

Are Information Systems and Computer Science Overlapping More and More?

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In this research, we posit the importance of including Computer Science topics in undergraduate Information Systems courses. A review of the existing literature has mentioned the importance of learning some Computer Science topics for an Information Systems career. Unfortunately, we have not found a consensus that could push this initiative. There is a set of concepts that Information Systems students should acquire from Computer Science or at least have a solid background in these areas. Therefore, we propose a set of courses from Computer Science that, we believe, should be considered in an Information Systems education.

INTRODUCTION

The field of information systems has evolved over the years, starting from understanding the business requirements, then continuing with the study of the needs of information management and the security of these assets. Subsequently, it evolved into an information system that needed to work with unstructured data and dispersed or missing information and had the need to extract useful information from the vast amount of data collected. Hence, with the advent of new technology trends in the business world, such as Big Data, Distributed Computation, and Business Intelligence, we are witnessing the overlap between two important branches in science: Information Systems and Computer Science.

The importance of data is remarkable today since they can be used to extract valuable information for different favorable and unacceptable purposes. The data can originate from various means or can be circumscribed to different types of organizations. In the research work of Gates and Matthews [9],

the authors established the importance that data has by reviewing different cases in which one can appreciate the value of the information that is extracted by analytic means.

ACM, according to their curriculum guidelines [13], established a set of core topics (Tier-1, Tier-2) and elective topics that a student should learn. One of these topics was the field of Intelligent Systems, which is closely related to the area of data analysis. These topics have evolved and formed the basis of a growing field known as Data Science (DS), which strives to get useful information from data collected by different means. For this reason, recently, some initiatives have emerged, such as the ACM Joint Data Science task force [7] that aims to create curriculum guidelines oriented to DS careers, which at the end are an evolution of the CS field. The point is that organizations have data, and they need adequate means to extract useful information from them, mostly driven by the desire to increase their competitiveness compared to their competitors.

Information Systems (IS) was one branch of computing that was formed to consider the flow of data by using Information Technologies inside the organizations. Recently, its scope changed rapidly and is now oriented to obtaining hidden information by analyzing patterns present in the data collected. Unfortunately, the changes in their curriculum basis have evolved in a plodding fashion. In contrast, other fields, such as CS have grown more rapidly to face computational solutions requirements in different areas. It is worth mentioning that we are not judging any curriculum guidelines related to Information Systems. Nevertheless, as the times have changed, there is the need for new knowledge on specific topics that certainly could be valuable for Information Systems students.

According to the research of Tatnall and Burgess [18], Information Systems refers to the study of the social and technical aspects that entail the use of information technologies (IT) within organizations, although, it does not necessarily involve the software development of these systems as in other fields, such as Computer Science. Additionally, the authors mentioned that this approach does not significantly mean overlooking the technical aspects of these technologies and the overlap that exists within areas such as Computer Science and Information Systems; overlap devised more than a decade ago [18]. This overlap is more substantial due to the new needs and trends that the current institutions have [8], and it supports the claim that Information Systems undergraduate education should be updated according to these unique needs and changes. As we mentioned, we center our position on making suggestions that could be deemed useful for future students of information systems as they face these current informational needs from organizations.

We also posit that there is a lack of integration between Information Systems and Computer Science, which is the main area in which other rising areas such as Data Science and even Cybersecurity are forming, and this is also mentioned in the research work of Topi [25]. For examples, Topi considers that, in the case of Data Science, the theories, techniques, and models are coming from areas such as Computer Science and Statistics. However, the IS area has become stagnant and is not showing progress in integrating these disciplines. Additionally, Topi mentions that apart from being educated on how big data fits into organizations, IS students should have, if they consider so, sufficient training in computer science and statistics. In another article [21], Topi refers to the IS curriculum guidelines from the ACM [26] and states how some fields related to computing, such as programming and algorithms, were ignored as core concepts to be learned by undergraduate IS students. These include skills that could help them to address some core information issues stated in the ACM guidelines [26], such as the processing and management of data within organizations. For example, organizations today are in the Big Data era, and they need to obtain valuable information from the data that they collect, which are in various structures and shapes. This information can be processed by using statistical, machine learning, big data algorithms, and computing skills in general. The undergraduates of IS careers need, at least, to have fundamental knowledge about these new trends, which are based on the classic models and techniques derived from computer science and statistics. We believe that this reinforces our hypoth-

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esis about the lack of computing skills that IS undergraduate students will need. As a side note, the mentioned article also focuses on computer science education research related to the teaching of these topics and how CS students could also benefit from the IS core subjects, such as IS project management or systems analysis and design.

