A Data-Driven Assessment of the U.S. Health Informatics Programs and Job Market

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Abstract

Background Health Informatics (HI) is an interdisciplinary field, integrating health sciences, computer science, information science, and cognitive science to assist health information management, analysis, and utilization. As the HI field is broad, it is impossible that a student will be able to master all the diverse HI topics. Thus, it is important to train the HI students based on the offering of the various HI programs and needs of the current market. This project will study the U.S. HI programs, training materials, HI job market, the skillset required by the employers, competencies taught in HI programs, and comparisons between them.

Methods We collected the training information for the 238 U.S. universities that offered MS, PhD, or postbaccalaureate certificate programs in HI or related professions. Next, we explored the HI job market by randomly checking 200 jobs and their required skillsets and domain knowledge. Then, we compared these skillsets with those offered by the HI programs and identified the gaps and overlaps for program enhancements.

Results Among the 238 U.S. universities, 94 universities offer HI programs: 92 universities with MS (Master of Science), 43 with doctoral, 42 with both MS and doctoral, and 54 with certificate programs. The most offered HI courses are related to practicum, data analytics, research, and ethics. For the HI job postings, the three most technical skillsets required in HI job posting are data analysis, database management, and knowledge of electronic health records. However, only 58% of HI programs offer courses in database management and analytics. Compared with American Medical Informatics Association's recommended 10 fundamental domains, the HI curriculum generally lacks training in socio-technical systems, social-behavioral aspects of health, and interprofessional collaborative practice.

Conclusion There are gaps between the industry expectations of HI and the training received in HI programs. Advance level technical courses are needed in HI programs to meet industry expectations.

Keywords

- health informatics
- HI courses
- HI program competencies
- HI jobs

Background and Significance

Health Informatics (HI) is a field of study, defined as the *"integration of health care sciences, computer science, information science, and cognitive science to assist in the management of health care information."*[1] It is an interdisciplinary field, including the understanding of health care domain knowledge (such as various diseases), the workflow of health care environments, cultural aspects of health care, designs of

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the clinical information systems, manipulation of health care data, the discovery of new knowledge, and improvement of the user interfaces of electronic health record (EHR) systems.[2] Due to the broad field and interdisciplinary nature of HI, employers anticipate a job applicant in HI to have an in-depth understanding of multi-domains, especially in both health care and informatics.[3,4] Also, HI professionals need a strong foundation in analytics skills, knowledge of enterprise applications, and leadership skills.[5] Thus, it is critical to enhance HI programs and train HI students based on the current market needs.

In 2017, to set the competencies of master's level HI programs, the American Medical Informatics Association (AMIA) Accreditation Committee has developed 10 foundation domains in HI. They are F1 (Health), F2 (Information Science and Technology), F3 (Social and Behavioral Science), F4 (Health Information Science and Technology), F5 (Human Factors and Socio-technical Systems), F6 (Social and Behavioral Aspects of Health), F7 (Social, Behavioral, and Information Science and Technology Applied to Health), F8 (Professionalism), F9 (Interprofessional Collaborative Practice), and F10 (Leadership).[6] These 10 domains set the foundational expectation and requirements for HI graduate students, who should demonstrate the knowledge and skillsets in behavioral, social, information science, and health information technology (HIT).

One primary challenge for HI curriculum design is that students come from various backgrounds, such as medicine, nursing, computer science, information technology (IT), and engineering.[7] The primary tasks are to ensure students with different backgrounds and domain knowledge learn optimally for the required HI skillsets. For example, medical professionals have rich health care knowledge. Still, they might lack skills in computer programming, while students with IT background are good at application development while lacking health care knowledge. Hence, an HI program should have breadth and depth in the curriculum design from which all students from diverse backgrounds will be able to learn lacked HI concepts and skills. As described above, AMIA has developed standards and competencies for the MS (Master of Science) level of HI programs.

Despite the existence of such standards, no data demonstrate how the HI programs and their curricula fulfill the standards and requirements. Moreover, it is unknown whether HI curricula and the AMIA standards satisfy the dynamic changing HI market demands. This project is one step forward to address these two issues. First, we will perform a systematic program review and curriculum analysis of the HI MS and PhD degree programs in the United States, including the course work, required credits, accreditation status, program competencies, and learning outcomes. Second, we will perform market analysis to identify the overlaps and gaps between the demanded industrial skillsets and student learning outcomes in the HI programs by mapping the required industrial skillsets with those offered by the HI programs. This study will help students determine the right fit to select the appropriate HI program based on their skill needs and career goals. The results will provide valuable information for educational professionals and HI programs to improve their curriculum and enhance their programs based on the market needs to better prepare their students to be career-ready upon graduation.

Data and Methods

Overall Workflow

We collected real-world data of HI curriculum, programs, and jobs to generate new information, knowledge, and wisdom (data-driven assessment). We first gathered the universities based on the 2017 university ranking from Data.World,[8] which included 238 universities. Second, we searched each U.S. university that offered either an MS or PhD program in HI, biomedical informatics, clinical HI, or other program titles related to HI[9] (sample program titles are listed in ►Table 1). From the programs' websites, we summarized the courses, program competencies, learning outcomes, and other program information. Third, we identified the accreditation status of these programs by matching the programs with the accredited programs from the Commission on Accreditation for Health Informatics and Information Management Education (CAHIIM).[9] Fourth, we randomly selected 200 posted HI jobs from indeed.com[10] and Google Jobs across the United States. When we conducted our initial review of 100 HI jobs through indeed.com, we focused on the HI jobs in 10 big U.S. cities. To confirm our findings, we performed another 100 job searches. However, at this time, we used a different job search engine (Google Jobs[11]) and we did not limit our search to 10 big cities only. The rationale for the second search is to confirm our research findings from our first search. Natural language processing (NLP) was performed from the job postings to identify the requisite skillsets and domain knowledge for ideal candidates.

The collected information is integrated, along with data quality check and preprocessing. The skillsets and domain knowledge from the job requirements are then compared with those offered by the HI programs, which helped us identify the gaps and overlaps.

