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THE ROLE OF THE DISCIPLINE OF INFORMATION TECHNOLOGY: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Aim/Purpose	The goal of this publication is to explore methods for advancing student success in technology related disciplines via improved program classification and selection within higher education.
Background	Increased demand for information technology (IT) professionals has been cited as a challenge in many fields including cybersecurity and software development. Many highlight the challenge as not just a numbers gap but a skills gap when comparing industry needs to the curricula in traditional disciplines within higher education. Closing the gap by increasing the number of skilled graduates remains a critical challenge we must address.
Methodology	This publication leverages a systematic literature review to identify factors that classify existing higher education programs within the discipline of information technology.
Contribution	Research in this area can act as a catalyst to increase relevance of IT related programs as well as graduation rates in technology and engineering.
Findings	Authors analyzed forty-four primary studies and found that 56.8% of the publications referenced programs that meet the IT framework definition although they were not classified as IT programs. The findings and further analysis highlight direct challenges between program classification and the potential impact on student success.

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Recommendations for Practitioners	Research in this area is relevant for academic administrators, private sector executives and others working to increase the technology pipeline.
Recommendations for Researchers	Researchers may benefit by exploring thematic analysis as a means of generating relevant classifications and taxonomies that highlight opportunities for improvement in a broad set of subject areas.
Impact on Society	Research in this area can serve as a catalyst to increase graduation rates in programs related to technology and engineering.
Future Research	This area would benefit from further research by comparing program success rates within varied disciplines. Future research may also produce a classification process.
Keywords	information technology, systemic literature review, STEM, discipline, classification

INTRODUCTION

Information Technology (IT) remains a high-demand industry (Kannan & Swamidurai, 2021). As businesses embrace digital transformation initiatives, opportunities in IT-related fields continue to expand (Kannan & Swamidurai, 2021). As a result, the need for professionals educated in a broad range of fields including software development and cybersecurity continues to grow at a rapid rate (Kannan & Swamidurai, 2021). In contrast, the number of professionals available to fill the growing need in areas like cybersecurity is insufficient to meet today's demands (Kannan & Swamidurai, 2021). Part of the challenge in filling this gap continues to be the inability of higher educational institutions to fill the workforce pipeline with enough qualified graduates (Akdur, 2021). Shortages in positions such as information security analysts have resulted in a significant staff shortage as high as 69% in 2020 (Kannan & Swamidurai, 2021). Cybersecurity at large faces challenges filling 200,000 positions yearly (Oden et al., 2010). This gap extends to many other disciplines including software development, software engineering, and data science (Kross & Guo, 2019). We believe that one of the challenges of our time is to find ways to produce enough professionals to keep pace with the growing demand.

Unfortunately, this is not a new reality. Many researchers have devoted considerable time over the past decade to analyze this issue. Reasons vary from the draining population of available students that enter post-secondary education to the lack of relevant preparation in presecondary education (Frailey, 2011). Akdur (2021) and Breaux and Moritz (2021) believe the widening gap may be related to the incongruence between industry needs and the curriculum provided in higher education. Data from the National Center for Educational Statistics (NCES) (2022a) suggests that challenges amass due to the sheer number of students who leave STEM programs, either by changing majors or exiting post-secondary education. Although the Association of Computing Machinery (ACM; 2020) and Said et al. (2021) define IT as broadly including people, technology, solutions, and information, ACM (2020) classifies some areas that fit the broad definition of IT, such as cybersecurity, within a separate discipline. Further complicating the landscape is the fact that programs such as cybersecurity are housed within the discipline of engineering at many institutions (Parrish et al., 2018). Given the contradictory variations, an assessment of both IT and engineering disciplines is warranted. Figure 1 demonstrates a stark trend when analyzing the overall growth rate in the number of engineering graduates in the United States from 2015 – 2020. The growth in the number of engineering graduates dropped dramatically from 9,842 in 2016-17 to 1,808 in 2019 – 2020.

