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MaCuDE IS Task Force: Final Report and Recommendations

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Abstract:

This Phase III report of the Management Curriculum for the Digital Era (MaCuDE) disciplinary task force on information systems (IS) synthesizes the main findings of the project's two earlier phases. Based on the synthesis, this report formulates the task force's recommendations (Phase III) for future IS curricula and graduate competencies associated with Big Data Analytics (BDA) and Artificial Intelligence (AI). During the MaCuDE project, the task force—collaborating with Association for Information Systems leadership on education— first (Phase I) surveyed a sample of representative universities to examine the status of IS education in the digital era. During the next phase (Phase II), the task force interviewed industry leaders regarding their information systems education needs with a focus on emerging BDA and AI needs. This report builds on Phase I and Phase II results and associated feedback from project stakeholders and outlines an IS curriculum framework that identifies projected competency levels for key IS competency areas (both new and changing) within main IS program types related to BDA and AI education (undergraduate and graduate programs; IS programs, other business programs, and non-business programs) in the coming decade. The report also highlights critical policy issues to successfully implement the proposed IS curricula changes addressing BDA and AI needs.

Keywords: Big Data Analytics, Artificial Intelligence, MaCuDE, IS Education, IS Curriculum Recommendations, Curriculum Design, Digital Transformation, Industry Needs, AACSB.

[Department statements, if appropriate, will be added by the editors. Teaching cases and panel reports will have a statement, which is also added by the editors.]

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Executive Summary

Since fall 2019, the Management Curriculum for the Digital Era (MaCuDE) project IS Task Force, one of the six disciplinary and three transdisciplinary MaCuDE task forces, has collaborated with Association for Information Systems Education leadership toward the following goals:

- Provide an overview of the status of IS education, identifying emerging industry needs and articulating recommendations for future curriculum work;
- Identify the impact of emerging IT capabilities associated with Big Data and AI (including machine learning) on IS curricula (especially in business schools);
- Identify new directions for IS education in business schools given the increased focus on digital technology across most business disciplines; and
- Review how and the extent to which IS faculty and units within business schools can collaborate with other groups in this new environment.

This executive summary provides a brief overview of the findings of the task force's work.

Phase I of the MaCuDE project investigated the status of IS education using survey research. It focused on the state-of-the-art in educating big data analytics (BDA) and Artificial Intelligence (AI). Main findings indicate a continuing impact of pervasive digitalization of operations and digital transformation on the content and goals IS education. This change comes with both new opportunities and challenges. Currently several business disciplines identify foundational digital competencies such as programming and data management as essential for their graduates. This requires IS to find a right balance in providing competitive content and collaborating with other disciplines. Local needs and university resources have a major impact on what is realistic for an individual program to offer, and it is likely that we will continue to see diversification of IS programs.

At the undergraduate level, most current IS programs pay relatively modest attention to BDA and AI topics, except for a small, but growing number of programs focused on analytics. Overall, IS programs are moving in the direction of increased specialization in areas such as cybersecurity, analytics, and digital design. Systems thinking and design thinking are not frequently featured in IS undergraduate programs. At the graduate level, the movement toward specialized programs (particularly in business analytics) is even more pronounced, and analytics topics have gained popularity within all IS graduate programs. New master's level specializations include digital innovation, automotive and mobility management, and FinTech. Coverage of AI topics remains sporadic, and there are few AI-focused programs in business schools. ACM, AIS, and EDSIG have recently released a new undergraduate curriculum recommendation (IS2020), but there are no ongoing efforts to address new specialized curriculum needs.

During Phase II, the task force explored industry needs associated with IS education. The group conducted 18 interviews among IT industry leaders with responsibilities in AI and big data development and associated management of workforce. This research identified three main categories of targeted positive impacts of BDA/AI providing guidance for educational programs: 1) changes in organization's operations, products, and services, 2) changes and improvements in automating and augmenting organizational decision-making, and 3) changes in digital transformation capability and organizational learning. At the broad level, the study identified four competency areas that IS graduates are expected to have: individual foundational competencies (e.g., critical thinking, communication, problem-solving, systems thinking, etc.); domain competencies; competencies in data, information and content management; and competencies in system design and development. At a higher level of abstraction, these areas are fully aligned with traditional IS curricula models. But BDA/AI and changes in the technology environment will have a major impact on the relevant pool of competencies, especially in data, information and content management, and system design and development. Industry experts identified the most significant gaps between expectations and reality in domain competencies, data management, and design. Additional identified areas of importance are cybersecurity and new technical competencies related to BDA and AI. The industry experts emphasized the importance of staffing programs with technically qualified faculty.

Based on Phase I and Phase II results and additional conversations with project stakeholder groups the task force specified the mission of IS education as follows: *Educational programs in IS prepare their graduates for roles in which they successfully contribute to and lead those organizational initiatives and*

operations that harness the transformative power of information technologies to serve current organizational needs and realize new opportunities to fulfill current or new organizational goals. At the level of program design and delivery, changes will continue to be substantial, because of continuously evolving information technologies—including BDA and AI technologies—and their expansive impact on organizational practices within most professional domains.

The project's final recommendations are based on Phase I analysis of IS programs, Phase II interviews of industry leaders regarding industry needs, and a synthesis of Phase I and II results in light of the proposed existing IS model curricula. The crux of these recommendations are conveyed in competency matrices that define a competency level for each program type / IS competency area intersection. The models cover emphasis areas and graduate competency levels for all university students, all business students, general IS degrees (undergraduate and graduate), and also for specialized degrees (both undergraduate and graduate, in areas such as business analytics, cybersecurity, applied AI, etc.). In addition to the competency level specification at the level of competency areas, the project identifies within competency areas detailed categories that are either new or significantly changed compared to the existing curricula. These include 1) focus on analytics competencies, 2) non-relational database technologies,3) development and deployment of BDA and AI capabilities based on packaged solutions and programming languages, 4) integration of BDA and AI into organizational systems projects, 5) cloud-based services for implementing BDA and AI solutions, 6) new life cycle models in data management and data science, and 7) ethical implications of BDA and AI capabilities.

Generally, this report recognizes the continued significant role of individual foundational competencies and domain competencies, with a specific focus on meta-learning, systems thinking, and design thinking in IS education. The proposed design perspective and related anchoring to design thinking in developing and applying BDA/AI in organizational contexts is the unique contribution that the information systems field can offer to education in business disciplines. Indeed, the identity of information systems field brings together computing competencies and domain competencies, which allows IS alumni to arrive at useful and workable organizational solutions.

