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Landscape of the Health Informatics Workforce
Rapid Response Brief

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KEY FINDINGS

Health informatics is an interdisciplinary field mixing science, innovation, and application. The ever-burgeoning health informatics field creates the need for a workforce distributed across multiple settings that can address the breadth of health information technology (HIT) functions and system interfaces while also keeping up with increasing demand for better integration and improvement of healthcare. However, the boundaries and areas of emphasis for this field are not always clear and frequently change, which creates ambiguity in defining a health informatics workforce. The workforce consists of a collection of professions and roles involved with health informatics at varying levels of administrative responsibility, patient service, and technology focus.

Using a framework identifying five subdomains of the health informatics workforce, this brief focuses on the clinical informatics and public health, population health and social service informatics subdomains. In addition to shared fundamental knowledge, basic skills, and a core vocabulary related to health informatics, most roles and job titles in the health informatics workforce can be associated with specific learning needs and educational requirements. Multiple pathways to careers in health informatics exist, ranging from continuing education opportunities to targeted education programs typically at the master's degree level.

Healthcare administrators and HIT leads, who often hold master's degrees, play influential roles in deciding which HIT to adopt and how to deploy HIT options. Healthcare workers in the fields of medicine, nursing, pharmacy, and clinical lab have recognizable education and career opportunities to specialize in informatics, with variation in oversight and curriculum development. In addition, public health agencies have engaged in informatics but using systems that have developed apart from electronic health record (EHR) systems.

With the growing urgency to address population health as part of healthcare delivery, driven by a move towards a value-based reimbursement model and the need to address the social determinants of health (SDOH), integrating public health and population health informatics with clinical informatics is increasingly important. Many SDOH resources and tools are emerging to support healthcare providers connect patients with services that address their social needs. Yet electronic health record (EHR) limitations and other structural factors challenge the effectiveness of these tools. In addition, patients in the community, particularly those from underserved or marginalized populations, face barriers accessing HIT systems due to limited broadband, digital health literacy, and other technological challenges.

The health informatics workforce's breadth and rapidly evolving nature make it difficult to define and track in the aggregate. Nonetheless, addressing gaps where data are not presently collected or standardized and assembling the pieces are important to illuminate the strengths and needs of this integrated workforce that plays an important role in leveraging technology to improve patient and population health.

HEALTH INFORMATICS CONTEXT: DEFINTION AND SCOPE

Health informatics is an interdisciplinary field mixing science, innovation, and application, which makes defining health informatics and its scope challenging. Boundaries and areas of emphasis for this field are not always clear and frequently change, which creates ambiguity in defining a health informatics workforce. Health informatics is an evolving specialty that connects communication and technological advancements with healthcare needs to improve patient safety and quality of care. Health informatics also aspires to enhance collaboration between various providers of healthcare services as well as improve patient engagement and empowerment. The ethical call, and in many cases a requirement, under the Health Insurance Portability and Accountability Act [HIPAA] of 1996 to keep sensitive data confidential and safe, accompanies the use of health information technology (HIT).[1] This brief provides a short overview of the health informatics field to help situate and understand the landscape of the health informatics workforce, including the occupations, roles, educational and training pathways, and interconnectedness of these workers in achieving health equity. This brief also highlights the barriers to developing a cohesive health informatics workforce and the gaps in our knowledge of the health informatics workforce.

The process of organizing, storing, integrating, and retrieving medical and patient information has evolved from a paper-based system to an electronic-based system. This move aimed to improve access to data and improve care decisions. The movement to electronic health records (EHRs) was accelerated with the Health Information Technology for Economic and Clinical Health (HITECH) Act of 2009 when the Centers for Medicare & Medicaid Services (CMS) launched incentive and training programs targeting the adoption and meaningful use of EHRs as part of an effort to stimulate the economy after the Great Recession through the American Recovery and Reinvestment Act (ARRA) of 2009.[1] Underpinning this effort was the belief that EHRs would accelerate healthcare transformation by leveraging technology to collect, analyze, and apply relevant patient data directly to care decisions. Subtitle D of the HITECH Act through provisions to strengthen the civil and criminal enforcement of the HIPAA rules partly addressed privacy and security concerns associated with the electronic transmission of health information.[2]