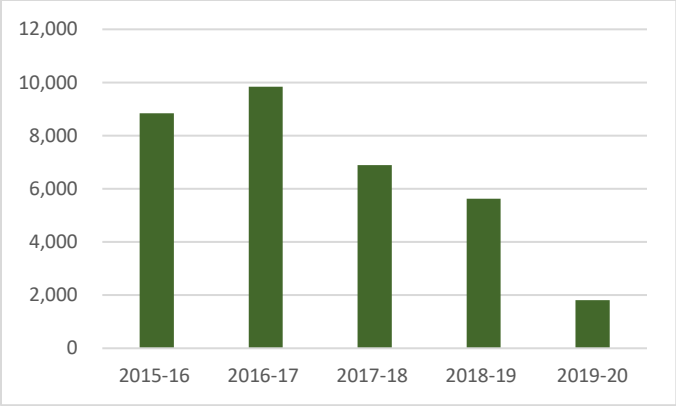

Figure 1. NCES United States STEM Degree Attainment Longitudinal Study Data
(National Center for Educational Statistics, 2022a)

A phenomenon exists when reviewing available government-curated data. In many cases technology is defined as a subset of computer science or computer engineering. Information technology is not identified as a separate discipline. NCES (2022a) for example conducts longitudinal studies across many disciplines and consistently subsumes technology within engineering and science. The table below shows no discernable recognition of IT as a separate discipline. One can also see in this table that only half of all students and less than a third of black students who pursue a degree in engineering or science persist through their undergraduate program.

Table 1. NCES STEM Degree Attainment Longitudinal Study Data
(NCES, 2022a)

	Attained bachelor degree	Attained associate degree	Attained certificate	No degree, still enrolled	No degree, not enrolled	No degree, left without return	Total
	(%)	(%)	(%)	(%)	(%)	(%)	
Science, engineering, and math (all)	48.9958	10.4094	4.1211	13.8993	‡	22.5743	100%
Science, engineering, and math (Black / African American)	30.5329	8.8300	5.9101	18.4473	‡	36.2797	100%

Parallel with the increasing need and decreasing growth rate in the number of graduates in fields like engineering (Kannan & Swamidurai, 2021), Said (2019) points out in the *Case Study: The Evolution of the IT Discipline in a Research University,* that a limited set of institutions acknowledge IT as a separate discipline spanning undergraduate and graduate education. The lack of a classification of Information Technology as a separate discipline may directly impact student pathways. Students unaware of the differences or deficiency of classification may opt to enter programs that lack a direct correlation to their true area of interest and to industry needs (Akdur, 2021). It is a broad question with a myriad of complexities that warrants a deeper analysis.

Accreditation Board for Engineering and Technology (ABET) established an accredited framework for IT in 2006 (Lunt et al., 2010), and ACM defined Information technology in 2020 as "the study of systemic approaches to select, develop, apply, integrate, and administer secure computing technologies to enable users to accomplish their personal, organizational, and societal goals (ACM, 2020)." The definition reinforces the understanding that the primary focus of IT is on solutions, closely aligned with user goals. This is further emphasized in the framework for IT as defined by Said et al. (2021). Although some institutions were early adopters of the evolving IT model, others continued to implement IT-related programs within traditional vectors such as computer science, information systems, or engineering. Even with the increasing number of IT programs, many institutions and other organizations classify IT within engineering, computer science, and other inherently different disciplines (Topi et al., 2010).

This paper hypothesizes that providing students with a clear understanding of the difference between IT, engineering, and computer science would help students select programs that more closely align with their goals and with IT-specific industry needs. Would students be better served and more successful by extricating programs from their traditional discipline and moving them to IT based on their definition, curricula, and institutional goals? As part of those broader questions, this study first attempts to ask the following:

> *What are the factors that classify a higher education program to be within the discipline of information technology?*

The goal of this publication is to identify pathways for program definition and affiliation within the field of IT. The authors believe that enhanced program classification will have a positive impact on student success by ensuring programs are more readily affiliated within the relevant academic discipline of IT. Research in this area is relevant for academic administrators, private sector executives and others working to increase the technology pipeline.