Changes in the BDA/AI-related graduate competency requirements and curriculum implementation have important policy implications: 1) BDA/AI-related curricula introduce new, challenging technical competency needs for faculty, which requires schools and departments to reconsider hiring priorities and introduces non-trivial training needs; 2) IS departments need access to cloud-based resources, both to allow students to learn to operate in these contexts and to provide access to services that are available on the cloud. Many departments will need additional support in securing these resources. 3) Expanded technical requirements will require flexibility in degree structure requirements particularly for the IS majors. 4) Many BDA/AI programs require collaboration across organizational boundaries within business schools, and across the entire university. 5) Increased focus on BDA and AI calls for stronger emphasis on design and a recognition of design thinking as one of the most important strengths of IS departments. 6) Offering and executing BDA/AI curricula needs to be based on experiential and problem-focused learning that advances system thinking, meta-learning skills, and professional IS competencies. 7) The resource and preparation levels of business schools/IS departments to offer BDA and AI programs vary significantly. Schools must carefully consider the best selection of BDA/AI programs for their local needs. Every business school and IS department needs to carefully consider in the next few years how BDA, AI, and other contemporary emerging technologies enabling deeper digital transformation will impact their curricula. In particular, schools that have not done anything yet to address these concerns must take immediate action and start to position their education offerings in the future so that they will not fall too much behind. Only such remedies will ensure that all graduating IS students at different levels will gain relevant BDA/AI-related competencies that they need to succeed in their work and professional life.

1 Task and Setting

AACSB International's Digital Transformation Affinity Group (DTAG) was established in February 2019. As its first major initiative, DTAG launched the Management Curriculum for the Digital Era (MaCuDE) project for which PricewaterhouseCoopers (PwC) has provided funding and Stevens Institute of Technology operational leadership. The MaCuDE project is tasked to recommend changes to business curricula based on digital technologies' transformational impact on organizations (no matter their type and size). It especially explores the impact that these changes have on resources that business schools need to fulfill their educational mission. The initiative is motivated by and expected to heed particular attention to the impact of the wide use of big data analytics (BDA) and artificial intelligence (AI) technologies in

organizations' operations, organizing, and decision-making. The project comprises nine task forces. Most of them explore the impact digital technologies on a specific business discipline or an area of practice—such as those related to accounting, operations, finance, information systems, innovation management, and marketing—and associated curriculum needs. The initiative has also cross-curricular task forces focused on analytics, cybersecurity and future of learning/work.

One of MaCuDE disciplinary task forces centered on information systems (IS) education at business schools. The Association for Information Systems (AIS) and the Association to Advance Collegiate Schools of Business (AACSB) jointly formed this task force in late 2019. Dr. Kalle Lyytinen (Case Western Reserve University, MaCuDE IS Coordinator) led the task force in collaboration with Dr. Heikki Topi (Bentley University, AIS VP of Education 2017-2021) while Dr. Jing Tang (RIT) served as the project coordinator. As the other task forces, the IS group followed a three-phase work plan. The first phase (2019-2020) focused on describing the current status of IS curricula in business schools, the second phase (2021-2022) explored industry leaders' and experts' expectations for future graduates of IS programs in business schools, while the third phase (2022) developed detailed curriculum and policy recommendations building on the results of the first and second phases[1]. The aim of the third phase was to integrate the findings into a set of recommendations regarding future curricula and educational policies and related institutional changes.

MaCuDE IS Task Force has focused on the following goals:

- Providing an overview of the status of IS education, identifying emerging industry needs and articulating recommendations for future curriculum work;
- Identifying the impact of emerging IT capabilities associated with Big Data and AI (including machine learning) on IS curricula (especially in business schools);
- Identifying new directions for IS education in business schools given the increased focus on digital technology across most business disciplines; and
- Reviewing how and the extent to which IS faculty and units within business schools can collaborate with other groups in this new environment.

The mindset guiding the writing process has been global. The task force from the beginning recognized that the effort needs to serve the information systems field and associated business education globally. The competency-based approach that the report follows admits the presence of significant differences in educational programs' legal and regulatory contexts, available monetary and infrastructure resources, faculty backgrounds, and cultural expectations. By selecting program graduate competencies as the shared set of expectations among the global community, it will be possible (and critically important) for local programs to design and implement curriculum content, pedagogy, and structure based on the local needs and resources and remain aligned with the shared global competency expectations.

MaCuDE IS Task Force recognizes that AIS (Association of the Information Systems) and ACM (Association of Computing Machinery) have jointly developed multiple IS curriculum recommendations over the past three decades (since early 90's[2]). Therefore, the project has drawn on these documents (particularly IS 2010, MSIS 2016, and IS2020; see Topi & al., 2010, Topi & al., 2017, and Leidig & Salmela, 2020) while creating its own recommendations and used the past curriculum recommendations as a baseline to identify gaps therein and provide input for future initiatives. During the process, the task force has collaborated with the IS2020 project as the concurrent IS curriculum initiative and its leaders and shared emerging insights with them. The task force organized two webinars jointly with the IS2020 project. The task force has also collaborated closely with the AIS Education Committee and thanks them for their generous support throughout the process.

This report presents the results of the third phase. Section 2 summarizes and integrates the results of the first phase concerning the status of BDA and AI education in the IS field. Section 3 continues with a summary of the results of the second phase focused on the emerging industry needs for BDA and AI related IS education. Section 4, the main part of the report, proposes competency-based educational requirements for undergraduate and master's level IS curricula, techno-MBA, IS undergraduate minor,

[1] The MaCuDE IS project finished the first phase during the spring of 2021. The results have been reported in Communications of the AIS article (Lyytinen et al., 2021). The second phase was finished in January 2022, the report was submitted to the Communications of the AIS in March and approved for publication in September 2022 (Lyytinen et al., 2023).
[2] Most recent recommendations are IS 2020 at the undergraduate level and MSIS 2016 at the graduate level.

and IS-related competencies for all business and all university students. Section 4 also articulates policy recommendations related to resourcing, governance and implementation of proposed curricula. Section 5 concludes the report with a summary. More detailed reporting of the analysis and synthesis of the BDA/AI curriculum needs follows.

