Engineers. It should be combined with additional approaches to education, such as short courses, training of various forms, and company schools or universities. In [25], the author proposes several priorities of the academic education transformation. One of the priorities is integration of university and corporate education. While corporate universities provide ultra-modern, but not systematic enough and fundamental education, classical universities are criticized as being still far from modern society education and new teaching technologies. However, they offer very important fundamental knowledge necessary for an expert to last on the HR market and to be able for long-life self-learning and moving to emerging technologies easily. Another important priority identified in [25] is that universities should become drivers of DT of society and economy. Nowadays, a new mission of universities, their technology parks, and business incubators together with teachers is to contribute to the development of (youth) startups.

To address Big Data Crisis Causes (B) and (C) and provide a transformation of academic education to face with DE, we start from the hypothesis that formal academic education is to strongly motivate raising the level of: (i) interdisciplinarity and multidisciplinary in profiling students' knowledge; (ii) abstraction and formalization skills; (iii) quantification, metrics, and analytical skills; (iv) specification, implementation, and integration skills; (v) business, management, communication, and soft skills; and (vi) problem domain skills. There are three general approaches to initiate modernization of a study program to face DE: a) starting with a CSSEI curriculum; b) starting with an EBAM curriculum; or c) hybrid or Integrated approach. The first approach motivates producing highly technically proficient digital engineers and, in some extent, digital managers, who can bridge the gap between technology and business. The second approach motivates producing digital managers with strong strategic and operational

skills, who can understand and leverage technology. The third approach means creating a curriculum mostly from scratch. Integration in this approach means unifying existing CSSEI, EBAM, and possibly AM curricula. The outputs in all cases can be interdisciplinary programs, joint, double, or dual degree programs, or even just collaborative courses.

To initiate the process of study program transformation, it is important to identify and formulate the general requirements to the transformed curriculum. In this case, we predominantly address such requirements for a CSSEI program. A proposal of the general requirements includes the following:

- (1) Interdisciplinary Curriculum;
- (2) Project-Based Learning;
- (3) Soft (Non-Cognitive, Metaskills) Skills Development;
- (4) Industry Partnerships and Internships;
- (5) Continuous Learning and Adaptation;
- (6) Entrepreneurship and Innovation;
- (7) Analytical Thinking and Data-Driven Decision Making;
- (8) User Experience (UX) and Design Thinking;
- (9) Cybersecurity and Compliance; and
- (10) Mentorship and Networking.

Identification of those ten requirements was inspired by the authors' experience, as well as the related work research mostly presented in [15], [26], [27], [28], [29], [30], and [31].

(1) Interdisciplinary Curriculum is an important advantage, as traditional CSSEI programs focus heavily on engineering and technology-oriented subjects, while it is a requirement to integrate it with business, management, digital marketing, and leadership courses. Integration with mathematics (algebra, discrete mathematics, probability theory) and statistics is also a must. It is to strive for embedding more holistic educational experience and combine general engineering and CSSEI disciplines. By this, one can create a field where interdisciplinary and multidisciplinary education has room to grow.

(2) Project-Based Learning is an achievement where not only theoretical knowledge with isolated coding projects are practiced. It means real-world project-based learning, working in multidisciplinary teams, simulating the collaborative environment. It is even more effective if it is applied in coordination with the selected companies that are ready to provide their real word problems or case studies to be adapted to students' projects with the company experts ready to be involved in the mentorship program of project-based learning.

(3) Soft Skills, Non-Cognitive, or Metaskills Development is an achievement where focus is not on technical skills only. The program should incorporate soft skills training, such as communication, teamwork, leadership, emphasizing effective communication, conflict resolution, and team management. Required skills for DT era are entrepreneurial vision, creative ability, holistic vision, with a focus on collaboration, ethics and social responsibility, and codes and programming.