Data Collection for HI-Related Programs in the United States

We collected an initial list of university names using the Data.World university rankings in 2017,[8] which include the top-ranked 238 U.S. universities. By checking each U.S. university website, we found 94 out of 238 (39%) universities in the United States that offered degrees in HI, biomedical informatics, and health information management (HIM). We collected the following information about these 94 universities: office contact address, types of programs (doctoral program, MS, or certificates), accreditation status, admission requirements, program required credit, courses offered, program competencies, and learning outcomes. The accreditation status is obtained from the CAHIIM[12] for both HI and HIM programs.

Data Collections for HI Job Postings

We manually collected job posting information through Indeed.com[10] and Google Jobs[11] websites. To avoid personal biases in job searches, we used an incognito private window to ensure the return of jobs was not affected by those who performed the searches. Typically search engines use device's browsing history, locations, cookies, and site data to conduct personalized search which may cause biased searches related to HI jobs. Incognito does not utilize any browsing history, cookies, and site data stored in the device which will produce bias-free searchers of HI jobs. Our first job search using Indeed.com was performed in January 2021, and the second job search using Google Jobs in October 2021 to ensure the consistency in the job search.

For the Indeed.com job search (performed in January 2021), the keyword *"Health informatics"* was used to look for posted positions. We used the 10 biggest cities as locations in the United States to conduct this search: New York City, Los Angeles, Chicago, Houston, Phoenix, Philadelphia, San Antonia, San Diego, Dallas, and San Jose. The *inclusion* criteria are that all positions must have "health informatics" within the content and must be full-time. For the *exclusion* criteria, any position requiring any specialized license, such as RN (for Registered Nurse), MD (Doctor of Medicine), and PA (Physician Assistant), is excluded from the data collection. The duplicated job postings (the same job was posted in different cities due to multiple sites) were also checked and counted only once. For each city, we randomly collected 10 eligible job postings from Indeed.com (in March 2021) and 10 from Google Jobs (in October 2021) which have the following information: city, job title, company/university/government, the requirement of any license, educational requirement, domain knowledge, technical skills required (skillsets), responsibilities, and required years of work experience.

For the Google Jobs search (performed in October 2021), we are not limited by any geographical regions, but across the United States. In addition, the search keywords are not limited to "Health Informatics" as we used additional keywords similar to the program titles in ►Table 1, such as "Applied Health Informatics," "Applied Health Science Informatics," "Biomedical Informatics," and "Informatics Data Analyst." The modified search ensures more generalized search results and avoids the bias of the 10 big cities.

Data Cleaning and Generation

For the HI program data, we first cleaned the data by removing nonessential information, such as removing the course numbers and program abbreviations in the course listing. Next, we consolidated courses based on the course description. For example, the "Foundation of Health Informatics" and the "Introduction of Health Informatics" were considered as "Foundation of Health Informatics." Another data preprocessing is to categorize the degree programs by using program abbreviations. For example, both Master of Science programs and MS programs were categorized into "MS program." Similarly, the Master of Arts and Master of Public Health programs were organized into "MA program" and "MPH programs," respectively. For doctoral programs, the abbreviations of "PhD" and "ScD" were used for the Doctor of Philosophy and Doctor of Science, respectively.

Table 1 The grouping of MS in Health Informatics programs and the corresponding original program titles

MS groups	Original MS program titles
Health Informatics	Healthcare Informatics, Applied Health Informatics, Applied Health Sciences Informatics, Health Informatics and Analytics, Health Informatics and Data Science, Applied Public Health Informatics, Health Sciences Informatics—Research, Clinical Science: Health Informatics Track, Computer Information Systems: Concentration in Health Informatics
Biomedical Informatics	Biomedical Data Science and Informatics, Medical Sciences—Biomedical Informatics, Translational Biomedical Informatics and Bioinformatics, Biomedical and Health Informatics
Clinical and HI	Applied Clinical Informatics, Clinical Informatics, Health and Clinical Informatics
Health Information Management	HI Administration, Health Informatics and Information Management

Abbreviations: HI, Health Informatics; MS, Master of Science

As demonstrated in ►Table 1, the program titles in HI are very diverse, sometimes with a slight difference. However, the course work and program requirements are similar to a HI program. Based on the concentration of each program, three professors and four masters students in HI have examined the programs, discussed the similarities and differences of the programs, and finally grouped them into the corresponding categories. The same approaches applied to the masters, doctoral, and certificate programs. Based on the concentration of each program, we grouped the MS programs into four categories: (1) HI, (2) Biomedical Informatics, (3) Clinical and HI, and (4) HIM. Similarly, we grouped the HI doctoral programs into three categories: HI, Biomedical Informatics, and others. We grouped some programs into above-described categories because they offered similar course work which is consistent with the HI curriculum. For the HI certificate programs, we classified them into five groups based on the concentration that include HI, Biomedical Informatics, Clinical and HI, HIM, and others. The original program titles of each group are listed in ►Tables 1, 2, and 3 for MS, doctoral, and certificate programs, respectively.

Similar data cleaning and preprocessing were performed on the descriptions of required domain knowledge in the 200 jobs, which were grouped into the following categories: clinical information system and application, data analysis,

Table 2 The grouping of Doctoral Health Informatics programs and the corresponding original program titles

Groups	Original doctoral program titles
Biomedical Informatics	Medical Informatics, Biomedical Data Science, Biomedical Data Sciences, Biomedical Data Science and Informatics, Biomedical and Health Informatics, Health and Biomedical Informatics, Medical Sciences—Biomedical Informatics, Health Sciences Integrated Program, Informatics—Health and Biomedical Informatics Specialization
Health Informatics	Health and Medical Informatics, Personal Health Informatics, Clinical Science: Health Informatics Track, Health Outcomes and Policy Research: Health Informatics Track, Health Services Research: Health Informatics Concentration, Informatics: Emphasis in Health Informatics, Information Systems: Healthcare Information Systems
Others	Informatics

Table 3 The grouping of Health Informatics certificate programs and the corresponding original certificate titles