2 Current State of IS Education

We identified the key challenges of current IS education based on the Phase I and Phase II results, the conversations with the MaCuDE Advisory committee board, and the feedback from webinars and other methods of solicitation of public comments. They are as follows:

General *new challenges* that IS education currently faces:

1. Ongoing pervasive digitalization of operations and related digital transformation present new opportunities and needs for IS education. There are a lot of opportunities for IS education, especially those related to BDA/AI technologies, as the industry has difficulties in finding qualified employees. For example, the digitalization of operations and digital transformation increase the needs for database and data governance skills, in areas such as SQL, data storage, and data engineering.
2. The demand for IS competencies has increased also outside of IS degree programs. For example, increased application of digital capabilities and tools across all business disciplines suggests that most business students would benefit from programming skills. IS faces the challenge of achieving and maintaining a leading role in delivering BDA/AI technologies and methods in business schools and in general education. Finding the right balance between competition and collaboration with other disciplines with offerings in this space is essential.
3. There is a need for increased variation in the content and scope of covered digital technologies in IS programs. This is true in general, and in relation to BDA/AI technologies in particular, as local needs and environments vary and are highly dynamic. We also observed the significant variation in the content and scope of BDA/AI topics and technologies in both undergraduate and graduate programs in our sample.

At the *Undergraduate* level:

1. Programs cover BDA/AI topics currently at a relatively modest level except for a growing number of specialized analytics programs. The programs that are highly involved in computer science or data analytics provide more courses covering BDA/AI or algorithms topics and teach techniques such as Python, R, SQL, or other programming languages. In these programs, AI/ML are introduced mainly at the awareness level. For most other programs, the tools used in the courses are mainly data discovery (e.g., Tableau, SAP & Splunk) or statistical tools (e.g., SAS, SPSS, and Excel).
2. IS education is generally moving in the direction of developing more specialized programs (such as cybersecurity, digital design/innovation, and analytics) instead of traditional general IS education. In addition to majors, IS units also now offer specialized minors or certificate programs in several areas for those who are majoring in other disciplines.
3. Currently only a few programs emphasize design thinking, a focus that was central in traditional IS programs. Some of the design-thinking-focused courses allow real-life experience in new digital business (mostly via collaboration with external partner companies).

At the *Graduate* level:

1. Specialized analytics programs have become popular. In addition to traditional IS programs, the Phase I survey sample included several master's programs specializing in business analytics. All these programs cover big data, AI, and automation/algorithms topics in some of their courses and introduce Python/R/SQL as the main tools.
2. Analytics topics are gaining real estate also in general MSIS programs. In our sample, 83% programs covered big data/data science, 70% programs covered AI/machine learning (ML), and 74% programs covered Automation/Algorithms topics.

3. Other specialized programs with a detailed IS thematic focus such as, for example, digital innovation, digital business solutions, automotive and mobility management, and financial technology are emerging.
4. Graduate programs currently acknowledge the importance of AI topics but, with a few prominent exceptions, cover them mainly at the awareness level of competency.

3 Industry Needs

The task force discovered several new changes and trends in industry needs associated with IS education based on a set of 18 interviews of industry experts in Phase II, as reported at a detailed level in a separate Phase II report (Lyytinen et al., 2023). We next summarize the key findings of that study here.

1. **Understand the Multiple Dimensions of Effects of BDA/AI technologies in Organizations**

Educational content and the context of using these technologies need to be connected to three main categories of targeted positive impacts of BDA/AI: 1*) changes in organization's operations, products and services, 2) changes and improvements in automating and augmenting organizational decision-making and related tactics, and 3) changes in digital transformation capability and organizational learning*.

These contexts require integration of education of BDA/AI technologies and capabilities with the study of multiple levels and contexts of organizational behavior and structure. This intertwining of complex structures demands analysis that is more encompassing than earlier coverage of how digital technologies support and enable organizational change and operations.

2. **Recognize three key competencies to meet the industry needs for various professional roles and profiles**

Our analysis of the emerging industry needs demonstrated that several of the previous IS curriculum recommendations and associated graduate competencies remain relevant. Generally, the competencies associated with BDA/AI education targets can be organized into three areas:

1. **Fundamental environmental competencies** that cover a) individual's cognitive and critical thinking skills, team skills, communication skills and problem-solving skills in addition to possessing b) both general business and organizational knowledge to align IT use with organizational needs and business value, and deeper domain knowledge at least in one domain (such as marketing, etc.)
2. **Data, information, and content management competencies**, including database, data analytics, data management and modelling, and business continuity and security competencies.
3. **System design competencies**, including programming and statistics, IT infrastructure, system architecture, systems analysis & design, system development and deployment, and project and system management competencies.

Different curricula at consecutive levels of education will cover and integrate these competencies at separate competency levels in varying proportions depending on the expected professional role and associated competency profile. Companies that focus on changes in improvement and transformation prefer to recruit people with competencies in data, information, and content management. Companies that have needs in changing the operations, products, or service would like new employees with systems design competencies. Companies emphasizing changes in strategies and tactics are more likely to hire people with better individual foundational competencies and business domain competencies. Moreover, top tier companies need the students with top tier skills and knowledge on BDA/AI. IS education needs to make it clear and easy for the students how they can obtain the skills sets that they desire.

Our analysis noted significant competency gaps between industry needs and current educational offerings in individual foundations (especially in domain competencies), data management, and design. Industry experts also noted new emerging needs in data security/continuity and deep technical/ analytical skills related to AI, and in related application development and design and execution.

Industry recognizes universities as main BDA/AI baseline competency providers, because of the current weaknesses in organizing such training in-house. Industry faces several key challenges of training: (1) high education cost, (2) no guarantee of learning performance, and (3) staffing limitations in training areas or resources. Generally, industry believes that universities can lay the foundation in the theories,

concepts, and the methodologies for their future training. Meanwhile, they expect more specialized training from universities, such as specific seminars, short-term AI/ML analytics trainings or classes, courses on refreshing the state of the art for certain technologies, or certification training for certain topics. The main challenge for university training is (1) how to develop experiential learning environments, lab-oriented learning, and design-oriented education; and (2) how to enable people who are at different stages in the careers and at different technical levels move to higher levels at a pace that works for the student. Moreover, we noted that industry have pointed out the significantly increasing trend in collaborating with commercial training providers, who provide both self-paced on-line learning and synchronous learning training.