METHODOLOGY

This study uses a systematic literature review methodology (SLR) using the protocol defined by Kitchenham and Charters (2007). The SLR was conducted to identify higher education programs that meet the framework established by Said et al. (2021) consisting of people, information, technology, and solutions. Although broad, the definition established by Said et al. captures the key components and provides a roadmap for relevant search criteria.

The scope of the literature review and thematic analysis was limited to the following search engines: ACM Digital, Summon, and Google Scholar. These three search engines were selected given the breadth and depth of peer-reviewed technology related information available in each.

SEARCH PROCEDURE

The search was conducted to ensure parity in the criteria across the three search engines. Syntax adjustments were required based on the specific requirements of each engine.

SEARCH SCOPE

The search scope was limited to only those publications published in the year 2000 and beyond. The year 2000 was selected to coincide with initial efforts to create an undergraduate program in IT (Kashefi et al., 2018). Sources were intentionally broadened by leveraging the three identified search engines (ACM Digital, Google Scholar, and Summon). ACM is a large database comprising of studies conducted by researchers and professionals in the computing field. Through Summon alone the retrieval process accessed and searched over 90 databases spanning technology, engineering, math, social sciences, and medicine. Google scholar was leveraged as an additional search engine to expand

our search result. Guidelines outlined by Kitchenham and Charters (2007) were used to build a query consisting of the following joined criteria:

- (Customer OR people)
- (information AND solutions)
- (technology OR comput*)
- ("academic discipline")
- ("PHD" OR " MS" OR " BS" OR " BA")

The development of the search criteria was an evolutionary process as adjustments were made to the criteria to optimize the relevance of the rendered results. Standard Boolean operations were used to join relevant search terms. Key terms were joined by leveraging the AND operation.

Differences in search syntax and implementation across the different engines required further refinement by engine to ensure the production of relevant results. Google Scholar produced the most noise and the greatest number of publications that did not meet the criteria. Summon was limited to only returning peer-reviewed publications. The final search criteria and syntax by engine along with the number of publications in each stage is documented in Table 2.

Inclusion and Exclusion Criteria

Following the systematic literature review protocol defined by Kitchenham and Charters (2007), the study identified the following inclusion and exclusion criteria.

Inclusion criteria

- Publications must reference technology.
- Publications must reference one or more-degree programs classified as one of the following:
    - Information technology focused.
    - All Multi-disciplinary programs with or without information technology included as one of the disciplines.
- Publications must reference information and solutions.
- Papers published after the year 1999 to coincide with initial efforts to create an undergraduate program in IT (Kashefi et al., 2018).

Exclusion criteria

- Publications that focused on specific courses and not overall program(s).
- Non-English papers.
- Books.
- Publications with no direct relation to higher education.
- Publications focused on a specific industry or research topic or activities with no reference to academic disciplines.

To ensure the review was limited to relevant publications, a two-phase assessment was adopted. During the first phase, a review of the title and abstract to assess relevance based on the inclusion and exclusion criteria was conducted. A more detailed review during the second phase included the introduction section as well. Table 2 shows the studies identified using the search queries and the application of the inclusion and exclusion criteria.

Table 2. Query Syntax and Number of Publications

Source	No. of publications that meet the search criteria	Number after Phase 1	Number after Phase 2 – Quality Assurance
ACM Digital Query: AllField:(Customer or people) AND AllField:(and information and solutions) AND Abstract:(technology or comput*) AND AllField:("academic discipline") AND AllField:("PHD" or " MS" or " BS" or " BA")	**63**	**62**	**24**
Google Scholar Query: "academic discipline" and (people and solution) AND ("information technology" or "science") AND ("PHD" or " MS" or " BS" or "MA")	**482**	**63**	**45**
Summon Query: (academic discipline) AND (people) AND (Solution) AND (information technology) AND ((\(Phd or MA or MS or BS\)) OR (computer) OR (engineering))	**144**	**61**	**16**

Quality Assurance Criteria

The quality assurance criteria are defined in Table 3 following the protocol defined by Kitchenham and Charters (2007). The quality assurance criteria were designed to assess the relevance of each publication. Each publication was rated on a series of questions using a five-point Likert scale that ranged from not at all focused to highly focused.