Certificates	Original certificate program titles
HI	Health Informatics, Health Informatics for Clinicians, Health Informatics and Data Analytics, Health Care Informatics, Health Data Informatics and Analytics, Health Data Analytics, Health Data Science, Public Health Informatics, Public Health Informatics for Leadership, Health Information Technology, Healthcare Information Technology, Health Informatics for IT Professionals
Biomedical Informatics	Biomedical and Health Informatics
Clinical and HI	Clinical Informatics Executive, Health and Clinical Informatics
Health Information Management	Health Informatics and Information Management, Health Information Security, Health Information Systems Architecture, Health Information Cybersecurity
Others	Dental Informatics, Pharmacy Informatics

Abbreviation: HI, Health Informatics.

database, medical terminology, and workflow. The expected responsibilities of job seekers were also classified into the following five categories: data analysis, reports, quality improvement, IT support, and application analysis. We utilized the Fuzzy LookUp function (Microsoft Research[13]) to automatically map the domain knowledge and job responsibilities to the standard categories as described above. The Fuzzy LookUp function is a fuzzy matching algorithm that matches lexical variants of a word such as abbreviations, synonyms, and spelling errors to the correct words. Two authors (J.S.P. and H.V.) independently reviewed the mapped domain knowledge, and job responsibilities to the standard categories and discovered that the Fuzzy LookUp function correctly mapped 98.2% (588/603) of words. They resolved the remaining 15 mismatched words through discussions and consensus.

Data Analysis and Data Visualization

Descriptive statistical analysis was performed on the collected data. The results were visualized using charts and illustrations. The program addresses were geo-coded to visualize the program distributions in the GIS (geographic information system). To visualize the information, Wordclouds.com[14] was used to generate word clouds for the course offering. Power BI (version: 2.90.1081.0 64-bit)[15] was used to visualize the geospatial information of program locations.

Results

Summaries of Health Informatics Program

Distribution of the U.S. HI-Related Programs

Out of 238 universities collected from the 2017 U.S. universities ranking, 94 universities (39%) offer HI-related programs. Not all the schools have all levels (certificate, MS, PhD), but most of them offer one or more of the three levels of HI programs, with program distribution illustrated in ►Fig. 1. Out of these 94 universities, 92 universities have an MS program in HI. In addition, 43 universities have doctoral programs, and 54 have certificate (mutually inclusive) programs. Fourteen universities offer MS and doctoral programs; 24 universities offer both MS and certificate programs; and 28 have all MS, doctoral, and certificate programs. In addition, two universities are offering certificate-only programs, and one university is offering a doctoral-only program.

►Fig. 2 illustrates the versatile location information of the U.S. HI programs. The mapped locations clearly demonstrated that the HI programs are concentrated in the northeast and southeast regions (61 out of the 94). There are very few schools that teach HI and related programs in the Mid-West (21 programs) and the West Coast (12 programs).

HI-Related Course Offering

A variety of courses are offered in HI-related programs. ►Fig. 3 shows a word cloud image of the course titles after course title preprocessing. The top 10 most common course subjects are Practicum, Data Analytics, Foundation of HI, Research Methods, Ethics, Database Management Systems, Health Policy, Machine Learning/Deep Learning/Artificial Intelligence (ML/DL/AI), Security, and Statistics. In addition, the Development of Decision Support Systems, Project Management, Clinical Informatics, Health Systems, and Programming are also popular HI courses offered.

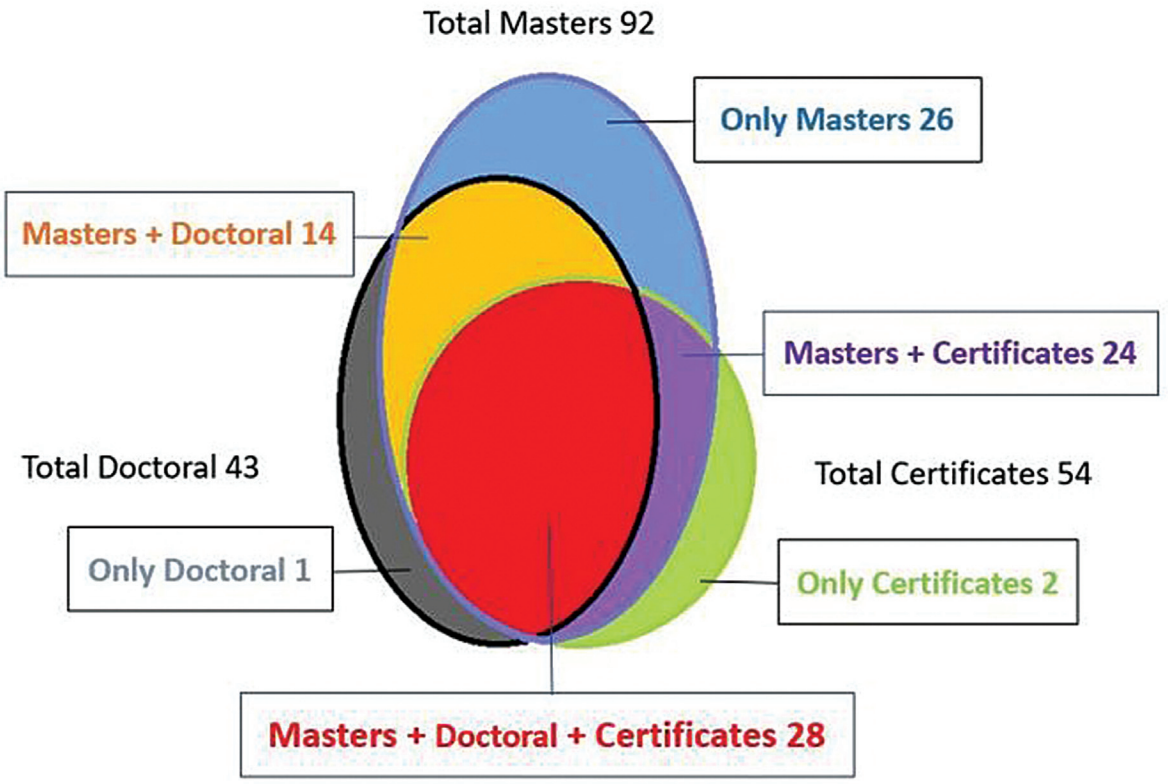

Fig. 1 The HI degree program distributions offered in 94 U.S. universities. HI, Health Informatics.