The industry representatives also notified that the specific needs of BDA/AI education should be carefully considered when departments recruit future faculty. IS education needs to focus on the practice needs and demand and recognize the fast dynamics and the complexity of BDA/AI use, and guarantee that we have the right faculty to make teaching useful and meet the industry needs. Industry representatives stressed two major needs: (1) the need for a diversity of faculty, especially those with more technical skills; (2) the need for the faculty with cutting edge knowledge or skills, who can contribute to augment the limits of current faculty.

4 Recommendations Regarding IS Program Types and Competencies

4.1 Introduction

At the highest level of abstraction, the expectations for the IS graduates have stayed essentially the same since the birth of the IS discipline in 1960s. **IS graduates are expected to successfully contribute to and lead those organizational initiatives and operations that harness the transformative power of information technologies to serve current and emerging organizational needs and to realize novel opportunities to fulfill current or new organizational goals.** Obviously, both information technologies and business practices within domains where these technologies are used have changed during the last half a century and will continue to change drastically in the coming decade. Consequently, the mechanisms with which IS professionals can fulfill this general mission will continue to evolve. This creates a constant need for IS programs to adapt, evolve and diversify. Given the deepening and accelerating digital transformation—driven among others by the extensive use of BDA/AI technologies—now more than ever, IS graduates are expected to play a leading role in identifying, appreciating, and effectuating the impact of the IT-enabled organizational transformation.

Unlike most other business disciplines, Information Systems has a decades-long tradition of developing global curriculum recommendations for both undergraduate and graduate level degree programs. These recommendations (most recently, IS2020 at the undergraduate level and MSIS 2016 at the graduate level) have focused on articulating the goals and content of general (broad) IS degrees with possible specialization tracks that either emphasize the technical or the business side of the IS development cycle. This report, however, recommends that **the future IS curriculum recommendation work needs to be extended to include also focused undergraduate and master's degree programs within the IS space.** These cover, among others, business analytics, cybersecurity, digital design, and artificial intelligence areas. In addition, the IS community would benefit from articulating curriculum recommendations for an IS minor (at the undergraduate level) and IT focused MBA concentration (at the graduate level) as such minors are increasingly needed as parts of other business degrees such as marketing, finance, management (HR), or accounting.

Furthermore, the widespread application of IT solutions within virtually all walks of human enterprise suggests that **the need to understand the potential contributions of deploying digital technologies is not limited to those who seek to become specialists in information systems used in business.** There are important reasons to ensure that most students in institutions of higher education are prepared to understand how information technology can contribute to their domains of interest and expertise such as health care, nursing, engineering, architecture, journalism etc. Therefore, we will address in this report some of the ways in which the information systems discipline can seek to serve these populations of university students.

4.2 Specifying Programs with Competencies

To serve educational goals and needs of institutions operating in a broad range of contexts with varying expectations and availability of resources, we will draw on the notion of competency. **Competency articulates what the graduates of each program are expected to possess as an identifiable outcome against which the education delivery can be designed and evaluated**. Competencies as a whole express expectations that various stakeholders (particularly employers) pose regarding the graduates' ability 1) to perform as members of the organizations that they serve after graduation, and 2) to mature and advance as professionals toward increasingly challenging responsibilities and tasks. Generally, a competency refers to an individual's ability to integrate related knowledge, skills, and disposition(s) in ways that makes it possible for the individual to perform well in specific organizational role (such as business analyst) and expediently and effectively carry out related organizational tasks. In Phase II, we conducted rich semi-structured interviews with industry leaders with the intent to identify the IS and IT-related competencies that the industry needs, with a focus on BDA and AI. Based on the interview transcripts from this representative sample, we conducted a grounded theory analysis and identified a multi-layered structure of main professional competencies. (See Lyytinen et al., 2023 for a detailed description). In addition, we mapped the industry needs -based competency structure with competency areas earlier identified in MSIS 2016 and IS2020 to ensure the consistency with existing curriculum recommendations. We will next articulate competencies for several IS programs.

4.3 IS Program Types and Contributions to Other Programs

Tables 1, 2, and 3 apply the proposed framework for IS education offerings covered by the MaCuDE Task Force. The key elements of the framework are specified in sections 4.3.1, 4.3.2, and 4.3.3.

4.3.1 Program levels and types

We categorize the program levels and types in this report as follows:

1) *General education* (separately for all students[3] and those within a school or college, such as business);
2) *General IS degrees* (at both graduate and undergraduate levels; the target level of the current IS2020 and MSIS 2016 recommendations, including ug minor and MBA concentration);
3) *Specialized degrees* (at both graduate and undergraduate levels; includes programs such as business analytics, cybersecurity, and AI); and
4) *Non-degree courses and programs* (such as certificate programs and various types of micro-credentials); details are outside the scope of this report.

4.3.2 IS competency areas

These comprise functional or domain-based aggregations of sets of competencies related to a domain or dimension of specific professional role and related practices. The areas included in the framework synthesize competency areas identified and covered in IS2020, MSIS 2016, and the detailed analysis of MaCuDE Phase II industry needs report. The areas we include in this report cover:

- Data and Information Management
- Digital Transformation/Innovation/ Systems Analysis & Design
- IT Infrastructure
- Secure Computing
- Application Development/ Programming
- Ethics
- IS Management & Strategy, and
- Artificial Intelligence

[3] We recognize that many universities would face substantial challenges in getting a curriculum change proposed here approved and expected learning experiences implemented that would allow students to attain foundational BDA / AI competencies. For us, however, this goal is important enough to articulate in the overall structure even if it is difficult to achieve.

These competency areas and associated more detailed competency categories are defined in Appendix B. In Tables 1, 2, and 3 the competency categories marked with red labeling are those identified with the most substantial curriculum update needs based on our Phase I and Phase II results.

4.3.3 Competency levels

The competency levels specify the expected performance level for each Program level-IS competency area combination. We use a five-level scale of the competency levels adapted from MSIS 2016 consisting of Awareness, Novice, Intermediate, Advanced, and Proficient levels (see Appendix A for definitions of the levels). Each successive level in the scale indicates a higher level of independent professional responsibility and a higher-level ability to guide and engage others in the conduct of a role or a task.

Tables 1, 2, and 3 collectively specify target competency levels for the main types of IS programs and IS discipline contributions to other program types covered by MaCuDE mission[4]. Table 1 describes proposed IS competency levels recommended for all university students (see the related footnote above) and all business students, respectively. Table 2 summarizes and updates the competency levels for current undergraduate and graduate level general IS major curricula updated with BDA and AI components. As a new recommendation, we also propose competency requirements for the IS undergraduate minor and graduate-level IS concentrations. For the general IS degrees described in Table 2, IS2020 and MSIS 2016 offer additional detailed guidance regarding the competency expectations. We also illustrate the professional opportunities for which different degree types prepare their graduates with examples of typical job profiles.