DIFFERENT CURRICULUM NEEDS OF AN INFORMATION SYSTEMS UNDERGRADUATE CAREER: A SHORT REVIEW

THE LACK OF PROGRAMMING SKILLS AND EDUCATION RESEARCH

Programming is an unavoidable task that is embedded in many fields of science currently, such as Statistics, Mathematics, Biology, and even the Communication and Design fields. Concerning the inclusion of programming in IS curricula, we can mention the work of Topi [23], where he addresses the importance of the inclusion of programming topics within the IS curricula. In this work, Topi emphasizes that there should not be any excuses based on myths such that learning programming is a difficult task and is not the primary goal of an IS business career orientation. Furthermore, [23] explains how it would be helpful to understand and apply basic computing concepts

to the business environment. However, computing is still seen as an activity that could be delegated for outsourcing. The author also mentions that IS students can benefit from learning programming in the same way that they can benefit from learning computational thinking, which itself is embraced within the CS field. Additionally, it helps the person or student to solve problems in different areas. The knowledge of programming, algorithms, logical thinking, and using data structures as data repositories will significantly benefit the IS professional in gathering a more profound understanding of the computational processes involved and related to some business tasks, e.g., organizational processes. This knowledge seems useful not only to the students who will orient their careers towards systems development but also to any IS graduate. However, according to the ACM IS curricular guidelines [26], the topic of programming is not compulsory, and it is only needed if a student decides to pursue the Developer track in IS. We also state the importance that learning about the algorithmic parts of the Data Science techniques has for IS undergraduates. Related to this issue, Gil [10] proposed a way to teach these algorithmic parts without relying heavily on programming. The article suggests

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lecturing on a group of topics mostly focusing on parallelism in Data Science and Big Data, which, according to the authors, is a topic that is part of Data Science curriculums. The intention is to teach Data Science concepts from an algorithmic point of view and by using workflows instead of programming. However, we believe that nowadays, learning how to program should not be considered a burden because of the short learning curve of current programming languages and the explosion of a vast number of available libraries.

Furthermore, we believe that the programming field has significantly evolved, primarily because currently there are programming environments that allow the user to not get involved or distracted in details, but that will enable them to fully deploy and test their ideas. Scripting languages such as R or multiparadigm ones such as Python, with their simplified syntax and fast learning curves, have allowed many noncomputer professionals to implement their ideas without having a formal education in the field. If, for one moment, we consider that Computer Science is not only about programming, but rather is about algorithmic thinking, we can accept that Information Systems professionals could benefit from this. This involvement in the programming world, along with knowledge of algorithms and their implementations, could also help start an immersion into the analytic and programming parts of some computational data science models. These models, in some cases, need to modify or integrate add-ons to the existing libraries available in the market. Furthermore, we believe that the programming field has significantly evolved, primarily because there are programming environments today that allow the users to avoid getting involved or distracted in details, yet will enable them to deploy and test their ideas fully. Scripting languages such as R or multiparadigm ones such as Python, with their simplified syntax and fast learning curves, have allowed many non-computer professionals to implement their ideas without formal education in the field. If for one moment, we consider that Computer Science is not only about programming, but rather is about algorithmic thinking, we can accept that Information Systems professionals could benefit from this. This involvement in the programming world and a knowledge of algorithms and their implementation could also help start immersion into the analytic and programming parts of some computational data science models. In some cases, these models need to modify or integrate add-ons to the existing libraries available in the market to be deployed.