The expanded use of EHRs in hospital and office-based physician settings, sparked by the HITECH Act and enhanced through other policy and market forces, vastly increased the volume of available health information. The health informatics field grew (and continues to evolve) as providers and organizations sought ways to leverage the abundance of data to improve patient care and responded to emerging policies, technologies, and methods. Additional driving forces of the growth of health informatics include expanding reimbursement for telemedicine services, the introduction of more advanced medical devices, and technological advances in machine learning and artificial intelligence (AI)[2] applied to amassing HIT data sets. Stakeholders including healthcare organizations, providers, educators, patients, and caregivers are driving the health informatics evolution with growing expectations of having access to meaningful data, experiencing efficient and effective integration of data into the care process, and adopting new technologies.

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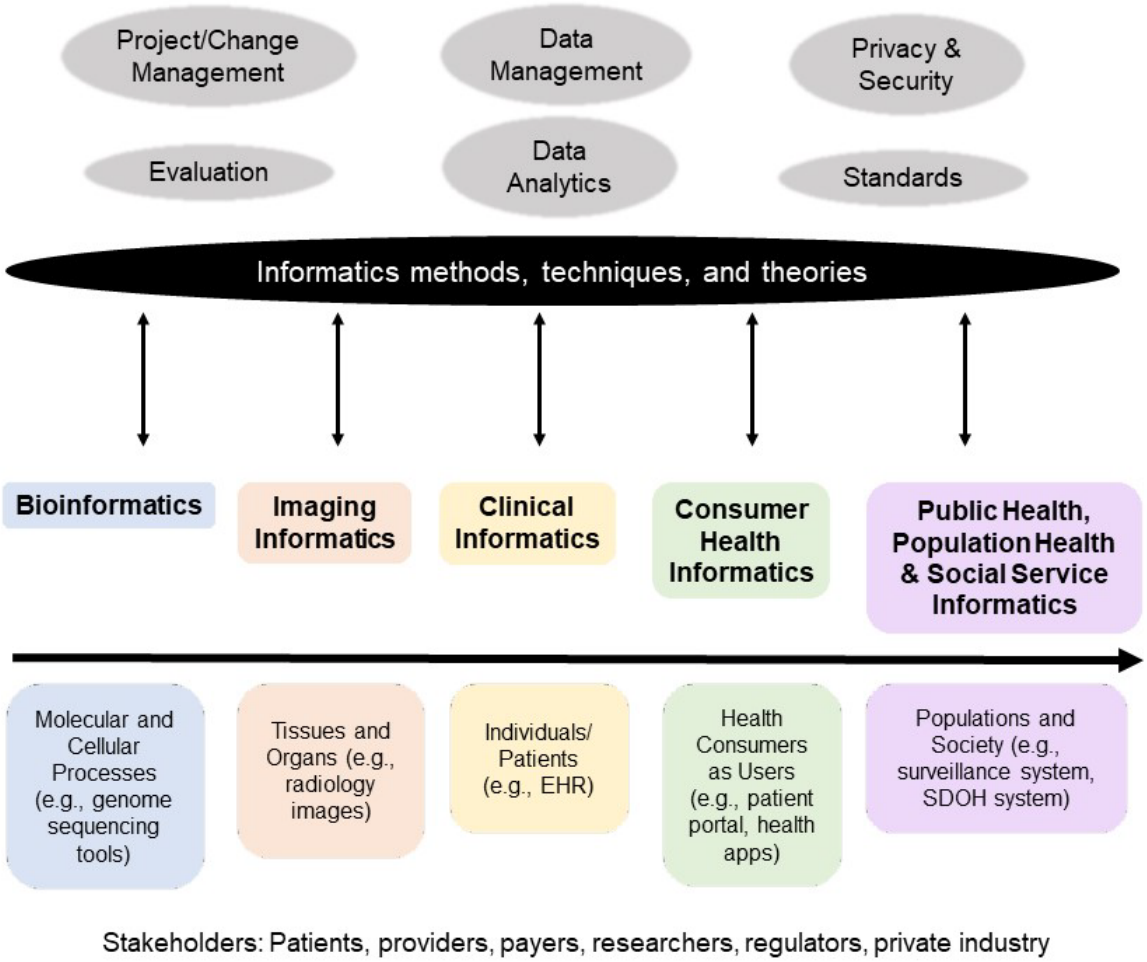
[1] HIT is a term encompassing the technical roles that process health data and records, such as classification, abstracting, and retrieval. Under the Health Information Technology for Economic and Clinical Health (HITECH) Act, HIT is defined as hardware, software, integrated technologies or related licenses, intellectual property, upgrades, or packaged solutions sold as services that are designed for, or support the use by, healthcare entities or patients for the electronic creation, maintenance, access, or exchange of health information. Source: https://library.ahima.org/doc?oid=107443