Majority of executives consider soft skills as increasingly important, while there are studies suggesting that both soft and hard skills are needed. In [32] and [33], the authors identify the following key leadership skills: communication skills, language knowledge, organizational skills, subject-specific

knowledge, digital literacy, and self-reflection. Executives are to be emphatic, open-minded, flexible, motivated, and stress tolerant. In [34] and [35] the authors identify behavioral leadership skills as core abilities of managers. They include motivational skills, team-building skills, and emotional intelligence. Also, in [35], the authors identify the Altro-centric leadership, as an other-centered leadership style, or adaptive leadership that is mandatory to support DT as a disruptive process. To provide such leadership style, increasingly important soft skills are empathy, humility, integrity and compassion, integrity, creativity, and human-ethical sense of judgement to AI's data-driven information and judgments. Managers' focus of such style is on coaching, motivating and empowering employees, while engineers' focus is on algorithmic management practice, particularly supported by Artificial Intelligence (AI) and Generative AI methods, and on handling quantifiable managerial tasks and quantitative performance evaluation.

(4) Industry Partnerships and Internships require strengthening partnerships with technology-oriented companies and startups. It includes internships, co-op programs, collaborative projects, experience and networking opportunities.

(5) Continuous Learning and Adaptation means that the curriculum is not just fixed with a static set of courses. It nurtures the culture of continuous learning and adaptability to teamwork. It insists to flexibility in offering elective courses on emerging technologies, providing access to online resources, and encouraging participation in workshops and conferences.

(6) Entrepreneurship and Innovation is a requirement for having courses on entrepreneurship, innovation management, and startup ecosystems. It should inspire students to think creatively and rationally, and take risks, allowing staying ahead of digital trends and implementing cutting-edge solutions.

(7) Analytical Thinking and Data-Driven Decision Making is an achievement in which not only coverage of data structures and algorithms with limited application to business contexts is enough. Instead, it requires having advanced courses in Data Analytics (DA), Machine Learning (ML), Business Intelligence (BI), decision theory, operational research, optimization methods, and stochastic processes. Emphasizing applications in strategic decision-making is expected.

(8) User Experience (UX) and Design Thinking requires integration of UX design, Human Computer Interaction (HCI), visualization methods, and design thinking courses. It provides emphasizing user-centric product development with full consideration of the Requirements Engineering (RE) discipline.

(9) Cybersecurity and Compliance requires fostering cybersecurity education and culture and including topics on regulatory compliance, risk management, and ethical considerations in digital management.

(10) Mentorship and Networking requires creation of various mentorship programs to connect students with industry professionals and alumni. It should provide guidance and career advice to the students.

In [22], critical skills gaps for DT are identified: Analytics, Big Data, Digital Strategy, Financial Modeling, Digital Marketing, Security, Privacy, Risk, Compliance, Smart Product Development, Software Development, and Web/mobile Development. We see those recognized skills for Digital Managers and Digital Engineers.

In [21], the author discusses new roles of Chief Information Officers (CIOs) in the DT process, by comparison to the past and well recognized CIOs' roles, as shown in TABLE I. It is evident that new roles of CIOs require much more proactivity, well understanding of both business and technology and applying strategic thinking effectively. As such, a new profile of a Digital Manager or even Digital Engineer should provide high-quality knowledge to cope with new roles of CIOs in DT, where CIOs take positions very close to strategic company management.

TABLE I.
CIO ROLES IN THE PAST AND IN DT FUTURE

Past CIO Roles	Future CIO Roles
Focus on IT outcomes	Focus on business outcomes
Sequencing of operations	Creating collaborative agenda
Support	Overcoming the unconquerable
Costs control	Developing the income plan
Process Reengineering	Data utilization
Outsourcing	Design of business
Focus on functions	Focus on (DT) platforms
Searching for parity	Searching for differentiation
In the scope of IT sector	Everywhere in the organization
Focus on IT risks	Focus on business risks

Finally, it worths to mention that a new notion of Digital Intelligence (DI) is proposed in [36] and [35]. By this, all employees, including managers, should develop DI as an ability to learn digital technologies, deal with digital technologies appropriately, read, decode and manipulate digital information, and acquire and apply new knowledge and skills connected to digital technologies to address insights and openness, and improve operational efficiency and outcomes.