Concerning education research or research related to more effectively teaching CS and IS concepts, Topi [24] addressed the importance of rigorous research on educational issues related to IS topics in the IS field. In addition, more emphasis should be put on the IS education field. A thought-provoking example is the SIGCSE community, which is focused on the field of CS education, but the author also believes that people in the related area of IS should not be excluded from this type of community. We believe that the overlap between IS and CS covers formal undergraduate aspects such as core courses, but, as mentioned in this piece, the overlap is also related to the field of education. The IS community would benefit greatly from the advances in

pedagogical techniques developed in the field of CS education and could be tested for lecturing on different topics within the IS curricula.

THE LACK OF MATHEMATICAL SKILLS

For example, the Information Systems Curricula guidelines proposed by ACM mention that the mathematical foundations for students in this field should not be as deep as those for other computing professionals. From what we stated previously, the organizations need to extract information from data, and the way to do it is by using Computer Science—more specifically, Data Science models. The basics of these models are statistical and mathematical concepts that do not necessarily need to be fully understood for the goal of proposing changes to these models; however, the students need to have an adequate background on the concepts to know which are the most suitable for the work at hand. For example, the foundations of the neural networks used for prediction or data classification rely on Linear Algebra for the matrix calculations and Calculus as its core concepts. The student who knows these concepts will understand how this model works and in which cases a simple logistic regression could outperform a more complex, advanced model such as a neural network. Only by knowing these theoretical math-oriented backgrounds will an IS student be able to discretize between one model and another with more confidence.

THE NEED TO DEEPEN COMPUTER SCIENCE

In the field of CS, there was a proposal to extend CS undergraduate education to include the subject of Information and Knowledge management [2]. This extension was necessary so that a CS student would be able to internalize the processes within organizations and would be fueled by the increase in the amount of data in them. The core of this proposal was to make an incisive study of data organization and management with courses such as Database Organization, Information Retrieval, and Machine Learning. All these concepts were amalgamated at the end with practical management applications oriented to the real world with the use of existing technologies. As we can observe, there has been a fusion of three core bodies of knowledge: Computer Science, Information Systems, and Information Technology. Computer Science gives the necessary computational thinking and background while Information Systems applies the topics learned to real management situations and Information Technology deals with the use of current software tools.

NEW COMPUTER SCIENCE TRENDS WORLDWIDE AND THEIR RELATIONSHIPS WITH INFORMATION SYSTEMS: AN ANALYSIS

We have mentioned the importance that knowing topics related to Mathematics, Computer Science, and Programming has for IS undergraduate students, but what about the new trends that have been derived from CS in the last couple of years? CS has brought up two areas of interest, which are Data Science and Cybersecurity, both of which have had their curriculum

guidelines established by the ACM [6,7]. In this section, we have done a brief review of how these two new areas related to the organizations and how the IS professional must have a grasp of these new trends.

DATA SCIENCE

The boost of big data within organizations has brought the need to deal with techniques that could handle the three v's of big data: volume, velocity, and variety. In the research work of Chiang, Goes, and Stohr [4], the authors found that one problem regarding the use of software tools is that some packages applied to analytics have no support whatsoever for relational database management systems. Additionally, [4] mentioned a set of analytic skills that a professional in Business Intelligence and Analytics should possess, including knowledge related to fields such as data mining, geographical information systems, time series analysis, sentiment analysis, and the techniques learned in any machine learning or natural language processing courses in the field of Computer Science. We believe that even though this knowledge should be instilled in Information Systems undergraduate students, one main problem will be to what depth to address these topics. First, if we rely too much on the theoretical part, we will end up with a course biased for Computer Science students. If we push the course to only use techniques without knowing their theoretical caveats in-depth, we could end up with a dry subject where the student only uses a method to solve a business problem related to data and is disinterested in how it works. Both cases are extreme and should be approached with caution. We hypothesize that for new groups of Information Systems students, there should be a combination of the theoretical and practical aspects of these topics. They should know the basics and the theoretical caveats of the techniques learned, even at an intermediate level, and apply them to real cases and situations. Fortunately, the strength of the business-related courses and practicum in information systems education will help in this issue.