Table 1. IS Competencies per Program Type: Contributions to Other Disciplines

		All undergraduate	All business undergraduate
Data and Information Management	Big Data Database Data Analytics Data Management	Awareness **Novice** **Novice** Awareness	Awareness Novice **Intermediate** Novice
Digital Transformation / Innovation; Systems Analysis and Design	Organizational transformation System Requirements Specification Syst Project Planning and Management Systems Design	Awareness Awareness	Novice Novice Awareness
IT Infrastructure	IT Infrastructure Systems Architecture	Awareness	Awareness
Secure Computing	Business Continuity & Info Assurance	Awareness	Novice
Application Development/ Programming	Systems Dev and Deployment Individual Analytics/Programming Skills[5]	**Novice** **Novice**	Novice **Intermediate**
Ethics	Ethics, Use and Implications for Society	Awareness	Novice
IS Management and Strategy	IS Management and Operations IS Strategy and Governance Enterprise Architecture		Awareness Awareness Awareness
Artificial Intelligence	Artificial Intelligence	Awareness	Awareness

[4] The columns that share the same background color in Tables 1, 2, and 3 represent the same program type.

[5] Based on the Phase II (industry needs analysis) results, "Individual analytics and programming skills", were defined as capabilities that individual professionals need to serve as productive members of teams of designing and constructing IT-based solutionsThis is a second-order category including "Programming" (Expressing and implementing systems requirements in a chosen programming language that can be executed as a solution as part of an IT application or infrastructure module) and "Statistics" (Developing and studying methods for collecting, analyzing, interpreting, and presenting empirical data) skills. We recognize that the component competencies Programming and Statistic/Statistical Analysis are different, but in our interview data the respondents frequently mentioned them together, leading to the combined second-order category.

Table 2. IS Competencies per Program Type: General IS Degrees

		IS minor	IS ug	MBA Tech	General IS master's
Data and Information Management	Big Data Database Data Analytics Data Management	Awareness **Intermediate** **Intermediate** Novice	Novice **Advanced** Intermediate Intermediate	Intermediate Novice Intermediate Intermediate	Intermediate **Proficient** Intermediate Advanced
Digital Transformation / Innovation; Systems Analysis and Design	Organizational transformation System Requirements Spec Syst Project Plan and Mgmt Systems Design	Awareness **Intermediate** **Intermediate** Awareness	Intermediate **Advanced** Intermediate Novice	Advanced Advanced **Proficient** Intermediate	Advanced **Proficient** **Proficient** Advanced
IT Infrastructure	IT Infrastructure Systems Architecture	Awareness Awareness	Novice Awareness	Novice Awareness	Advanced Intermediate
Secure Computing	Business Continuity & Info Assur	Novice	Intermediate	Intermediate	Intermediate
Application Development/ Programming	Systems Dev and Deployment Individual Analytics/Programming Skills	**Intermediate** Novice	Intermediate **Advanced**	Novice Novice	Advanced **Proficient**
Ethics	Ethics, Use and Implications for Society	**Intermediate**	Intermediate	Advanced	Advanced
IS Management and Strategy	IS Mgmt and Operations IS Strategy and Governance Enterprise Architecture	Awareness Awareness Awareness	Novice Novice Novice	Advanced **Proficient** Intermediate	Advanced Intermediate Intermediate
Artificial Intelligence	Artificial Intelligence	Novice	Novice	Novice	Novice

Table 3. IS Competencies per Program Type: Specialized IS Degrees

		Business Analytics ug	Applied AI ug	Business Analytics Master's	Applied AI master's
Data and Information Management	Big Data Database Data Analytics Data Management	Intermediate Intermediate **Advanced** Intermediate	Intermediate Intermediate Intermediate Intermediate	Advanced Advanced **Proficient** Intermediate	Advanced Advanced Intermediate Intermediate
Digital Transformation / Innovation; Systems Analysis and Design	Organizational transformation System Requirements Spec Syst Project Plan and Mgmt Systems Design	Novice Intermediate Novice Novice	Intermediate Intermediate Novice Novice	Intermediate Intermediate Intermediate Intermediate	Advanced Advanced Intermediate Intermediate
IT Infrastructure	IT Infrastructure Systems Architecture	Novice Awareness	Novice Awareness	Intermediate Intermediate	Intermediate Intermediate
Secure Computing	Business Continuity and Info Assurance	Intermediate	Intermediate	Intermediate	Intermediate
Application Development/ Programming	Systems Dev and Deployment Individual Analytics/Programming Skills	Novice **Advanced**	Intermediate **Advanced**	Intermediate **Proficient**	Advanced **Proficient**
Ethics	Ethics, Use and Implications for Society	Intermediate	Intermediate	Advanced	Advanced
IS Management and Strategy	IS Mgmt and Operations IS Strategy and Governance Enterprise Architecture	Novice Novice Novice	Novice Novice Novice	Intermediate Novice Novice	Intermediate Novice Novice
Artificial Intelligence	Artificial Intelligence	Intermediate	**Advanced**	Advanced	**Proficient**

Table 3 includes examples of specialized (focused) undergraduate and graduate programs, such as the currently widely offered business analytics programs. We also outline requirements for an emerging applied artificial intelligence degree program for undergraduate and graduate levels.

An on-line appendix (available at MaCuDE Final report online Appendix C.pdf) provides additional details regarding the process that led to these competency levels and the key sources that contributed to them.

For all other degree and IS contribution levels, we recommend that the IS community launches a new task force to develop detailed competency models and formulates more detailed technical guidance for curriculum goals and implementation.

4.4 New and Changing IS Competency Requirements

Our diagnosis of the current industry needs demonstrates that several of the long-term IS competency areas continue to form an essential part of the IS competency core for graduates majoring in IS. These include **competencies in data management, systems analysis & design, IT infrastructure, and IT management.** Generally, at a high level, it is critical for graduating IS professionals to prepare for and reach consequent competency levels in all these areas at a level that is consistent with the degree type and level. Yet, the competency expectations specified for each of these areas have changed significantly over time—even since the latest recommendations—and will continue to do so in the coming decade and adjustments to the levels need to be carried out consistently.