V. A NEW EDUCATION MODEL

To cope with Big Data Crisis Causes (B) and (C) by applying DT in academic education, we propose introducing the profiles of Digital Manager and Digital Engineer. A body of knowledge of the study programs supporting the two profiles is to be based on four widely set-up scientific and engineering general disciplines (Fig. 1):

- (1) Computer Science, Informatics, (Software) Engineering, and Data Science (CSIEDS);
- (2) (Applied) Mathematics, Statistics, and Science (MSS);
- (3) Business, Social Science, and Economics (BSSE); and
- (4) Humanities and Soft Skills (HSS).

As such, a body of knowledge includes numerous disciplines. We give here a list of the disciplines grouped by the four general disciplines, not pretending to perceive it as a complete list of the knowledge being offered.

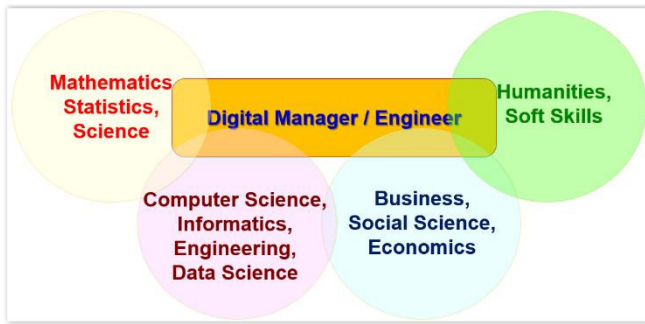


Fig. 1. General disciplines for digital manager and digital engineer

(1) Computer Science, Informatics, (Software) Engineering, and Data Science as a general discipline includes all core CSSEI disciplines, such as Programming, Computer Architecture, Operating Systems, Algorithms, and Compilers. Also, it covers Computational Intelligence and ML, HCI, Software Engineering, Databases, Information Systems, DevOps, and Cyber Security. Then it covers UX and Requirements Engineering, System Engineering, Decision Engineering, Formal Methods, Domain Specific Modeling and Languages, Model-Driven Engineering, Conceptual Modeling, and System Thinking, where general engineering disciplines are included.

(2) (Applied) Mathematics, Statistics, and Science should cover Algebra and Linear Algebra, Calculus, Discrete Mathematics, Graph Theory, Combinatorics, Logic, Probability and Statistics, Stochastic Processes, Operational Research, Optimization Methods, and Data Series Processing. Also, Physics or relevant science disciplines for a problem domain can be included.

(3) Business, Social Science, and Economics should cover Domain knowledge and Customer Experience (CX) with some selected focus areas across physical and social sciences of interest, Finance and Quantitative Finance, Financial Engineering, Marketing, Fundamentals of Economics, as well as Organization Design, Management, Privacy, Entrepreneurship, and Strategic Thinking.

(4) Humanities and Soft Skills should cover Communication, Critical Thinking, Adaptability, Problem-solving, Leadership, Creativity, and Innovation topics [22], [23].

Looking at the pretty long list of disciplines included in education of Digital Engineers and Digital Managers, it is obvious that one student cannot select and pass all those disciplines through B.Sc. and M.Sc. levels of education (five years in total). As such, following student's affinities and vision, some selection of all those disciplines must be done. We propose a flexible selection model, in which students can profile themselves, literally speaking in a 'Lego bricks' style. As such, some possible business roles of interest that can be derived from our general body of knowledge model can be:

a) The Digital Manager roles:

- Digital Product Manager,
- Digital Business & Finance Manager,
- Digital Sales & Marketing Manager,
- Digital UX / CX Engineer,

- Digital Operations Engineer, and
 - Business Analyst,
- b) The Digital Engineer roles:
- ML Engineer,
 - Data Scientist,
 - Data Analyst,
 - System (Design) Engineer,
 - Data Engineer,
 - Information System Engineer,
 - Cyber Security Engineer,
 - DevOps Engineer, and
 - Software Engineer.

The list is not complete. By further practice of application of such flexible model, new roles may appear, or some of the roles being listed here can become obsolete.

Following the proposed body of knowledge we further propose a highly flexible education model and curricula structures that are based on the following principles.

- (P1) Coverage of all four general curricula disciplines: MSS, CSIEDS, BSSE, and HSS, as mandatory disciplines. Students are forced to select courses from each of the mandatory disciplines.
- (P2) The program structure is designed in a way that each general discipline is covered with a defined percentage of share in the whole structure. Thus, students are forced to select courses from the mandatory disciplines to a designed extent.
- (P3) The coverage of all general disciplines is mandatory at all study levels (including B.Sc., M.Sc., Ph.D. studies), while percentage of share may vary slightly from one to the other level.