This related need regarding professionals in the field of data science and the skills required for the IS field has also been examined in the research work of Topi [25]. In this work, he addresses the increasing growth in analytics and graduate courses in this area of expertise over recent years. This article explicitly addresses the issue of how the subject of big data is positioned in an IS curriculum. One problem Topi mentions is that most

of the techniques in this area come from a well-established area such as Computer Science. Also, IS has not made significant efforts to include this subject in its curriculum. We believe in the need to include basic Data Science courses that are Computer Science oriented in these areas so that the students will have enough theoretical knowledge. Therefore, when they need to apply an information technology tool, adapted to the practice of the concepts learned, they will have more knowledge about why they are utilizing one technique over another. In [6], this contribution also points to an analysis of IS specialists' potential application domain. Additionally, specialists should acquire

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the intuition regarding when to choose one technique that would be more useful than another or even to try to expand one theoretical method, with expert help, to other areas related to Information Systems. In [25], the need for IS students to understand the technical part and the business or organizational part is also mentioned. Therefore, we believe that it could be worth adding the CS theoretical part. These theories will be useful to understand the backgrounds and bases of these technologies so that the students could successfully apply them to organizational issues, which is an idea that is also corroborated by Topi [24]. However, the

author considers that these topics depend on the background that the student wants to have, but we believe this should be required. In another research work [20], Topi addresses how this would be needed in the context of data analysis within the business world, which later could be useful when extracting meaningful information using Data Science techniques. He also addressed the idea that advocating changes in operational business processes is a difficult task, but one whose difficulty could be lessened by having a solid understanding of how to achieve the required outcomes from those processes. Concerning this part, process modeling is a critical point that could help in the integration with data science. We hypothesize that a similar situation can occur; conversely, when an IS graduate needs to apply machine learning (ML) or DS techniques, he will need to know the caveats of the methods used. This could lessen the time taken by trial and error and result in more robust knowledge of which techniques should be used for some scenarios.

The move to the use of Analytics in Business has surpassed Machine Learning and Data Science topics, reaching even the more general field of Artificial Intelligence. For example, in an opinion piece written by Topi [22], he shows the benefits that AI and Analytics could bring to organizations such as increased

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process efficiency, waste reduction, and better offerings of products and services. It also addresses the situation in which these areas of computing are leaving behind the traditional ways of managing information in the IS field. Additionally, he highlights the importance of CS as the driving force behind these changes in Analytics and AI, presenting the opinion that there may be no room for general IS programs because these careers do not consider the importance of computer-based systems that use analytics or AI. The author believes that there will still be roles for those IS graduate students who do not want to become experts in AI or analytics, such as in the integration field of joining these intelligent computer systems with information systems. Furthermore, he mentions that there could be enormous consequences for AI or Analytics systems with poor designs. To overcome this, we believe that the IS graduates should know the basics of these techniques, which also encompass the need to know more about different related subjects of a CS career.

There have been some successful attempts to connect the IS and DS fields. For example, in the research work of Benamati, Ozdemir, and Smith [3], the authors considered proposed curricular changes that consider the needs of the industry. In the work of Marttila-Kontio, Kontio, and Hotti [14], they manage a group of students who have their internships and master's theses within the context of business organizations focused on Advanced Data Analysis (ADT). In this schema, the students managed and conducted their research work by solving the needs of organizations and learning what is entailed. The organizations themselves get trained and even can assess themselves by using a maturity model. The schema appears self-paced and adequate for both interested parties, but the authors mention that one difficulty was in the education of future data scientists. Programming skills were required for the students, but this was not seen as a drawback for them because the selected students were from the Computer Science field. The experiment would have been more interesting if the authors had considered pure Information Systems students with the necessary business background but not necessarily the programming or computer science background. It is also remarkable that the authors found that most of the students lack mathematical education in fields such as statistics and mathematics, topics that are needed to understand the bases of a considerable number of models in DS.