[2] The US Department of Health and Human Services defines artificial intelligence (AI) as enabling computer systems to perform tasks normally requiring human intelligence while machine learning is a type of artificial intelligence that gives computers the ability to learn without being programmed by humans. Source: https://www.hhs.gov/about/agencies/asa/ocio/ai/index.html

While EHR technology is a cornerstone of health informatics, it does not encompass the full health informatics spectrum. Health informatics includes five subdomains: bioinformatics, imaging informatics, clinical informatics, consumer informatics, and public health, population and social service informatics. Figure 1 illustrates how these subdomains relate to exemplary technologies and the overriding competency and skill areas (e.g., data analytics, privacy and security) needed to support domain-specific knowledge. Seated in the clinical health informatics subdomain, EHRs can connect domains as they share and receive data from other EHRs, other clinical systems (e.g., clinical decision support systems, order entry, laboratory systems), and other subdomain systems (imaging systems, public health systems).

Figure 1. Framework of the Health Informatics Landscape



Adapted from Chatterjee S, LeRouge CM, Tremblay, MC. Educating students in healthcare information technology: IS community barriers, challenges, and paths forward. Communications of the Association for Information Systems, 2013. 33(1), 1.

We expanded the “public health informatics” subdomain to be the "public health, population health, and social service informatics" in our adaptation of Chatterjee, LeRouge, and Chiarni Tremblay’s framework in Figure 1 to reflect increasing recognition of the importance of population health and social service informatics. Population health informatics refers to the information technology and the analytic needs of groups and organizations responsible for managing the health of defined populations.[3] Social service (including social welfare) informatics recognizes the technologies that increasingly support essential social services (e.g., welfare services,

supplemental nutrition assistance programs) provided and data collected outside healthcare organizations. Population health and social service system data have not historically been accessible via comprehensive EHRs or extensions in the US. However, recent efforts spawned by the movement towards value-based care combined with the increasing attention toward health equity have necessitated efforts to integrate social service and population health system data (particularly social needs data) with EHR data.[3] By expanding this subdomain, we highlight the importance of the health informatics workforce in community organizations and health systems' population health initiatives.

Each subdomain and supporting competency and skill area creates a need for dedicated roles, system users, and, therefore, training and education. For example, security and privacy needs (HIPAA compliance) create HIT positions and the need for training across roles to protect personal health information as data is collected, stored, retrieved, and shared. Furthermore, as HIT systems evolve, the health informatics workforce can be found outside of healthcare settings and laboratories, particularly in the consumer health informatics subdomain, where stakeholders include health consumer users and private industry developers. Technological advances like Fast Healthcare Interoperability Resources (FHIR) help to connect consumer health data or improve access to the data within health systems while maintaining the integrity of protected health information.[4] While not explicitly referenced in Figure 1, administrative and management systems, including third-party payer systems, are increasingly integrated with these health informatics subdomains, for example, by facilitating and contributing to tailored health care messages and promotion of preventive and managed care services.[5, 6]

Overall, the ever-burgeoning health informatics field creates the need for a workforce distributed across multiple settings that can address the breadth of HIT functions and system interfaces while also keeping up with increasing demand for better integration and improvement of care. Given the wide and varied scope of the health informatics workforce, this brief focuses on the clinical health informatics and public and population health, and social service informatics subdomains, which are both patient/community facing and tied to the healthcare delivery system.

OVERVIEW OF HEALTH INFORMATICS ROLES AND WORKFORCE SIZE

The responsibilities and functions that organizations may assign to workers involved in health informatics can be characterized by five pillars of health informatics:

- Health information technology (health and welfare technology development and use)
- Healthcare data analytics
- Information governance
- Patient and organizational information privacy and security
- Health systems leadership

Enacting this spectrum of responsibilities and functions is a network of roles in the healthcare sector focused entirely or substantially on health informatics. As stated by Huber et al.,

> *The term "health informatics" comprises informatics for different disciplines and professions and recognizes that inter-professionalism as an intrinsic feature of informatics. This view matches activities to reshape healthcare from a silo-dominated field to a process and patient-oriented service, which requires HIT to support inter-professional care across the continuum, based on proper process management and inclusive of quality management.[7] [p. e31]*.