Regarding the percentages of share of the general curricula disciplines, we differentiate between the two model interpretations: (a) basic and (b) refined. In a basic interpretation, the share percentages of general disciplines are defined just for the common roles of Digital Manager and Digital Engineer. As such, the following principle should hold.

- (P4a) In the basic model representation, the percentage of share of all four general disciplines is customized to the roles of Digital Manager and Digital Engineer. It is expected a relatively higher share of CSIEDS for Digital Engineer, while a share of BSSE is higher for Digital Manager.

As an illustration, for Digital Engineer we can define percentages of share as: (MSS: 20%; CSIEDS: 50%; BSSE: 15%; HSS: 15%), while for Digital Manager we can propose percentages of share as: (MSS: 20%; CSIEDS: 30%; BSSE: 35%; HSS: 15%).

In the refined interpretations, the share percentages of general disciplines are defined at the finer level of granularity, for specific Digital Manager and Digital Engineer roles. Even, study program designers have a freedom not just to refine a model interpretation to the specific roles, but also to the sub-disciplines of the four general disciplines. As such, the following principle should hold.

(P4b) In the refined model representation, the percentage of share of all four general disciplines is customized to the specific roles defined under the Digital Manager and Digital Engineer, as general roles. Further refinements are possible by decomposing the four general disciplines to the subdisciplines.

As an illustration, for Data Scientist, we can decompose the CSIEDS discipline to Computer Science, Informatics, and Engineering (CSIE) and Data Science (DS). Also, MSS can be decomposed to Mathematics and Science (MS) and Statistics (S). Then we can define percentages of shares as: (MS: 10%; S: 15%; CSIE: 30%; DS: 15%; BSSE: 15%; HSS: 15%). For Data Engineer, the distribution of percentages will be different in favor to CSIE: (MS: 10%; S: 10%; CSIE: 50%; DS: 10%; BSSE: 10%; HSS: 10%). On the contrary, for Business Analyst, the distribution of shares will be in favor to BSSE: (MS: 10%; S: 15%; CSIE: 15%; DS: 15%; BSSE: 30%; HSS: 15%).

- (P5) MSS, CSIEDS, BSSE, and HSS disciplines are mandatory rather than sole courses. A proposal is to have very few mandatory courses, e.g. max. 1 per each semester. In this way, students are rather free about what courses to select from each mandatory discipline.
- (P6) A study program structure should provide a selection of a great number of courses in each of the four mandatory general disciplines.
- (P7) Each course is to be classified according to the level of rigor and defined prerequisites, as follows: (i) Basic; (ii) Intermediate; and (iii) Advanced. There are no prerequisites for basic courses. Prerequisites for each intermediate and advanced course are clearly defined, however not always with sharp requirements.
- (P8) Students are advised to select courses from all three levels (basic, intermediate, advanced) to a designed extent, while there is a minimum percentage share of the courses of all three levels. The percentage share of the course levels is different for various study levels (B.Sc., M.Sc., and Ph.D. level).

As an example, for B.Sc. study level one can define a minimum of 20% of basic courses, 30% of intermediate courses, and 20% of advanced courses. For M.Sc. study level, a percentage of share may significantly vary with respect to the conformance of the previous level of studies completed by a student. As a rule, at the M.Sc. study level a study program designer can expect a predominant selection of advanced courses. However, if a conformance of the previously completed B.Sc. level of study is not very strong with the M.Sc. level being enrolled, some basic or intermediate courses are important to be included in the student's study plan.

- (P9) Internship is a mandatory slot in any study program of the B.Sc. and M.Sc. levels. Study visit of at least one month to some other foreign university is a mandatory requirement in any study program of the Ph.D. level.
- (P10) The study framework should provide a formal possibility of including distinguished industry experts in the

lecturing process, at the selected advanced courses and to the designed extent.