There have been some proposals for teaching undergraduate majors and minors in data science, such as the research of Anderson et al. [1]. These authors considered three main topics: Data Science, Computer Science, and Mathematics. In the Data Science parts, students were taught preliminary introductory issues, and in the end, there was a capstone project. In the CS

part, programming and data structures were taught. Meanwhile, in the Mathematics part, students were trained in a mix of Linear Algebra, Mathematics, and Statistics.

For example, in our institution, we have a research course for undergraduate theses for students whose works are oriented to the CS or Data Science fields. We found that they have a hard time understanding when to use some Machine Learning or Data Science models, mainly driven by the lack of recalling

topics in Calculus, Statistics, or Linear Algebra courses taught in the first years of their studies. This lack of understanding increased substantially when the student used CS or DS models in a sort of trial and error way or what we call “picking apples” models. Furthermore, when we asked the students about the decisions made regarding the use of a technique or results' interpretation, we found that the theoretical grounds on which

their answers should be based were missing. We argue that the students must understand the theoretical bases of these techniques instead of just focusing on the higher layers of a solution for a problem. When the student knows the basics, the time it takes to determine the most successful model to apply to the problematic situation that they want to solve is shortened.

SECURITY AND CYBERSECURITY

The research work described by Ralevich et al. [17] proposes the implementation of a specialization in Information Systems oriented to Computer Security. This field was established because of the industry's needs and lack of specialization in this area. It was interesting to notice how the authors overlapped Computer Science core topics and Information Systems ones. Topics such as Introductory and Advanced Object-Oriented Programming, which, according to [26], were only for undergraduates who would like to pursue an Information Systems career as a Developer, were required in this model. Additionally, other topics as Operating Systems and even Cryptography were included in this undergraduate education. We believe that because of the need for Information Systems specialists who would like to acknowledge Computer Security topics, a set of required and elective courses should be included in Information Systems education due to the increased overlap of IS and CS topics. For example, to understand the concepts in Cryptography and Cryptology, it is necessary to have at least some knowledge of Number Theory, a subject offered in Computer Science courses, but now needed in Information Systems. We found, however, a small discrepancy with what was exposed in [17] since the authors decided not to include courses related to Artificial Intelligence or Machine Learning in their proposed undergraduate information systems security career, even though a group of students wanted the

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inclusion of these courses. These are topics that we believe are vital for obtaining useful data from significant volumes of information that the actual businesses manage; also, the inclusion of AI-related topics for detecting malware or attacks within the organizations is an evolving field since years ago.

The research paper of Taylor and Azadegan [19] proposed the inclusion of security concepts within different courses in the CS and IS curricula instead of just developing isolated courses. In the institution under discussion, IS students are required to pass CS1 and CS2 courses. This is relevant to the current proposal because the security concepts that the authors plan to teach rely on intermediate programming concepts. The same case can be brought up for the new concepts that IS students need to know to obtain a grasp of ML's basic concepts. For example, they should have enough knowledge of specific topics in CS.

RECOMMENDED COURSES PROPOSAL

The need for an integrated curriculum that joins the fields of Information Systems and Computer Science is not a novel one. For example, Anderson et al. [1] made a proposal in 2001. In this work, the authors discussed the need of a more technical IS career by considering some courses in the line of CS. This proposal aims to separate IS careers from the businesses approach but consider the technical part of CS in what they called a hybrid subject or CIS. An important point to consider is that the authors recommended the inclusion of programming, software engineering, computer organization, and Decision Support courses along with Artificial Intelligence. This proposal would help the students to get the technical part that they were missing in a pure IS education oriented to business or what is called MIS (Management Information Systems).

We believe that Information Systems should include a set of courses related to the following fields that mostly correspond to Computer Science:

- Discrete Structures,
- Algorithms and Data Structures,
- Machine Learning,
- Data Mining, and
- Distributed Systems.

In this part, we will examine how our proposal could fit into the Information Systems Curriculum Guidelines stated by the ACM [26]. According to this document, if we strictly adhere to their recommendations, we found that the following courses are necessary.