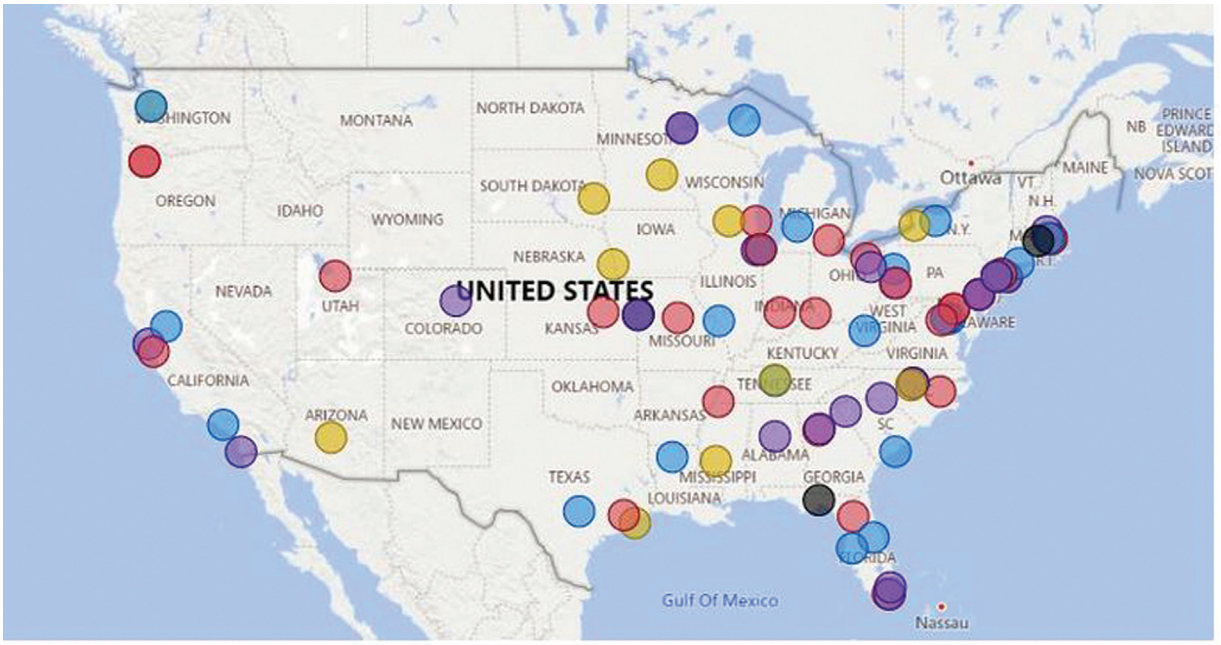

Fig. 2 The geospatial locations of Health Informatics (HI)-related programs in the United States.

It is worthy to note that the practicum courses include capstone, internship, thesis, and project courses. On another note, computer programming should be on top of the list. However, it was separated into multiple categories, such as programming software development, HIT, application development, NLP, and many others.

HI-Related Program Names

The 94 universities with HI-related programs have different program names, as illustrated in ►Fig. 4, for the frequency of the MS, PhD, and certificate program names. There are four popular names: HI, Biomedical Informatics, HIM, and Clinical and HI. The results also showed that "Health Informatics" is

Fig. 3 The word cloud image of the Health Informatics course titles offered in the 94 universities in the United States.

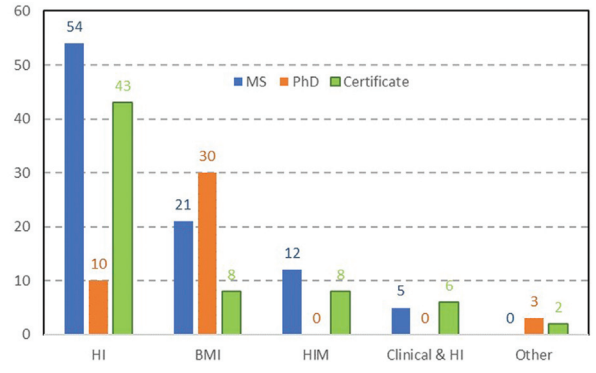

Fig. 4 The distributions of degree programs for different program titles in the 94 U.S. universities.

the most popular title for master and certificate programs while "Biomedical Informatics" is the most popular title for doctoral programs.

Credits and Units

There are two types of credit systems to meet the HI program requirements: the credit and unit systems. One unit is equivalent to 3.5 credits/semester hours. Out of the 94 universities, 90 universities (95.7%) follow the credit system, while the other four (4.3%) follow the unit system. These four universities are the University of Pennsylvania, University of Southern California, Yale University, and Columbia University, all private universities. Except for the MS HI program at Johns Hopkins University, School of Medicine, which requires 96 credits, all other MS HI programs required less than 62 credits. Thus, Johns Hopkins University's MS HI program is not included in the program credit analysis. ►**Fig. 5** illustrates the credit hour distributions among the different programs. The [minimum, maximum, average] of credits for the MS, PhD, and certificate programs are [30, 61, 38], [42, 135, 75], and [9, 24, 15], respectively.

Out of 43 universities with PhD programs in HI, four universities (University of Wisconsin, University of Minnesota, George Mason University, and Johns Hopkins University) required students to have an MS degree for their PhD admissions. For the rest 39 universities, applicants with a BS can be admitted directly to the PhD program. One university

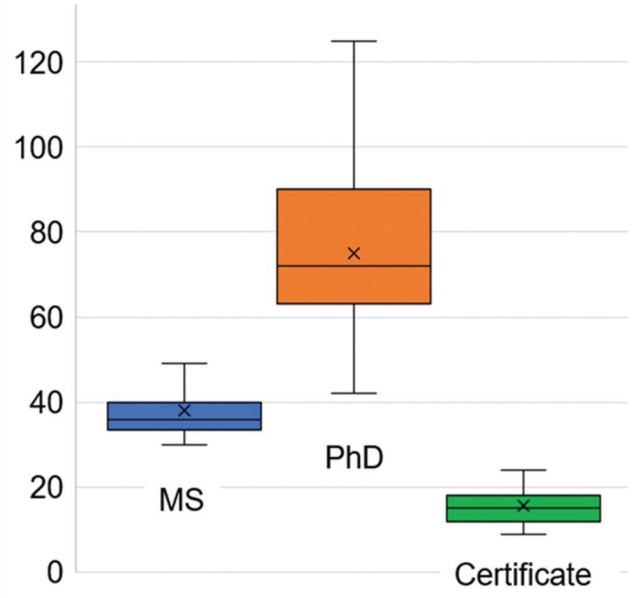

Fig. 5 Total credits distributions in Health Informatics programs.