Recent technical and organizational developments within BDA and AI design and use have led to some drastic changes in the IS competency levels. Many of them go beyond what has been identified in the traditional core competencies in the general undergraduate and master level programs. Most of them either expand existing competencies in traditional core or introduce totally new competency areas. In particular, we note the following changes:

1. Generally, IS graduates need **stronger analytics and interpretation competencies,** including those related to statistical analysis and inference, storytelling, and visualization. Our industry leader interview data that IS professionals increasingly need data analytics competencies so that they can successfully contribute to BDA and AI projects.
2. **In data management**, **non-relational database technologies** are gaining popularity, and aspiring IS professionals need to attain competencies in them.
3. **In systems analysis and design, effective development and deployment of BDA and AI capabilities** rely on packaged solutions and programming language libraries, which are often a required part of an IT professional's set of competencies.
4. **In IT infrastructure, big data analytics and artificial intelligence** solutions are increasingly **integrated into large-scale organizational systems**. These require new competencies not only in developing one-off BDA/AI solutions but in designing them so that they serve as part of a larger system.
5. **IT infrastructures used for developing and deploying BDA and AI solutions are increasingly based on cloud services** offered by external service providers on their scalable computing infrastructures. Hence, competencies related to the **effective use of cloud services** have become highly valued.
6. **In IT management**, IS graduates will need competencies that allow them to execute and manage **new life cycle models in data management and data science**.
7. **In IT management**, IS graduates need competencies in **decision-making based on sound ethical principles as** to understand the implications of algorithmic decisions and to maintain their fairness and equity.

4.5 Individual Foundational Competencies and Domain Competencies

All graduates of **IS programs continue to need individual foundational competencies and domain competencies**.

In IS2020 and MSIS 2016, the individual foundational competencies that all knowledge workers need included the following elements. A great majority of them were recognized in the industry needs analysis during Phase II:

- Collaboration/Teamwork

- Negotiation
- Leadership
- Oral Communication
- Written Communication
- Critical Thinking
- Problem Solving
- Creativity
- Ethical Analysis
- Intercultural Competency
- Mathematical Foundations
- Lifelong Learning and Development and
- Ambiguity Tolerance.

These individual competency areas are defined in Appendix B.

The analysis of industry needs added to the list **Meta-learning** and **Systems thinking skills**. **Meta-learning** refers to building competencies in learning to learn, and this set of competencies continues to increase in importance, given the speed at which the technologies enabling organizational transformation change and have to be re-learned. Meta-learning skills are used for coping with future, still unknown, challenges. **Systems thinking** is useful for all knowledge professionals and particularly important for IS experts whose core competencies are all related to building systems. Systems thinking—according to Senge (2006, p. 73) "a discipline for seeing the structures that underlie complex situations, and for discerning high from low leverage change. Ultimately "[systems thinking] simplifies life by helping us to see the deeper patterns lying beneath the events and the details"—was one of the key competency expectations identified in the MaCuDE project Phase II industry needs analysis.

The analysis of industry needs emphasized the importance of **design thinking** at multiple levels and in multiple contexts for effective service development. We refer to design thinking as the systematic and principled use of design-oriented and human-centered principles and creative problem-solving methods that individuals and teams apply to identify and address business problems and advance consequent innovations (Lockwood 2010; Nagaraj et al. 2020). Design—creation of new solutions and alternatives—forms an overarching theme that cuts across all levels of the development and use of information systems. At the highest level of abstraction, design thinking competencies include several separate categories integrating organizational design, process design and technical (software, hardware, and systems) design. Within these large categories, there are several specialized areas of design that ultimately call for a detailed understanding and skillful application of design principles for developing and using BDA and AI solutions with an emphasis on imagination and exploration. The design perspective and its anchoring to design thinking in the development and use of BDA/AI is the unique contribution that the information systems thinking can offer among business disciplines. Indeed, the identity of the information systems field brings together computing competencies and domain competencies, allowing IS graduates to design and deliver useful and workable organizational solutions. In all design work, including that of using BDA/AI technologies, a solution-focused and action-oriented design mindset (see e.g. https://www.creativityatwork.com/design-thinking-strategy-for-innovation/) remains important.

5 Policy Changes Required for BDA/AI Curriculum Implementation

Successful implementation of IS curricula that prepare students well for planned organizational roles and tasks with new BDA and AI competencies **mandates numerous policy changes within academic departments and business schools.** The specifics of implementing the recommendations will depend ultimately on the characteristics of each unit's program portfolio, faculty competencies and resources. At the general level the following new policy requirements can be noted:

1. BDA and AI education require highly specialized faculty competencies that are now in short supply. Therefore, designing and delivering BDA/AI curriculum content demands a recognition that schools need to increasingly depend on **technically competent IS faculty. This**, in turn,

calls for **flexibility and reconsideration of priorities in hiring and tenure decisions**. Achieving a required level of technical competence may, for example, require hiring more faculty with an academic or professional practice background in a technical discipline, such as computer engineering, computer science, statistics, mathematics, or design science. In addition, universities need to be willing to provide opportunities for in-depth retraining in a broad range of subareas of BDA and AI and for flexible industry collaboration.