IS1) For all students: Foundations of Information Systems

IS2) IS Minor and Majors:

- Data and Information Management
- Enterprise Architecture
- IS Strategy, Management, and Acquisition

IS3) IS Majors:

- IS Project Management
- IT Infrastructure
- Systems Analysis and Design

Considering the curricula for national and international CS oriented careers, it is worth mentioning that some IS curricula are already offering some CS courses as compulsory or elective courses for their students. According to this, we will propose wherein an IS-related career could fit our set of proposed courses that we stated in the above paragraph. First, we will establish where the CS courses will fit along with the compulsory IS courses stated by ACM [26], with a set of compulsory and elective CS courses. This will help us to establish where an IS curriculum fits in our proposed CS courses.

To start, when we look at the description given in [26] concerning three of the compulsory courses, which are a) Data and Information Management, b) Systems Analysis and Design and c) IT Infrastructure, we can see that all three courses already have similar courses in CS education with d) Databases, e) Introduction to Software Engineering and f) Networks, respectively. This could help to limit the number of credits/courses that an IS student must take. In this way, the IS student will feel comfortable and will get a grasp of the field of CS.

In the ACM curriculum recommendations mentioned previously, the recommendations give a sample of the elective courses that a student can choose to obtain competencies in one of the 17 different career tracks. These guidelines recommend that there should be approximately 15 courses, including the foundational core courses mentioned in points IS1, IS2, and IS3, at the beginning of this discussion. One example of the electives that can be chosen [26] will leave us with approximately seven courses that could be replaced by the five courses in our proposal. It is worth mentioning that we can also use the remaining two courses that are left from the seven possible electives that a student could take to increase the credit hours of some of our proposed CS courses. Roughly, following this schema, we will have a set of courses that will comprise the following:

- a) Basics IS and CS courses
 - Foundations of Information Systems (IS)
 - Discrete Structures (CS)
 - Data and Information Management (IS)
 - Introduction to Programming (CS)*
- b) Intermediate IS and CS courses
 - IS Strategy, Management and Acquisition (IS)
 - Algorithms and Data Structures (CS)
 - IT Infrastructure (IS)
 - Systems Analysis and Design (IS)
- c) Advanced IS and CS courses
 - Enterprise Architecture (IS)
 - IS Project Management (IS)
 - Machine Learning (CS)
- d) Probable electives
 - Any from the list given in the ACM curriculum guidelines (IS)
 - Data Mining (CS)
 - Distributed Systems (CS)

* The Introduction to Programming course can be taken considering the programming background of an IS student.

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JUSTIFICATION FOR THE INCLUSION OF MATHEMATICAL AND STATISTICAL SCIENCES

For example, the Information Systems Curricula guidelines proposed by the ACM indicate that the mathematical foundations for students in this field need not be as deep as for other computing professionals. Due to the significant amounts of data that organizations extract and analyze, we believe that this will soon be changed since some core concepts in the fields of Machine Learning, Data Mining, and Information Retrieval need a sound set of background concepts such as Calculus, Linear Algebra, Probability, and Statistics. Those sets of topics that a few years ago remained specific for computer science undergraduates are now needed, at least in their basic form, for Information Systems students. For example, a review of material available for DS, such as the books of Goodfellow [11] and Hastie [12] and even the well-known online course material of Andrew Ng [16], shows the need to know the basics of these mathematical theories and concepts. We hypothesize that if students only know the novelties of a specific software tool, it will limit their capacity to make judgments and sound analyses of the information within organizations.

JUSTIFICATION FOR THE INCLUSION OF GENERAL DATA SCIENCE COURSES

Organizations deal with massive amounts of data from which they need to extract useful information. When students know the basic mathematical and statistical concepts behind different data science models, they will spend less time testing the diverse models and choosing the appropriate model for the task at hand. The data that the students will face in their daily labor will not be organized, unlike the data found in public repositories. So, the data will need to be cleaned, appropriately visualized, and analyzed using statistical methods to detect anomalies or patterns. For this part, statistical courses oriented to descriptive statistics and concepts from Data Mining, such as Data wrangling and the CRISP model, are needed. Once the data have been prepared, adequate classification, prediction, or pattern-finding models will be employed. These courses oriented to data manipulation and the application of statistical learning models have been confined to the field of Computer Science and in courses such as Business Intelligence in Information Systems education. Nevertheless, we believe that Information Systems graduates will need to know these topics and models to address the organizations' actual and future information needs.