(University of Iowa) provides an MS degree when a PhD student successfully passes the comprehensive qualifying exam by the end of the second year in the program. All PhD programs require students to complete the comprehensive qualifying exams to continue the program, followed by a formal proposal defense, oral examination, and dissertation defense as a part of their PhD curricula.

Program Competencies and Expected Learning Outcomes

We collect the program competencies and expected learning outcomes if the information is available from the program websites. Program competencies of HI are very specific on data and IT in the health care field. ►**Fig. 6A** shows that informatics and data are the most popular program competencies. Other common competencies are domain knowledge on management, analytics, clinical, research methods, systems, and technology. Expected outcomes also match the curriculum competencies: both have data and informatics as the most popular words (►**Fig. 6B**). Other common domain knowledge in both program competencies and learning outcomes includes management, clinical, research methods, and technology. Research methods is a topic of discussion as many HI researchers perform big data analytical research on digital health. Through checking on some available research methods syllabi, the research methods course teaches the methods used for HI research such as survey design, interviews, focus groups, epidemiological methods, systemic reviews, and meta-analysis.

Additional frequent program competencies and learning outcomes are privacy and security, application, development, and design. There are differences between the program competencies and the learning outcomes. The program competencies focus more on *general knowledge* of a graduate from the program, such as data mining, research, computing, and system development. In contrast, the learning outcomes focus on *specific skills and capabilities* of what a student will

Fig. 6 Health Informatics program competencies and expected learning outcomes.

be able to do, such as the words of practices, solutions, applications, implement, and development.

Results from Health Informatics Job Postings

NLP is performed on the randomly selected 200 HI job postings to identify the required technical skills, domain knowledge, job responsibilities, and expected experience in HI jobs.

Technical Skills Required in HI Jobs

The five most frequently required technical skillsets are database management systems, statistical tools (such as SAS, Tableau, Power BI), knowledge of EHRs, data visualization, and programming languages such as R and Python (see ►Fig. 7). For example, applicants are expected to know EHR applications, whether as end-users or directly through experiences in developing, deploying, and supporting vendor proprietary enterprise application software. Direct experiences in widely known EHR vendors are highly valuable, such as Epic, Cerner, eClinicalWorks, NextGen, and MediTech.[16] Other skills, such as business intelligence tools using Tableau or Power BI, are also highly sought.

Domain Knowledge Required in HI Jobs

About 41% of the HI jobs require applicants to have domain knowledge in clinical information systems and applications, data analysis, project management, medical terminology, and database management (►Fig. 8). Clinical information systems and applications are explicitly designed for use in critical care settings, which help manage information in electronic patient records to "reduce errors, improve patient safety, and support better patient outcomes."[17] Data analysis in health care examines current and historical high-quality clinical patient data to draw essential insights and accurate decision making. Project management helps plan and

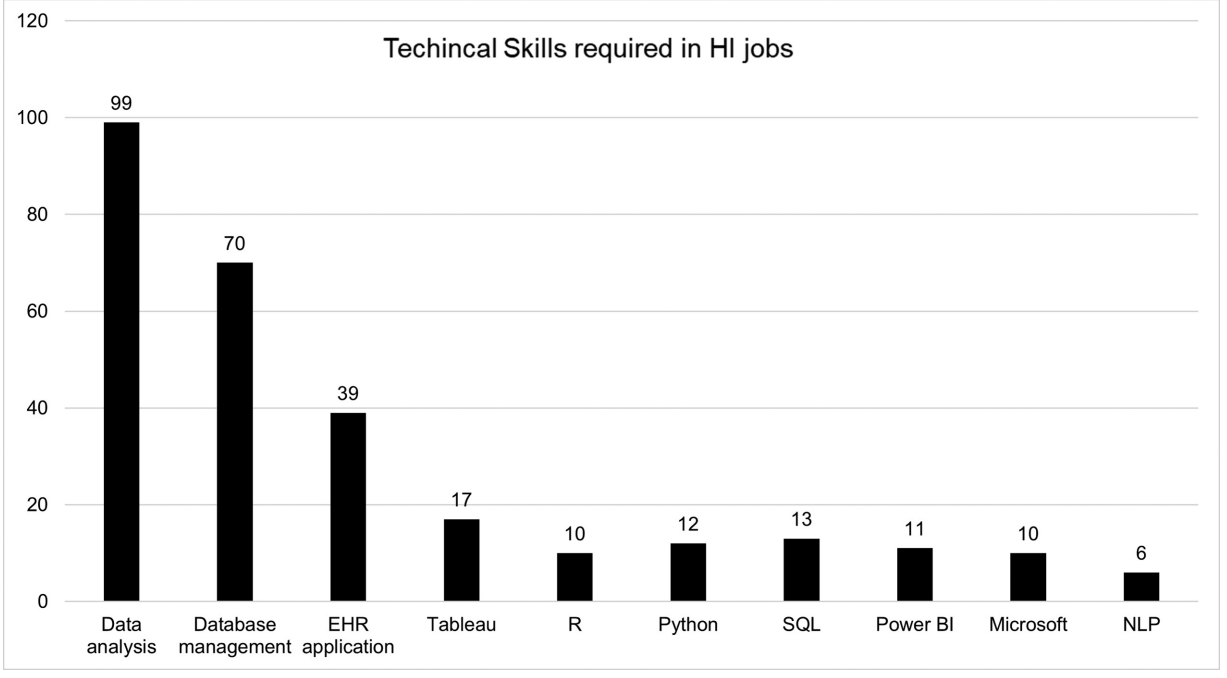

Fig. 7 Technical skills required in 200 health informatics jobs.