Table 3. Quality Assurance Criteria Research Questions

Field	Attribute	Description
A1	Technology Focus	To what degree does the publication focus on technology?
A2	Degree Focus	To what degree does the publication focus degree programs in one of the following: BS, BA, MS, PhD?
A3	Academic Discipline	To what degree does the publication address an academic discipline in higher education?
A4	Info and Solutions	To what degree does the publication include a focus on information and solutions?
A5	Other Discipline	To what degree does the publication reference other disciplines such as computer science or computer engineering?
A6	Curriculum	To what degree does the publication focus on curriculum within a degree program?
A7	Non acad	To what extent does the publication focus on a specific topic outside the scope of an academic discipline?
A8	Non-Higher Ed	To what extent does the publication focus on education outside of the scope of higher education?
A9	Specific Course	To what extent does the publication focus on a specific course as opposed to a program?
A10	Post-Secondary	To what extent does the publication focus on presecondary education?

Analysis

The final 44 publications were considered the primary studies for analysis. Thematic analysis was used to analyze these publications. Airtable software was used to tag publications during the execution of the inclusion and exclusion process, tagging was implemented to identify both disciplines and programs within each publication. A publication was tagged as discipline only if the program of study was branded as academic disciplines within the publication. In parallel fashion, a publication was tagged as program only if specified as a program or area of study within the publication. Each publication could be tagged with one or more programs or disciplines. Programs and disciplines were stored in separate fields to ensure accuracy and provide more delineation during the analysis phase.

In congruence with SLR guidelines documented by Kitchenham and Charters (2007), we used the quality assurance criteria phase as an additional step in our selection process. Items that received a score below 3 were excluded which resulted in 44 publications selected for further analysis. The breakdown by percentage of relevance is outlined in Table 4.

Table 4. Percentage of Relevance by Question after Applying Quality Assurance Criteria

Technology	Degree Focus	Academic Discipline	Other Discipline	Info and Solutions
41%	36%	37%	32%	35%

Results

All publications used in the study were published between 2001 and 2022 with 2018 presenting the largest number of primary studies within a year at 15. We analyzed the primary studies using Airtable software. Airtable provided an efficient means of working collaboratively across researchers and reviewers to visualize data and gather insights. The publications referenced 24 unique disciplines and 50 unique programs or areas of study. Academic programs are defined in general terms as a collection of courses, while a discipline is broadly defined as broad area of study such as Information Technology. Programs and disciplines were identified as they were explicitly listed in the selected publications.

The analysis found that a significant number of the publications, 56.8%, identified IT-related programs as residing within academic disciplines other than Information Technology. It is important to note that 82% of the time, disciplines were referenced outside of IT. Only 9% (4) primary studies identified programs that were solely within the IT academic discipline domain and 43% of the primary studies identified programs that spanned Information Technology and other academic disciplines. Most frequently other disciplines included computer science, engineering, and information or applied science. There were in total 24 unique disciplines and 50 unique programs or areas of study (See Figures 2 and 3).

Programs related to Software Development, Programming, Software Engineering, and Information security were referenced most frequently. There were also notable references to Human Computer Interaction (HCI), Informatics, Artificial Intelligence (AI), Data Science, User Experience, Project Management, Modeling and Simulations, and Business Analysis. In many cases, the publications directly discussed the placement of these programs within specific disciplines (Kashefi et al., 2018).