The collection of roles and professions that can be construed under varying definitions of health informatics makes estimating the size of the workforce difficult, though we have some snapshots within the field that

provide a sense of the size and direction of growth in the field. The Healthcare Information Management Systems Society (HIMSS) has an eight-stage model of EHR adoption (i.e., Electronic Medical Record Adoption Model [EMRAM]). The current HIT workforce will not be able to reach the highest stage of the model without increasing its level by about 50%, based on estimates at the time of publication.[8] Actual need may be much higher since, for example, these estimates do not necessarily encompass the implications of healthcare "big data." With over 2,000 exabytes of new healthcare data emerging annually,[9] there is increasing demand for trained IT specialists to manage and leverage big data.[10] Furthermore, it is unclear to what extent increasing interest in population health and social services may further fuel anticipated growth.

Health informatics roles can be categorized as technical, analytical, or leadership:

- **Technical health informatics roles** implement, support, test, design, query/report, protect and maintain technology supporting data. Recognized HIT technical specialist roles include programmer, technical support/help desk, HIT project manager, and telecommunications/network support.
- **Analytical health informatics roles** (e.g., systems analysts and healthcare data analysts) focus on contextual insights. The number and responsibilities of health data analysts are expanding due to big data. Health data analysts analyze data and trends, create visualizations and identify actionable insights to help administrators and organizational leaders plan and deliver safe and efficient services.[11] Technical and analytical specialists address the mechanics of HIT operation under the guidance of leadership. Recognized titles for HIT analysts include clinical informatics analyst, health informatics specialists, clinical informatics specialist, and clinical informatics scientist.
- **Leadership and managerial roles** have emerged to lead and manage efforts related to the growing demands and complexities of health informatics.[12] These roles go beyond healthcare administrators' core skill of technological management. Recognized titles for health informatics leaders have emerged, including Chief Medical Informatics Officer, Senior Director of Clinical Informatics, Clinical Nurse Informatics Manager, Nursing Informatics Manager, and Pharmacy Informatics Coordinator.[13]

In addition to these roles, the health informatics workforce includes **end users** who interact with HIT to perform direct patient care and related supporting duties (e.g., registered nurses, licensed practical nurses, medical assistants). It is not far-reaching to say that most of the clinical, public health, and community health workforce do or will soon interact with HIT. To be effective, any end user interacting with HIT will require a level of competency in informatics to meet performance expectations, which will be further addressed in this report.

Some healthcare providers (e.g., physicians, nurse practitioners, physician assistants) may aspire to move into HIT technical, analytical, and leadership roles and thus enroll in health informatics educational offerings. Reasons for this migration may include the worker's desire for greater work-life balance,[11] a safer work environment, the ability to leave the bedside yet make a difference in patient care, and upward mobility opportunities.[14, 15] In addition, given that health informatics is at the intersection of information science, computer science, and healthcare, those with clinical education and experience coupled with technical abilities may be poised for health informatics positions requiring an understanding of care delivery. In the next section, we provide an overview of the education and training landscape for health informatics.

HEALTH INFORMATICS EDUCATION AND TRAINING LANDSCAPE

All HIT users need some level of training and education that may include integrated knowledge and skills in biomedicine, healthcare, computer science, mathematics, data science, and machine learning to augment human capabilities with technology.[16] Health informatics workers may also require skills in navigating management and organizational issues. In addition to fundamental health informatics knowledge and skills

leading to a core vocabulary, the different roles and job titles in the health informatics workforce have specific learning needs and educational requirements.

While there is no universally accepted training or educational pathway into informatician roles, some health informatics workforce pathways are recognized. Educational programs in health informatics, health information management, and even health library science have developed over time, producing workers to fill health informatics roles. A wide range of HIT employees work in a technical capacity, coming from a background of computer science, management information science, analytics, and other related programs that are traditionally found in Schools of Engineering/Computer Science and Business.