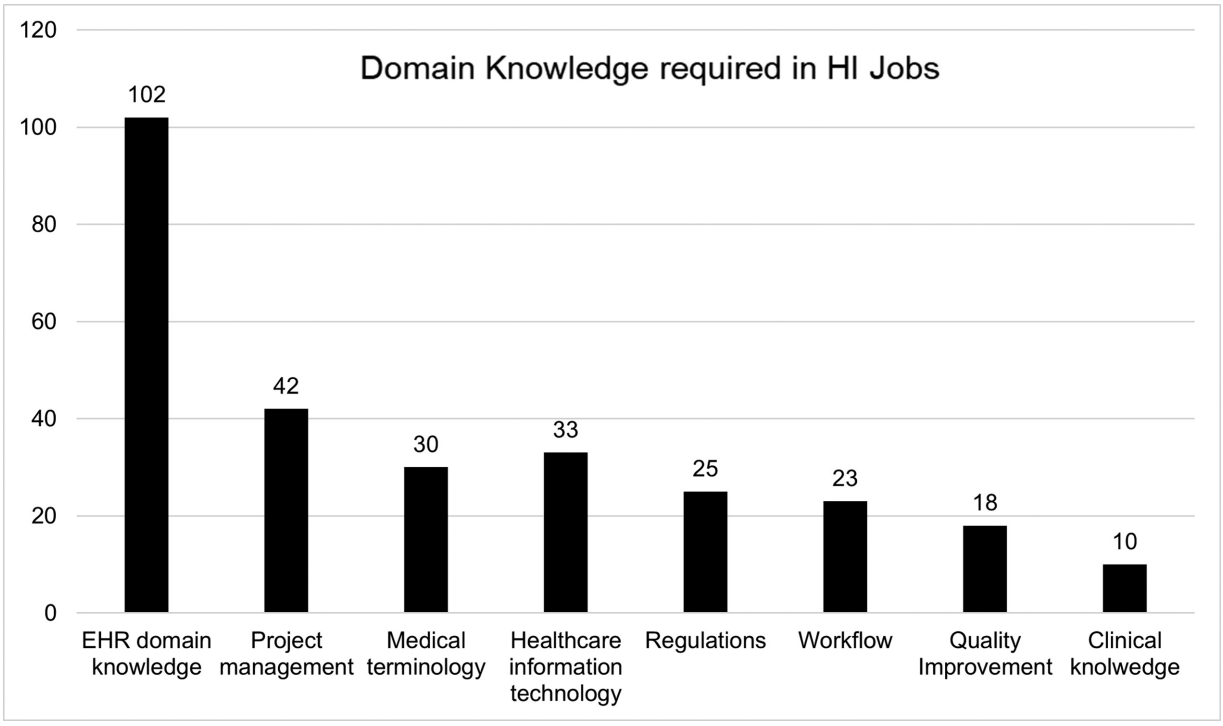

Fig. 8 Domain knowledge required in 200 health informatics jobs.

implement projects, define project scope and deliverables, manage team and budget, create schedule and project timeline, monitor and report on project progress, and evaluate and assess the project outcomes.[18]

Responsibilities in HI Jobs

The top two most demanded responsibilities for HI jobs are data analysis (44%) and reporting (33%) (►**Fig. 9**). For data analysis, the typical advertised tasks include collecting and

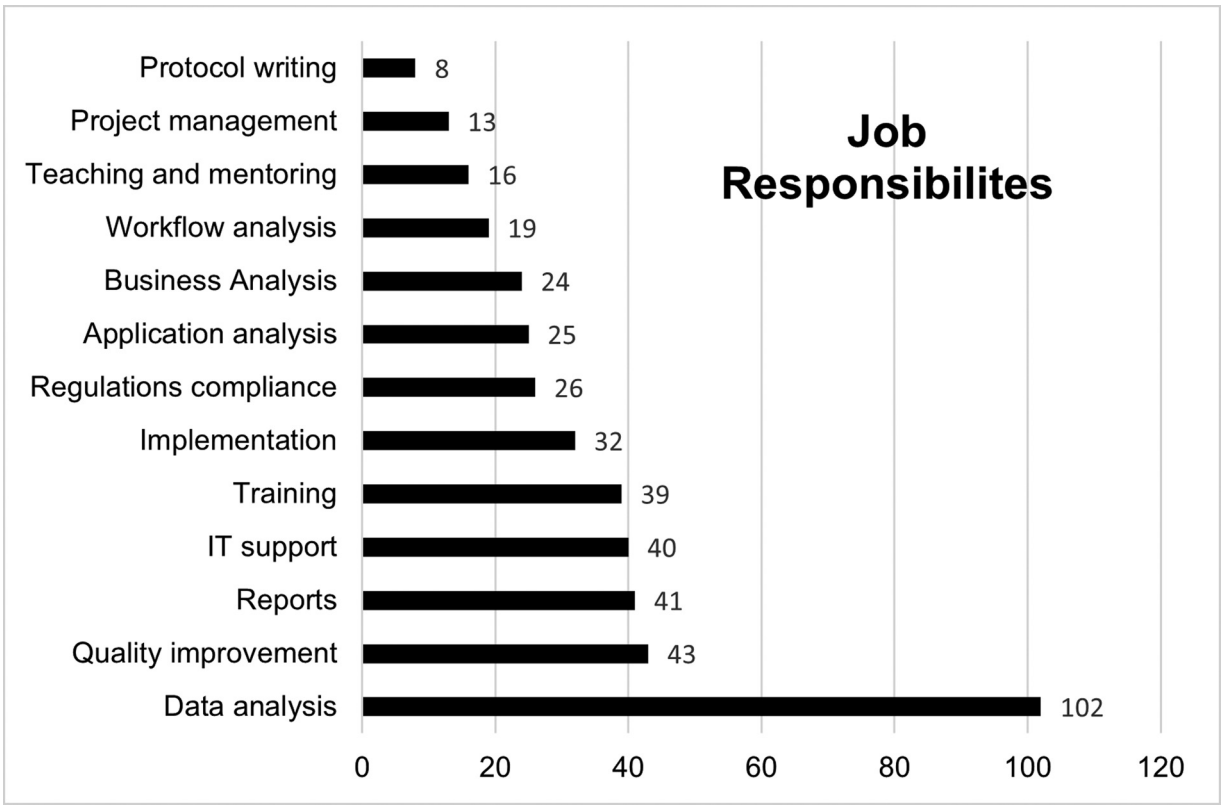

Fig. 9 Common job responsibilities in 200 health informatics jobs.