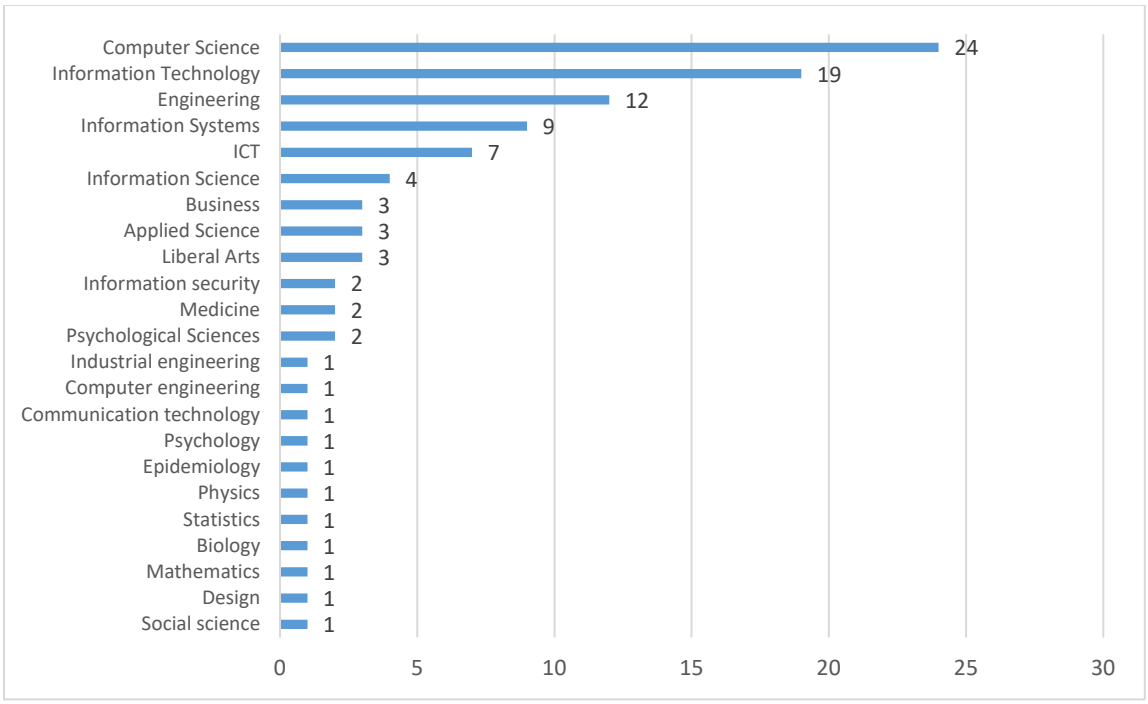

Figure 2. Publication Count by Discipline

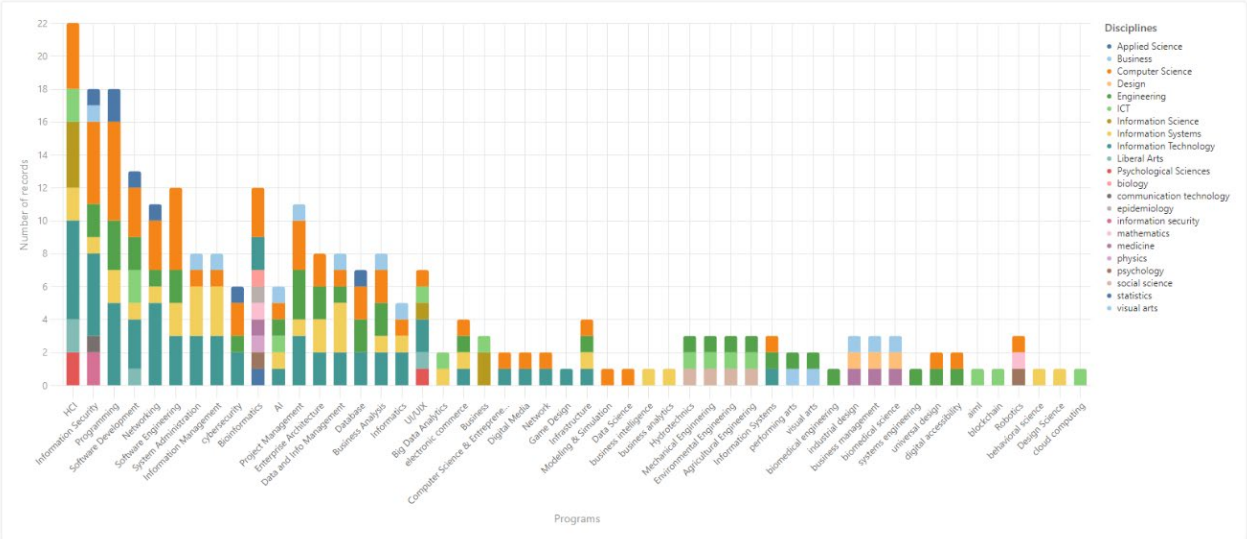

Figure 3. Programs by Discipline

A summary of the programs that included no reference to the discipline of IT is represented in Table 5. Although each of these areas referenced all the key criteria associated with the discipline of IT (Said et al., 2021) none of the institutions within the study population identified these heavily IT related programs highlighted in yellow as belonging within the discipline of IT.

Table 5. Programs with No Reference to the IT Discipline

Programs	
Behavioral Science	Hydrotechnics
Design Science	Mechanical Engineering

Big Data Analytics	Environmental Engineering
AIML	Agricultural Engineering
Blockchain	Industrial Design
Biomedical Engineering	Business Management
Business	Biomedical Science
Business Intelligence	Information Management
Business Analytics	Electronic Commerce
System Administration	Modeling & Simulation
Cloud Computing	Systems Engineering
Cybersecurity	Universal Design
Data Science	Digital Accessibility

The word cloud analysis in Figure 4 shows the most relevant terms when we analyzed both discipline and program information. Although expected terms such as information or computer are heavily weighted, there are many references to areas not historically associated with IT such as environmental, epidemiology, and biology. This may reflect the incursion of IT into other disciplines.

Figure 4. Most Referenced Terms by Discipline and Program

For further analysis, we leveraged depth as defined by Said et al. (2021) to mean an association with either the hardware layer, algorithm layer, or solutions layer. An additional tag was added to determine if each primary study was most associated with the hardware layer, algorithm layer, or solutions layer. Toward that end an initial assessment of primary studies for depth shows that although there is representation at each level, most of the 44 primary studies are tightly associated with the solutions layer. To decrease the amount of bias during this analysis, each author and an additional reviewer tagged each primary study. A three-point scale was leveraged to identify the associated layer (hardware, algorithms, or solutions). In some cases, the publication focused on more than one layer (i.e., algorithms and solutions) and in those cases we leveraged .5 increments to denote (see Figure 5).