The HITECH Act (and subsequent ARRA endorsement investment) was a catalyst not only to HIT practice and research but also fueled context-specific courses and programs to educate and train those pursuing HIT career paths. The Office of the National Coordinator for Health IT (ONC), created out of the HITECH Act, invested $118 million in workforce development to help meet anticipated demands.[8] With these targeted incentives, community colleges developed standardized non-degree short-term certificates to produce health informatics workers such as workflow and information management redesign specialists, implementation managers, clinical practice consultants, implementation support specialists, technical and software support staff, and trainer roles.[17] Licensed health professionals were particularly well-suited to go through these certificate programs to help ensure that clinical process expectations and outcomes could be met with EHR products. The HITECH Act also resulted in university-level dedicated health informatics programs to fill higher-level health informatics professional roles that targeted employed healthcare and information technology professionals, recent healthcare and IT graduates, current healthcare and IT students, displaced healthcare and IT workers, and returning veterans with healthcare or IT skills gained during military service.[17]

Currently, programs range from a single class to dedicated degree programs at the associate, bachelor, master, doctoral, and post-doctoral level (see **Appendix A** for representative degree levels and programs mapped to target health informatics roles). Integrated and dedicated health informatics education exist among current health informatics formal educational offerings.[18]

Integrated Academic Programs. Health administration, library science, and information systems degree curricula frequently integrate health informatics courses among required or elective offerings. Medical schools recently started to incorporate health informatics into their curricula.[19]

Dedicated Academic Programs. Schools of Medicine, Public Health, Nursing, and Business are frequent homes for various forms of dedicated university health informatics programs. While some offer a general health informatics curriculum, others are tailored to a specific role (e.g., nursing informatics program) or HIT-related activity (e.g., healthcare data analytics). In addition, different schools within one university can offer various flavors of health informatics degrees as an independent or collaborative, joint school offering. For example, the University of Washington offers the following health informatics-related programs at the master's degree level through three schools, with the first program listed here being a joint school offering:

- Master of Science in Clinical Informatics & Patient-Centered Technologies (CIPCT)[20]
- Master of Biomedical and Health Informatics Research Science (Data Science Option)[21]
- Master of Health Informatics & Health Information Management (MHIHIM)[22]

Similarly, one school (or even one academic department) may offer multiple graduate-level health informatics tracks or concentrations. For example, Boston University Metropolitan College offers an Applied Data Analytics and a Health Information Management track in their Master of Science in Health Informatics program[23]; they also provide a certificate in Medical Information Security and Privacy under their health informatics umbrella.

Dedicated programs are typically offered at the graduate level. Graduate offerings align with the school of thought advocating that "in informatics, the best educational model is one in which individuals already possessing a formal education in a discipline are trained in informatics as it applies to that discipline."[24] Students can enter a graduate program in informatics with undergraduate degrees in a related field. Whether by design or intent, informal conversations with health informatics program leaders indicate students in these programs frequently possess an undergraduate education in either an IT or healthcare-related program (e.g., nursing, pharmacy, health administration, or medical doctor). Guidance from the American Medical Informatics Association indicates curriculum in dedicated graduate programs promote student competency related [25]to:

- Health
- Information Science and Technology
- Social and Behavioral Science
- Health Information Science and Technology
- Human Factors and Socio-technical Systems
- Social and Behavioral Aspects of Health
- Social, Behavioral, and Information Science and Technology Applied to Health
- Professionalism
- Interprofessional Collaborative Practice (ICP)
- Leadership

Continuing Education. A cadre of applied health informatics continuing education training offerings exists outside of more structured higher education academic programs. In this brief, we feature a few offered by key organizations that influence the health informatics workforce. An early standout was the American Medical Informatics Association (AMIA) 10X10 program started in 2005. The AMIA 10 × 10 program aimed to educate 10,000 clinicians in medical informatics by 2010. The initial 12- to 15-week training program was a foundational health informatics training covering a broad range of topics and competencies.[26] It was, and continues to be, delivered primarily online with some AMIA courses culminating with an in-person, collaborative session at an AMIA or other healthcare conference. Various entities, overwhelmingly academic institutions, have offered health informatics training through AMIA. Of these, Oregon State Health University wan initial and enduring AMIA health informatics training partner.