Following all the principles, and particularly (P4a), (P4b), and (P8), it is possible to come to a 'default' profiling of students, by creating series of matrices of the Business Roles / Study Program Disciplines type. The matrix cells can be organized in various ways:

- recommended percentages (or even numbers) of basic, intermediate, and advanced courses;
- recommended percentages of share (or numbers of courses) of each of the four general disciplines;
- recommended percentages of share (or numbers of courses) of individual subdisciplines derived by the decomposition of the four general disciplines; and
- recommended individual courses that are appropriate for a business role.

A study model which is in line with the principles presented in this paper can be perceived as highly flexible. Such flexible model requires a possibility of running some massive courses both in Winter and Summer semesters and working with students in smaller groups, to motivate collaborative work and project-based learning. Thus, such model requires engagement of larger number of education staff. Both education staff and students are to be highly motivated for their involvement in such study model. By this, significant organizational and social efforts are to be invested in raising the level of motivation and awareness of the students and teachers about the values coming from the implementation of such model.

A significant difference between the proposed model and 'conventional' models is that the students take very strong responsibility for their future profiling in this model. In 'conventional' models, students take a more passive role just having freedom to select and enroll in a study program and then selecting some elective courses. Here, students must be quite proactive and strongly motivated to think about the details of their professional future early in advance. Therefore, proactive mentorship of students in their profiling in this model is of crucial importance, bearing in mind that mentor will just give advice, while students will make final decisions, as they should be the most responsible for themselves. We see such approach as an effective way to create proactive, satisfied, motivated, brave, and highly innovative experts ready to cope with the issues of modern business in DE. One evident psychological issue in the implementation of such approach is that the teachers predominantly believe that they know best what an appropriate selection of topics for students is, as the students "are mostly not enough mature to know it in advance". Instead, we insist here that the students of a higher level of responsibility must know what the best selection of topics for them is.

In the proposed model, students have much wider freedom in a selection of individual courses than in 'conventional' models. On one hand, it creates a high degree of freedom, and the university management may complain about realistic execution of such study programs. On the other hand, we believe that in the first two school years of execution, typical clusters

of selected courses will be created naturally, and it will reduce the degree of freedom to a rational level, without forcing students to select courses they do not want to select and thus reducing their level of freedom.

In general, development, implementation, and execution of such study models is more expensive than of 'conventional' models. It is always a question of how to involve relevant stakeholders who are ready to support such models in practice, and it could be a matter of further research.

VI. CONCLUSION

Addressing Big Data Crisis Causes and challenges of DT is a strategic and long-life task. To address Digital Talent Gap phenomenon, a DT approach is necessary to open new perspectives for academic education. Facing the era of DE requires new profiles of Digital Manager and Digital Engineer and producing a huge number of digital experts ready to cope with DE challenges. In some segments, formal academic education for digital experts is to be significantly transformed to the level of a disruptive modification. A new and more effective form of academic education is expected to be in line with the DT principles, with clearly defined education and business strategy. It should be designed as a flexible framework providing reasonable combination with high quality alternative forms of education. Such study programs must present a clear multidisciplinary and interdisciplinary orientation. They are expected to be implemented through highly flexible education models and curricula structures to guarantee freedom of choice to students, raising their level of responsibility, vision, motivation and understanding in their profiling, and adopting both fundamental and cutting-edge knowledge, necessary for an effective participation in the DE processes in the upcoming decades.

In this paper, we have proposed general principles on how to come to the new model of academic education for DT and DE, as a prerequisite for strengthening human resources and proper addressing Digital Talent Gap phenomenon. Creating new academic educational models requires formulation of a clear vision and strategy. As a rule, such education models are more expensive, first to develop and implement, and then to execute, for several reasons. We believe that the process of creating such new education models is painful, and takes a lot of courage, particularly as academic community is rather conservative and rigid. However, societies and economies that are more proactive and show more bravery in realizing what are the real advantages, as well as tangible and intangible benefits of such transformation, have much better chances to open new strategic perspectives of sustainable and long-term society development. For emerging economies, it could be an excellent opportunity to reach the level of well-developed economies more efficiently. Otherwise, missing such opportunity means further prolonging the development delays.

ACKNOWLEDGMENT

This work was supported by the University of Belgrade – Faculty of Organizational Sciences.

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