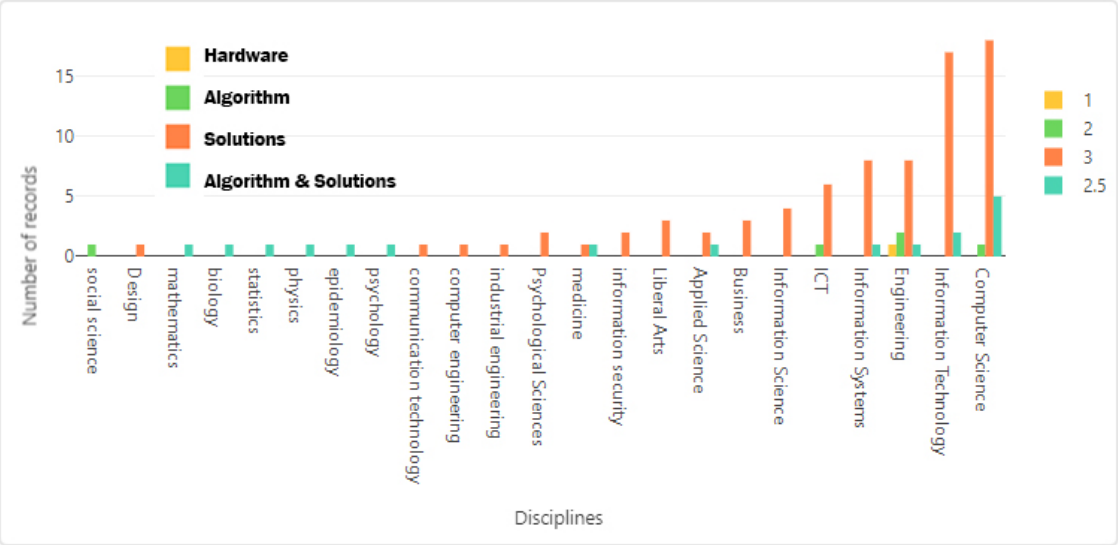

Figure 5. Disciplines by Layer

DISCUSSION

The results support the possibility that systemic classification has the potential to successfully identify programs that fit within the umbrella discipline of IT. This study finds that 52% (26 programs) do not identify as an IT discipline although they meet the broad definition of people, information, technology, and solutions (Said et al., 2021). In the case of one of the most referenced programs, Information Security, it is described as a meta-discipline where program placement is highly dependent on established goals and placement of programs within an institution [38]. Further reading of the primary studies reveals questions around placement based on institutional convenience versus an assessment of the disciplinary aspects of the program (Parrish et al., 2018).

For example, Kross and Guo (2019) summarized the challenges in classifying data science as a program within one or more disciplines. Fidoten and Spacco (2012) highlight recent evolutions in this area where professionals who identify as data scientists originate from a broad range of backgrounds and disciplines spanning engineering, computer science, IT, business, and liberal arts. It is also evident that definitions for some programs have broadened to include functions or areas of study that encompass multiple disciplines. As a result, the implementation of some programs such as data science warrant a deeper examination to understand if IT may represent a primary base for vectors within these programs.

MacKellar et al. (2015) address the topic specifically by providing a summary of the evolution of IT and Computer Science. The authors assert a definition of information technology as a focus on "all aspects of computing technology" while computer science is more focused on algorithm development. The authors further highlight the oversimplification in the definitions and the confusion it creates for both advisors and students who select the wrong pathway based on a lack of clarity and misinformation regarding their selected discipline. Data Science is a good example of an area where many institutions may define IT as belonging under the discipline of computer science given its emphasis on algorithm development. However, there are many data scientists whose role is focused on the use or application of algorithms as solutions for a multitude of needs. In this case, it falls more in line with the discipline of IT.

In *Skills Gaps in the Industry: Opinions of Embedded Software Practitioners*, Akdur (2021) discusses research related to the gap between industry needs and the curriculum used in many higher education institutions. Ironically, the disciplines identified include engineering and computer science but not IT.

Breaux and Moritz (2021) further emphasize the impact of this mismatch by highlighting the demonstrable shortage of qualified software developers during a period of increasing industry need.

Validity

This study adheres to the SLR guidelines as established by Kitchenham and Charters (2007) to provide assurance regarding the validity of the research. The authors leveraged best practices to ensure that the process used to gather and analyze the data was transparent and replicable. The search was carried out by two of the coauthors who split the search, criteria, and quality assurance assessment. The analysis of the 44 publications was conducted by both authors. To improve the overall conclusion validity, the authors expanded the analysis of the 44 publications to an individual external to the core research team. The analysis of the layer attribution (hardware, algorithm, solutions) was conducted by three reviewers including the two authors and one external reviewer. The accuracy of the layer assessment across the three reviewers showed significant congruence.

Future Directions

To achieve the goal of IT discipline classification, this study has opened the door to further research. Future research in this area should be expanded to include additional programs that may not have been captured during this systematic literature review. Future research should expand the years covered to include post-Covid analysis as well as publications prior to the year 2000.