AMIA leaders advocating for the 10X10 program emphasized that every hospital needed at least one physician and nurse trained in health informatics to guide HIT implementation.[27] Therefore, the 10X10 program targeted clinicians to play leading roles in expanding HIT in their organization. About 1,000 people were trained through the 10x10 program by 2010, falling short of its aim to train 10,000 people by 2010.[16] However, participant evaluations indicated that the majority of those completing the training felt that the "depth and/or breadth of the content was very valuable."[28] Respondents saw the course as a springboard to further expanding their health informatics knowledge. Multiple MDs reported that the online format accommodated their time constraints, job responsibilities, and travel. One MD commented, "I humbly felt a whole lot better with my 'Titles' after the course." As a leading 10X10 training provider, Oregon State Health University extended 10X10 training delivery through other sponsoring organizations and reports matriculating 3,000 trainees from inception to mid-2022.[16]

In addition to the more general health informatics course, the 10X10 course offerings now includes specialized topics courses (e.g., clinical decision support courses) and health informatics courses tailored to target audiences (e.g., health informatics for emergency physicians).[29] AMIA health informatics continuing education has expanded to include AMIA's Health Informatics Essentials (five certified online courses for continuing

medical and nursing education), geared toward professionals involved in direct or indirect patient care and who come from nursing, medicine, pharmacy, dentistry, public health, health informatics, and computer science.

In contrast to AMIA, HIMSS (currently under *Accelerate*[30] membership) offers topic-specific (e.g., FHIR and value-based care) and shorter self-paced continuing education training. Some of these free resources can be as short as a 60-minute webinar. In addition, the HIMSS Resource Center includes a myriad of free white papers, articles, reports, and webinars addressing health informatics issues, education, and career/workforce concerns.[31] For example, a recent webinar topic, "Are Nurses Able to Lead in the Digital Health Evolution? Developing an Informatics Competent and Capable Nursing Workforce,"[32] includes in the description:

> *The United States healthcare system is slowly evolving from one built on mostly episodic and ambulatory in-person encounters to one that is digitally based, technology-rich and informed by data… Formal education tracks and the postgraduate novice-to-expert continuum have historically contained an insufficient focus on technology and informatics as a core component of nursing practice.*

Low-cost Massive Open Online Courses (MOOCs) courses play an interesting role in communizing health informatics education in an increasingly global HIT workforce.[7] Available via platforms like Coursera (e.g., Fundamentals of Machine Learning for Healthcare) and LinkedIn Learning (e.g., Using Public Health Data Sets and Dashboards), MOOCs reach mass numbers of learners from diverging backgrounds, settings, and countries. The Health Informatics Forum (reporting 13,000 international members) also provides free health informatics education for health informatics professionals, including a 17-lesson, free-access MOOCs sponsored by the US Government.[33]

ORGANIZATIONS GOVERNING AND INFLUENCING THE HEALTH INFORMATICS WORKFORCE

Assorted organizations have overarching missions that guide and influence the direction of the health informatics field and its workforce. Table 1 highlights several public sector and professional associations that have significantly shaped the workforce through accreditation models, recommended curricula, program development funding, listings of academic programs, training offerings, certifications, conferences, and job postings. Many of these organizations also fostering networking for health informatics professionals (and those interested in these fields), which shapes the workforce more organically by opening the door to opportunities like mentorship and peer-to-peer learning.

Most professional associations in Table 1 target a general health informatics audience with subgroups serving special interest groups within the associations. While some associations target specific interest groups such as the Association of Medical Directors of Information Systems (AMDIS), which targets Chief Medical Informatics Officers (CMIOs), they offer a "CRASH Course" bringing CMIOs together with other leaders in health informatics, such as Chief Health Information Officers, Chief Nursing Informatics Officers, Chief Data Officers, Chief People Analytics Officers.[34]

Several organizations in Table 1 (e.g., AMIA, IMIA, AAMC, TIGER) have developed **competency models** for education. More encompassing health informatics competency models, including the one used for accreditation by the Commission on Accreditation for Health Informatics and Information Management Education (CAHIIM) and developed by the AMIA Accreditation Committee do not target a specific role. Others are more role-specific such as the Technology Informatics Guiding Education Reform (TIGER) model for nurses and the Association of American Medical Colleges (AAMC) model for clinical health informatics physicians. The recently updated competency model from International Medical Informatics Association (IMIA) claims a global focus of international recommendations and reflects health informatics changes that accelerated markedly during the COVID-19 pandemic.[40]