2. Offering BDA/AI curriculum content calls for **new and different types of technical environments and resources.** These demand significant investments and collaboration which traditionally have been in short supply in business schools. Large cloud-service providers (such as AWS, Microsoft/Azure, Google, etc.) offer complex and sophisticated BDA and AI service stacks as part of their cloud offerings. These encompass machine learning tools, natural language processing tools, tools to analyze conversational experiences, translation services, speech-to-text processing, vision, video processing, document extraction, etc. These services are not, however, inexpensive or trivial to use. We need tighter collaboration between universities, academic/professional organizations, and service providers to ensure that higher education institutions have access to contemporary technical environments and related capabilities to be able to teach students for today's environments and to allow the faculty members to learn to be effective teachers.
3. Offering and executing BDA/AI curriculum calls for **changes in degree regulation and the required common content of degree programs**. The learning experiences needed to develop graduates with sufficient technical skills are intensive and time-consuming, potentially requiring allocation of more time and real estate for the IS major within a degree structure than many other business school majors demand. This, in turn, will call for more flexibility and diversity between program types than current accreditation criteria allow. Collaboration between academic and professional societies such as Association for Computing Machinery (ACM), Association for Information Systems (AIS), American Statistical Association (ASA), Information Systems & Computing Academic Professionals (ISCAP), The Institute for Operations Research and the Management Science**s** (INFORMS) and others will be essential to agree on minimal requirements related to the technically intensive degree types. The collective and active role of the academic and professional societies will be essential in discussions with education regulators and accreditors, specifically, on politically sensitive topics such as the allocation of curriculum time/credits and defining topic focus. The academic and professional societies can play a constructive role in addressing the common interests of accreditors that operate in the same organizational context. For example, ABET accredits both information systems and data science programs, some of which are in AACSB-accredited business schools. Even though these accreditations take place at different levels (ABET at program level, AACSB at the school level), they both share a common interest in the quality of IS, analytics, and AI programs within business schools.
4. Offering BDA/AI educational programs demands **flexible governance and new organizational arrangements** across the university. Many of the new and revised degree types call for new types of collaboration across traditional disciplinary and school boundaries. Analytics and data science degrees in several universities have already led to new kinds of organizational structures and responsibility sharing between combinations of computer science, information systems, mathematics, operations research, and statistics. In such settings, it is difficult to avoid turf battles, but in most cases all parties will ultimately benefit from a collaborative mindset that leads to integrated program designs.
5. As discussed above in the context of the BDA/AI curriculum requirements, **design** needs to be one of the overarching themes and signature contributions of IS offerings. Indeed, designing and delivering BDA/AI curricula in IS requires the **integration of design thinking** as a dominant underlying principle reflected all aspects of an IS student's experience with educational program. This calls for innovating with **new pedagogical approaches** (e.g., expanded use of real-world based case scenarios, use of business lab environments, design of solutions for real industry needs)**, problem focused education,** and intense collaboration with industry.
6. To allow the graduates of IS programs to achieve the identified competencies during the study period, the IS programs need to pay specific attention to **not only BDA/AI curriculum content,** because offering and executing BDA/AI curricula needs to be founded on **experiential and problem-focused learning** that advances system thinking, meta-learning skills, and professional IS competencies.

Developing BDA/AI based educational programs forms an incremental curriculum revision process, where one **needs to consider the maturity levels of each school as the process is conditioned by the access to specific resources and experience contexts**. Schools in different digital stages can aim at different targets and then apply the curriculum approaches and pedagogical methods to get to the competencies that are suitable for their own environments. We fully acknowledge the difficulty and significant challenges in reconsidering priorities in faculty hiring and tenure decisions. The suggested policy changes are not "one size fits all"; instead, it is essential that each organization will carefully consider its own resources and constraints. For the schools that are experiencing a scarcity of technical talent or related resources, there are several ways to develop BDA/AI educational programs: (1) leverage the digital environment, the web-based capabilities, and online open training; (2) pursue the community-based resources, for example, in collaboration with AIS or other professional community organizations; (3) create a joint program or partner with online programs of other universities. Every business school needs to carefully consider how BDA, AI, and other emerging technologies enabling comprehensive digital transformation will impact their curricula. Specifically, those schools that have not done anything yet to address these issues must take immediate action so that they will not fall too much behind. Only this will enable attending students to gain relevant BDA/AI-related competencies that a students need in the professional career. At the same time, recognizing these competencies does not mean that traditional IS competencies (e.g., design thinking or IS infrastructure) will lose their significance. Instead, integrating analytics, AI, and other contemporary technologies with more established IS competencies will be the main contribution of IS programs to build the workforce of the 21st century.

6 Conclusion

This report builds on the systematic and foundational curriculum development and competency specification work done by the IS community over the past decades. Based on this work this final report of the MaCuDE project Information Systems Task Force identifies the core curriculum changes in IS degrees and related minors demanded by BDA/AI technologies. Carrying out changes recommended in this report will help business schools and other educational institutions in their efforts to educate future IS /IT professionals and prepare IS students and other business students with adequate technology and data skills to grow successful contributors to ongoing effort to digitalize organizations' products, processes and operations using BDA/AI applications. The report recognizes the specific need for all business students to gain a base level of Information Systems (IS) competencies including those related to big data analytics and artificial intelligence. It also outlines multiple degree types at both undergraduate and graduate levels that prepare IS graduates for organizational roles that require specialized expertise in integrating IS competencies, domain competencies, and individual foundational competencies. The report outlines a portfolio of degree types from which business schools can select those that best fit their resources and local needs, including specialized IS degrees focusing on applied AI.

BDA and AI technologies and their escalating use in the coming decade will significantly increase the technical competency requirements for IS graduates. At the same time, these changes have made it more important to understand the implications of their use on organizational systems and operations. BDA and AI applications also intensify the need for systems thinking, design thinking, and meta-learning as a resource for continuous change.

The report writers also surmise that it is essential for regulators (such as accreditors of business programs) to understand the growing need for intensive specialist preparation and the creation of new curricula real estate that industry needs. The report recognizes also changed resource needs, including the increased need for faculty who are technically competent in BDA and AI specialties and an access to advanced cloud-based services and scalable AI/BDA systems. Educating technically competent professionals who have an in-depth understanding of the business opportunities that new technical capabilities (such as BDA and AI) create is vital for future businesses, government organizations, non-profit organizations, and societies, at large. Therefore, it is essential that business schools seek to contribute to this education by educating both IS specialists in BDA/AI and by making sure that all business students gain a sufficient foundational understanding of the core transformational technologies. It is also very important that the business school community collectively recognizes the time required to develop advanced technical capabilities and the impact of these demands on curriculum time allocations.

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Appendix A: Competency Level Specifications

The competency levels used in the main body of the report are defined as follows (adapted from MSIS 2016 (Topi et al., 2017)):

- **At the Awareness level**, a graduate knows that the competency category exists and is aware of the reasons why it is important for the domain of practice and individual organizations that use information systems to achieve their goals. Graduates at this level have not yet reached SFIA[6] level of responsibility 1 (https://sfia-online.org/en/sfia-8/responsibilities).

- **At the Novice level**, a graduate can effectively communicate regarding matters related to the competency, perform component activities under supervision, and develop on-the-job experience related to the competency. This level corresponds closely to SFIA level of responsibility 2.

- **At the Intermediate** (Supporting in MSIS 2016) level, a graduate has achieved a level of competence that allows them to collaborate effectively in a supporting role with colleagues who have achieved a higher level of the competency to produce the desired outcomes. This level corresponds closely to SFIA levels of responsibilities 2 and 3.

- **At the Advanced** (Independent Contributor in MSIS 2016) level, a graduate has achieved a level of competence that allows them to perform without continuous support/supervision the tasks required to produce the desired competency outcomes. This level corresponds closely to SFIA level of responsibility 4.