Future research may also produce a classification process. The generation of a classification process requires more definition refinement to account for not just the breadth but also the depth within the discipline framework. More clarity regarding the impact of a given discipline on the solutions layer of the IT framework may open the door to better stratification and classification of disciplines. Programs that operate only at the hardware level, for example, may be excluded from the IT discipline. This study provides a base of both disciplines and programs upon which further analysis can occur. The impact of such assessments will be a roadmap for higher education students to select the right program and thus increase the number of professionals to combat the increased demand seen in the IT industry.

Conclusion

In summary, the discipline of IT continues to evolve as new technologies emerge and existing programs are redefined to meet today's increasing demand. As globalization and the acceleration of technology continues to expand, there is a deficit of professionals to meet growing needs. Industry and higher education institutions continue to work towards filling the widening gap. Key to that effort is ensuring there are clearly defined pathways that map educational outcomes to industry needs (Akdur, 2021). For more than a decade, IT has evolved as an academic discipline that, although recognized by accrediting bodies such as ABET (Lunt et al., 2010), is still fighting for broader use throughout academia.

The framework provided by Said et al. (2021) provides a roadmap for discipline classification that can serve as a catalyst to transition academia from decisions based on tradition to one that acknowledges the dynamic and emerging nature embedded at the core of IT. This systematic literature review attempts to take the next step by identifying a model that can be used to classify programs that would benefit as an established component within the discipline of IT.

This review demonstrates that many existing classifications exclude IT from programs and areas of study that clearly meet the framework of people, information, technology, and solutions. More research is needed to fully answer the question regarding a standard assessment or factors to define programs that belong to the discipline of IT. For example, expanded questions regarding the depth and scope of software engineering through the disciplines of engineering, science, and IT may lend

themselves to define software engineering as a program that spans all three areas of engineering, science, and technology. A further analysis will highlight what was described in the literature as an evolving definition of software engineering more focused on the application of solutions (Akdur, 2021).

In addition to the evolving definition of programs such as software engineering, we also see that references to information technology have increased over time. Figure 6 shows a time analysis of primary studies that referenced information technology as a discipline. From 2001 to 2022 we see an uneven increase in the number of publications that reference IT as a discipline. We also see an uneven decline in the number of references to computer science (yellow) and engineering (burgundy). For example, computer science transitioned from 5 references in 2018 to only 2 references in 2022. Given the limited number of years leveraged in this study, further analysis is needed to determine if the decline is an established pattern. The increase in references to IT however may demonstrate that academia is slowly transitioning towards an increasing adoption of IT as a discipline.

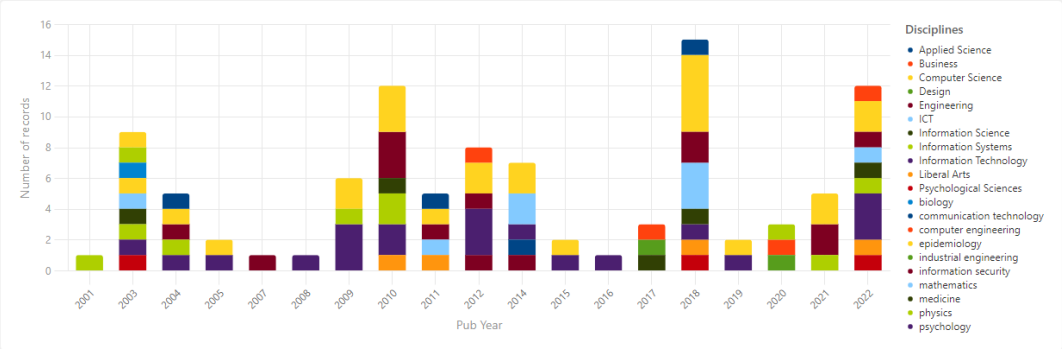

Figure 6. Disciplines by Year

This study highlights the varied classifications among institutions of higher learning and the potential impact such inconsistent stratification and definitions may have on student success. The study also highlights the lack of common definitions between higher education and industry. Students navigating the pipeline in technology and engineering will benefit from clear program definitions and discipline associations. The broad strokes provided by this systematic literature review provide a skeletal structure upon which a strong foundation can be forged.

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