JUSTIFICATION FOR THE INCLUSION OF OTHER COMPUTER SCIENCE COURSES

In this part, we will focus on describing how programming and computational thinking could aid Information Systems students in some of the tasks that they will address. Information Systems graduates should be able to conduct the information and management of IT resources within organizations.

The problems that could arise are from the business field, and they require a set of specific skills. For example, the Bloom Taxonomy is oriented to the analysis and synthesis of different organizational scenarios and the use of the Bloom Taxonomy to guide tasks to increase critical thinking among students in the business field has been studied by Nentl and Zietlow [15]. If we focus on these two tasks of the Bloom Taxonomy—analysis and synthesis—we see that they have a relationship with Computational Thinking Taxonomy; and these skills are related to the field of Computer Science, as stated in the research work of Collins [5]. In this thesis, the author mentioned a relationship between different levels of the Bloom Taxonomy and their respective matches in Computational Thinking. In the two levels that we indicated—analysis and synthesis—the corresponding complements are the abstraction of data, the abstraction of the functionality and decomposition for the analysis, and the algorithm design for the synthesis [5]. These two levels of learning and their relationship with computational thinking have inherent counterparts in CS courses. Let us consider the Computational Thinking skills of abstraction of data and functionality and decomposition. Some business processes and problems related to them simultaneously require a level of abstraction not to get confounded regarding the details and knowledge of how the different processes interact with each other, not to jeopardize the functionality between them. These concepts are taught in a Data Structures and Algorithms course, where the students learn to divide a task in a subset of multiple tasks that could be solved separately and that at the end would serve to solve the initial problem, e.g., the divide and conquer technique or dynamic programming algorithms. The same occurs with the algorithm design part, which is related to the synthesis domain. This part is also a skill taught in an algorithms related course, in which most of it is also related to programming tasks.

HOW IS THE SITUATION WORLDWIDE? A SMALL SAMPLE

We have gathered information about roughly twenty-five universities that teach Information Systems (IS) for related career—see Table 1. The criteria for choosing this sample of universities are that they have public information about their programs and appear in at least one recognizable university ranking system, such as THE, QS, or Shanghai records. We found some interesting material, in which there is no consensus on the recommendation of the courses for the Information Systems career—some of them leave a certain number of core courses recommended by the curriculum guidelines in IS [26] while having a bias to Computer Science (CS); and vice-versa. We have anonymized the names of the institutions and the exact positions in the world (extracted by the QS World University Rankings or The Higher Education ranking) or local rankings (United States or European rankings) in which they appear. Regarding the positions, we used an interval for not showing the exact location of those rankings.

Table 1: A subset of the universities that teach Information Systems related curricula