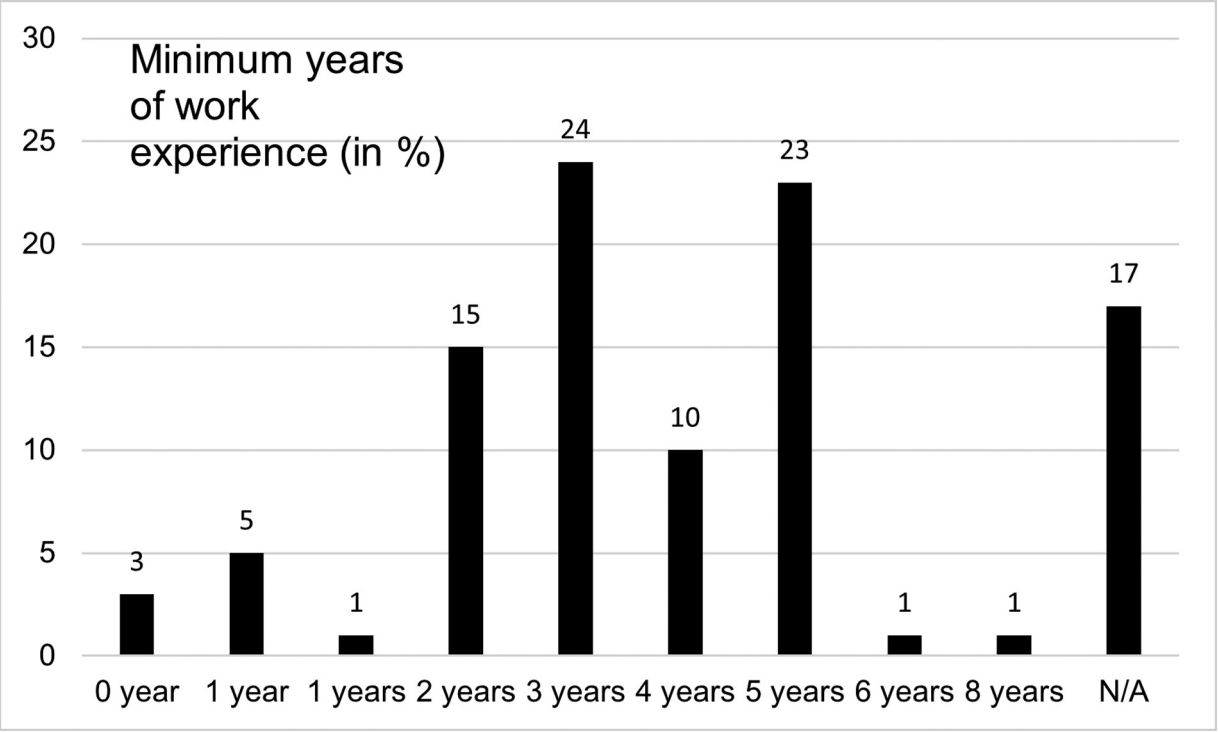

Fig. 10 Minimum years of work experience required in 200 health informatics jobs.

interpreting the data, analyzing results, identifying patterns and trends in datasets, defining new data collection and analysis process, etc. Reporting involves developing the reports (whether through writing or dashboard using business intelligence tools).

Other than the top two responsibilities, the next three commonly required HI job responsibilities are quality improvement (24%), EHR training (20%), and IT support (20%) (►Fig. 9). Quality improvement encompasses different tasks such as performing quality audits, resolving quality issues, and identifying quality improvement needs. The EHR training includes providing training of EHR modules to physicians, nurses, and other staff members. The IT support needs to maintain the organization's computer systems (both hardware and software), update systems and servers, and provide support for EHR systems to ensure a high level of productivity by hospital staff. We also found a few positions that required advanced data analytical skills such as NLP to mine unstructured EHR data.

Years of Work Experience in HI Posted Jobs

Depending on the HI positions, the required years of work experience varied significantly (►Fig. 10). At least 27% of the positions required 3+ years of experience. For HI jobs requiring 0 to 3 years of experience, the sample job titles are entry-level data analysts, associate application analysts, system analysts, and specialists. Mid-career (3+ years of experience) position titles typically are project managers, coordinators, and consultants. Senior HI jobs with 5+ years of experience are titled project developers, senior application analysts, and senior data analysts.

Comparison of Indeed.com and Google Jobs)

Most of the HI job responsibilities and skills requirements were similar between the Indeed.com and Googlejobs.com searches. In Goolglejobs.com, we found more jobs requiring advanced analytical skills to mine free-text data of EHRs and social media data to extract information in a structured format for further analysis. Moreover, in Googlejobs.com, more jobs were available for the entry-level health informaticians compared with Indeed.com, where the years of work experience varied as described above.

Discussion

This study aimed to review existing U.S. HI programs and identify gaps between the industry demands in HI jobs and the HI program competencies and learning outcomes.

First, we have identified the shortages of HI education opportunities. The high adoption of EHR systems across the United States has increased the demand for HI professionals. However, only 39% of U.S. universities are offering HI-related programs despite the heavy industry's needs. Especially, there are fewer HI programs available in the Midwest, Southwest, and West (except the West Coast) regions. Moreover, the medical field moves toward personalized patient care, which requires more HI skills and support. For example, ML and AI are increasingly adopted in developing models for disease diagnoses and treatment recommendations.[19] In addition, the hospitals have also developed learning health systems to learn from the data about quality assurance, performance, revenue, and patient satisfaction. These research skills, including critical thinking, analytics, and hands-on techniques, are mainly developed in doctoral

programs. However, only 18% of the U.S. universities have PhD programs in HI. Thus, strategic efforts in HI education should be taken, particularly at the government levels.