- **At the Proficient level**, a graduate has achieved a level of knowledge and skills that allows them to perform in demanding leadership roles both as an independent expert and a leader of a team. This level corresponds closely to SFIA levels of responsibility 5 and 6.

[6] The Skills Framework for the Information Age (SFIA) refers to the global skills and competency framework for the digital world, developed and maintained by SFIA Foundation (sfia-online.org/en). SFIS is an experience-based and flexible framework, which is updated by real practitioners (mainly business and technology professionals) who advance the digital world.

Appendix B: Competency Area Specifications

Unless otherwise specified, the competency area definitions are based on the work by the MaCuDE IS Task Force. IS2020 and MSIS 2016 refer to the IS curriculum recommendations specified in the body of the text.

Table B1. Specifications of IS Competency Areas

Data and Information Management		Competencies related to gathering, organizing, curating, and processing data to help run an organization or extract actionable information to increase effectiveness (IS2020).
	Big Data	Competencies related to the acquisition, management, governance, and utilization of data resources characterized by high volume, velocity, and variety.
	Database	Competencies related to the use of various computing-based database technologies to address organizational needs for structuring, storing, retrieving, and managing data.
	Data Analytics	Competencies related to the use of analytical tools and techniques to extract meaningful and valuable patterns from data in a way that is valuable for the organizational context.
	Data Management	Competencies related to the organizational and managerial processes that enable effective and secure structuring, storage, retrieval, and analysis of organizational data.
Digital Transformation / Innovation; Systems Analysis and Design		Competencies related to the planning, discovery, and innovation processes with which organizations determine how to best use information technologies to advance their goals or pursue new goals and/or business models.
	System Requirements Specification	Competencies related to the identification, structuring, and documentation of the functional and non-functional information systems requirements.
	Systems Project Planning and Management	Competencies related to structuring IT-related development work in projects and managing them in ways that lead to desired outcomes in terms of system capabilities and the resources used by the project.
	Systems Design	Competencies related to expressing systems requirements with tools for functional and technical design to build a foundation for system implementation and deployment.
IT Infrastructure and architecture		Competencies related to the integrated planning, design, and implementation of an architecturally sound technical design for proposed IT solutions.
	IT Infrastructure	Competencies related to the planning, design, and implementation of an organized set of information technology resources and capabilities and interacting with associated communities that enable and support information systems functions and capabilities within an organization or industry.
	Systems Architecture	Competencies related to the creation and maintenance of a high-level structural organization and related decisions regarding organizational information systems components and their relationships including management of technical debt.
Secure Computing		Competencies associated with assuring secure business operations in the presence of adversaries, including the creation, operation, defense, analysis, and testing of secure computer systems (adapted from IS 2020).
	Business Continuity and Info Assurance	A subset of secure computing competencies specifically related to securing organizational data and ensuring the continuity of organizational business operations under all conditions.

Application Development/Programming		
	Systems Development and Deployment	Competencies related to the activities required to convert requirements and functional designs into systems that actively support the organization's pursuit of its goals.
	Individual Analytics/Programming Skills	Competencies related to the effective use of computing tools and techniques for constructing IT-based system components.
Ethics		
	Ethics, Use and Implications for Society	Competencies related to the planning, design, and implementation of environmentally and socially sustainable IT solutions aligned with principles of equity and social justice within organizations and societies and in compliance with legislative and regulatory requirements and industry standards (adapted from MSIS 2016).
IS Management & Strategy		Competencies related to operational, tactical, and strategic management of IT applications and infrastructures so that they are fully aligned with and support the achievement of organizational goals.
	IS Management and Operations	Competencies related to the ongoing management and operation of information systems infrastructure and systems solutions.
	IS Strategy and Governance	Competencies related to creating long-term plans for implementing and using organizational information systems to achieve current or new strategic organizational goals and objectives and develop associated business models (adapted from IS2020).
	Enterprise Architecture	Competencies related to the management of the structure of an organization's information systems and supporting technologies with long-term architectural design involving planning and integrating business, application, data, and technology architectures and maintaining them with desired qualities (reduction of complexity).
Artificial Intelligence		
	Artificial Intelligence	Competencies related to the use of artificial intelligence tools and techniques for discovering, designing, and developing advanced IT capabilities to support and automate organizations' operations and decision making that align with organizational goals.

Table B2. Specifications of Individual Foundational Competency Areas

Ambiguity Tolerance	Competencies that enable IS professionals to be adept and working with and adapting to ambiguous situations with incomplete information (IS 2020).
Creativity	Competencies that enable the production of "novel and useful ideas in any domain" (Amabile et al., 1996, p. 1155).
Critical Thinking	Competencies related to the analysis and evaluation of IT design and use issues to form a judgment of them by evaluating assumptions, making conjectures, and finding counterfactuals (adapted from Oxford Languages)
Collaboration/Teamwork	Competencies related to collaborating effectively with other agents in a team towards a common goal.
Ethical Analysis	Competencies related to determining what is right and what is wrong and "defining the practices and rules that underpin responsible conduct between individuals and groups." (Connock & Johns, 1995)
Intercultural Competency	Competencies related to developing "targeted knowledge, skills, and attitudes that lead to visible behavior and communication that are both effective and appropriate in intercultural interactions." (Deardorff, 2006)

Leadership	Competencies that allow an individual to act effectively to influence “the activities of an organized group in its efforts toward goal setting and goal achievement” (Stogdill, 1950)
Lifelong Learning and Development	Competencies associated with learning how to learn and continuous growth and development of related skills (adapted from IS 2020).
Mathematical Foundations	Competencies related to choosing and applying appropriate mathematical and statistical models and techniques to solve a broad range of problems in the domain of practice.
Meta-learning	Competencies related to learning how to learn and being reflective of and flexible in using alternative learning approaches.
Negotiation	Competencies related to acting effectively in contexts in which multiple parties are working to resolve their, potentially opposing, interests.
Oral Communication	Communicating effectively orally with a variety of audiences and stakeholders
Problem Solving	Identifying and defining a problem, developing solution alternatives, selecting a solution and implementing it.
Systems Thinking	Competencies related to improving “the capability of identifying and understanding systems, predicting their behaviors, and devising modification to them in order to produce desired effects.” (Arnold and Wade, 2015).
Written Communication	Communicating effectively in writing with a variety of audiences and stakeholders

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