University	University Ranking (W)orld or (L)ocal	Description of the Program
A	>200 <400 (W)	Students only take one course related to Programming, CS, or Databases in the first year along with a Business Intelligence course and an extra course oriented to Software Engineering or Web Programming. One recommendation is to include some courses focused on programming and databases for the students majoring in Computer Science.
B	>200 <400 (W)	For the major, the student should obtain approximately 50 credits, including major courses and track requirements. The major courses cover the fundamental domain of programming, which can be reinforced in courses oriented to the internet or mobile application programming. The elective courses are oriented to tracks that are more business oriented.
C	>10000 <2000 (W)	The education is related to Information Systems but with an Engineering focus. It is not strange that it includes courses oriented towards the mathematical foundations of CS, and within the compulsory courses, the student should also take statistics and different programming courses. There are also a couple of courses in Data Science.
D	>600 <800 (W)	The focus is on the Management of Information Systems as a major track. There is only one compulsory programming course. The other CS-related courses are tailored to Databases and Communications with some courses in Systems Analysis and Design. There are no compulsory courses in Mathematics, Statistics, or Data Science.
E	>100 <300 (L)	From the compulsory and elective courses, one can see that courses oriented to programming, algorithms, and data structures could lead to a position as a Systems Developer. There are no compulsory or elective courses oriented to mathematics or statistics that could lead to the field of Data Science.
F	>100 <200 (W)	The program is oriented to the management part of Information systems. The number of programming courses is scarce, but there are some teaching foundations in the field of statistics. There are no courses oriented to CS that could serve as an entrance to the field of Data Science.
G	>800 <1000 (W)	The education is biased to Information Systems related to the business area, but the courses are heavily tailored to CS, ignoring compulsory IS courses.
H	>600 <800 (W)	The education is oriented to the management of information systems, but the CS courses are oriented heavily to the programming part. There are some math and statistics courses oriented to obtaining a business degree, but that is also compulsory for an IS major. There are some courses oriented to the field of Data Science embedded in the CS area.
I	>600 <800 (W)	This major is oriented to the IS guidelines from the ACM. Some basic mathematics courses seem to refresh previous knowledge in the area. The programming courses are oriented to specific software tools, so it seems that the programming concepts are taught using one of these programming languages. There are no statistical courses or courses oriented to Data Science.
J	<100 (L)	This program has the education tracks suggested by the ACM IS Curricula. Nevertheless, there are concentrations in Management and Security. They follow general courses related to programming without a background in Discrete Mathematics or Algorithms as with our proposal. The importance of these two topics in a CS career is widely known, but they are not considered in the curriculum.
K	>400 <600 (W)	This program covers almost all the courses of our proposal except for Distributed Systems; an Artificial Intelligence course replaces the Machine Learning course. The name of the education path has IS in it, but it only has two managerial basics courses and does not comply with the ACM IS recommended compulsory courses in this area. Due to the region in which this curriculum exists, this situation is relatively common.
L	>1000 <1400 (W)	The major contains courses related to discrete mathematics and programming. There are no formal algorithmic courses, and it only requires a basic stats course. Compared to our proposal, it is missing a basic Data Science course. It is valuable to mention that in the compulsory courses, there are only three courses that are related to the fundamental courses suggested by the ACM: one of these is related to IS Management, the second course is related to Data and Information Management, and the third one is related to IT Infrastructure. In this scenario, only half of the compulsory courses are taken, leaving behind the ones related to IS foundations, Enterprise Architecture and Systems Analysis and Design.
M	>400 <600 (W)	This major has four of the education tracks recommended by the ACM ISC curricula. It seems that their education considers a CS approach because they included Discrete mathematics, programming, and even AI courses. There is not so much information about the core IS courses, apart from a course similar to the Foundations of IS course, but there are some advanced courses in IS such as IS Strategy, Management, and Acquisition. Enterprise Architecture or IS Project Management is missing from the curriculum. Compared to our proposal, it is also missing courses in Algorithms, Data Mining, or Distributed Systems.
N	>1000 <1200 (W)	This institution has an IS program, but it appears to follow the vision of having a CS career because of the region where this was created. Therefore, they have not followed an international standard. More than half of the courses recommended by the IS curriculum guidelines are missing, corresponding to intermediate and advanced courses in this area.

Are Information Systems and Computer Science Overlapping More and More?

CONCLUSIONS

In this paper, we've proposed the thesis that the field of Information Systems is beginning to need more topics in the field of Computer Science so that their graduates will be able to cope with the organizational requirements and needs of current organizations. In the standard schemata of an Information Systems education, skills such as programming or the knowledge of intermediate or advanced topics in Computer Science, which could lead to understanding such fields as Data Science, have been relegated only to CS education. We believe that current organizations need information systems professionals who not only know the organizational parts of the business, but that are also able to extract useful information from the continuously gathered data. This need for information extraction is based on mathematical, statistical, and computer science models that Information Systems students need to know so that they can choose the appropriate model to fulfill the organizational needs. We believe that the Information Systems curriculum guidelines and core constituents should be deeply revised and modified—in the same way that the CS guidelines have been revised and adapted to new specialization fields such as Data Science and Cybersecurity. ❖

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DOI: 10.1145/3396367

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