Next, we also discovered gaps in HI skills between industry needs and the HI training competencies. Real-world HI jobs require applicants to have hands-on technical skills, such as database management and health data analytics. The most popular technical skill advertised in HI jobs is database management. However, only 58% of HI programs offered courses on database management. In addition, most of these database courses are entry level and introductory. Thus, one recommendation to the HI programs is to provide more advanced database courses, particularly on NoSQL database platforms including Graph databases and Data Lakes.[20–22]

Third, this study helps us understand the key subfields to be improved in the HI curricula. AMIA recommended 10 fundamental domains (i.e., F1–F10 as introduced in the section Background and Significance) that HI graduate students should possess before completing their graduate program.[6] Out of these 10 fundamental domains, F4 (Health, Information Science, and Technology) and F2 (Information Science and Technology) are the two most prevalent in courses offered by HI programs. However, domains such as F5 (Human Factors and Socio-technical Systems), F6 (Social and Behavioral Aspects of Health), and F9 (Interprofessional Collaborative Practice) are scarcely offered in the HI curricula. Thus, another recommendation to the HI programs is to add courses in the three domains (i.e., F5, F6, and F9).

Fourth, this study has also recognized potential challenges for HI with different accreditation standards. Due to the widely spread topics in HI, one HI program will not be able to cover all the aspects of HI in depth. Instead, each program might have specialized focus areas. Perspective students learn about the field of HI from a variety of sources, such as accreditation agencies, program websites, social media sites, friends, coworkers, or someone within health systems, pharmaceutical, and insurance spaces. Current accreditation competencies and course offerings can be confusing for potential students with American Health Information Management Association (AHIMA) HIM competencies and AMIA HI competencies. The competencies from accreditation standards can be overly generalized and vague, which is good in leaving course designers and teaching faculty to develop fine-tuned learning objectives. On the other hand, it is challenging to balance the learning objectives for students with varied backgrounds with different clinical, administrative, and technical disciplines.

Last, students' educational and employment backgrounds also impact the course offerings in a HI program. For example, for students in health care professionals with limited computer backgrounds, more introductory courses, such as introduction to computer programming and database design, should be offered. Students can learn the foundational concepts of health IT for data modeling, data storage, and basic data extraction using informatics tools, such as MySQL Workbench and Microsoft Access.[23] On the other hand, students with an informatics or computer science background should have the options to introductory courses for health care and advanced analytics courses on health care data wrangling, data profiling, data mining, transformation, and learning from massive data using data analytics programs such as Tableau Desktop and Prep Builder, Microsoft Power BI, R Studio, and Python Integrated Development Environments.[23–25] Impacts from having bimodal class distributions in terms of foundational knowledge can be a driver to design advanced level database and analytics courses. Utilizing a variety of team science-based group work can help to bridge the gaps in foundational competencies.[26]

Moreover, we also attempted to compare and contrast the CAHIIM[27] and AMIA[6] standards and it would be critical to summarize the necessary abilities and required skills for HI professionals. CAHIIM[27] sets the standards for HI programs, but not the competency requirements. AHIMA[28] develops the knowledge, skills, and abilities for HIM programs. CAHIIM[27] and AHIMA[28] do not set the competency and abilities, and skills for HI. The AMIA[6] sets the knowledge, skills, and abilities and is directly mapped to HI curriculum learning objectives. Thus, having a comprehensive summary of the standards and competencies for HI based on both CAHIIM[27] and AMIA[6] will be appealing yet need more in-depth investigation. The topic itself is worth to be a separate paper, which we would like to perform the comparison and summary after this article.

Just like any other studies, this study has the following limitations. First, in the HI job study, we came across many jobs that only required either data analytics skills or computer programming skills which are more relevant to data scientists or computer scientists-related jobs. It is partially due to the language and terminology inaccuracy in job advertisements since "health informatics" is a loosely used term. We were unable to control this as the employers used the "health informatics" term in the job titles. Second, we excluded those HI jobs that required licensing such as MD or NP (nurse practitioner) which may have eliminated clinical informatics jobs component from our study. Third, we looked into only 200 HI jobs in 10 big cities. The results may not precisely represent HI careers at all geographic regions due to the location-specific profiles of health care industries. However, the detailed information extracted from these jobs helped us understand the current industry needs. Moreover, after 200 job searches, we reached to a saturation point and found similar information that has already been reported in these 200 job descriptions.[29]

Conclusion

We have studied the HI programs in the United States and the industrial requirements for HI jobs. This study identified the gaps between the industry expectations, academic program accreditations, and HI program competencies. Based on the reviews, we have provided recommendations on overall HI curriculum improvements and program enhancements. Generally, more technical courses are needed in HI programs to meet industry expectations. Further studies are needed for each program to understand the overlaps, gaps, and

challenges to enhance the HI curriculum for industrial requirements and accreditation standards.

Clinical Relevance Statement

We found the gap exists between the industry expectations, academic program accreditations, and HI program competencies. HI programs should add more technical courses, and training in socio-technical systems, social and behavioral aspects of health, and interprofessional collaborative practice.

Multiple Choice Questions

1. What training is essential for HI graduate students which is lacking from the most HI programs?
   a. Social and behavioral aspects of health.
   b. Data analysis.
   c. Statistical analysis.
   d. Research design.

   Correct Answer: The correct answer is option a, social and behavioral aspects of health. Compared with AMIA's recommended 10 fundamental domains, the HI curriculum generally lacks training in socio-technical systems, social and behavioral aspects of health, and interprofessional collaborative practice.

2. What are the major skillsets required by HI industry jobs?
   a. Database management.
   b. Clinical research.
   c. Data analysis.
   d. Computer programming.

   Correct Answer: The correct answer is option a, database management is one of the top skillsets required in the HI jobs.

Protection of Human and Animal Subjects

Human and/or animal subjects were not included in the project. Since this study utilized publicly available data and no protected human subject, Institutional Review Board approval is not required for the study.

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Conflict of Interest

None declared.

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