Table 1. Key Organizations Influencing Health Informatics Workforce Development

Organization	Highlights of Health Informatics Workforce Development Influence
Commission on Accreditation for Health Informatics and Information Management Education (*CAHIIM*) https://www.cahiim.org/	• Provides CAHIIM accreditation for health informatics programs • Responsible for health informatics and health information management accreditation processes • Establishes and enforces standards for the educational preparation of health informatics, health information management, and other health professionals
American Health Information Management Association (AHIMA) https://www.ahima.org	• Manages various health information management certifications, including certified health data analyst (CHDA) and Healthcare Privacy and Security • Provides a fee-based educational platform, Vlab ®, a virtual practice environment for health information education affording hands-on access to various HIT applications used in practice and associated assessments • Offers continuing education webinars, particularly those related to data management and security • Hosts an annual conference
Healthcare Information and Management Systems Society (HIMSS) https://www.himss.org/	• Hosts annual conferences with various educational and CEU sessions • Provides an educational resource center • Provides health informatics certification programs and preparatory courses • Delivers CEU training courses, and health informatics early and continuing career-building resources • Offers educational partnership program
Technology Informatics Guiding Education Reform (TIGER) Committee https://www.himss.org/what-we-do-initiatives/technology-informatics-guiding-education-reform-tiger	• Operated as an independent committee focused on the nursing community from 2006-2012; transitioned under HIMSS in 2014 with a focus on health informatics educators as change agents and learners • Provided International Recommendation Framework of Core Competencies in Health Informatics for Nurses (Framework 1.0)[7] • While under HIMSS, the TIGER International Competency Synthesis Project joined with the EU*US eHealth Work Project to develop Framework 2.0 that describes and validates Framework 1.0 to an expanded focus on a broad range of worldwide health professionals and their inter-professional collaborators[35]
International Medical Informatics Association (IMIA) https://imia-medinfo.org/wp/	• Provides recommendations and guidelines on health informatics education via a framework for national initiatives in health informatics education and for constituting international programs and exchange of students and teachers in this field • Provides forums to grow and support a global health informatics community and international health informatics initiatives • Offers International Conference (every four years) • Posts job opportunities
American Medical Informatics Association (AMIA) https://amia.org/	• Developed competency model to guide master's level education in applied health informatics, which is used for CAHIIM accreditation of graduate programs quality[25] • Established guidelines for the core content of the clinical informatics subspecialty for physicians

Organization	Highlights of Health Informatics Workforce Development Influence
	• Provides CEU training courses, health informatics certification programs and preparatory courses • Hosts annual conferences with various educational and CEU sessions • Offers searchable listing of health informatics academic programs
Association of Medical Directors of Information Systems (AMDIS) https://amdis.org/	• Provides resources for physicians interested in and responsible for healthcare information technology with informatics C-suite focus • Hosts annual symposium and Annual CMIO CRASH Course on evolving topics • Offers a private forum for member community mainly targeting those in informatics C-suite positions • Posts job opportunities
Association of American Medical Colleges (AAMC) https://www.aamc.org/	• Provides guidelines for competencies in clinical informatics for 21st-century physicians • Provides resources for career description and tools for physicians interested in practicing clinical health informatics • Collects data through member surveys to track education programs, medical specialties, and residencies
The American Nurses Credentialing Center (*ANCC)* https://www.nursingworld.org/ancc/	• *Affiliated with the American Nurses Association and accredited by the American Board of Nursing Specialties and the National Commission for Certifying Agencies* • Hosts annual conference • Delivers CEU training courses • Provides nursing informatics certification programs and preparatory courses
Office of National Coordinator (ONC) https://www.healthit.gov	• Provides policy and guidelines to support the federal government's effort to facilitate interoperable, private, and secure nationwide HIT systems • Offers periodic funding opportunities to fuel health informatics education
National Library of Medicine (NLM) https://www.nlm.nih.gov	• Provides funding through University-based Biomedical Informatics and Data Science Research Training Programs (T15 Program)[36] • Administered funding from Robert Wood Johnson Foundation targeting enhancing the public health informatics workforce[37]

Centers for Disease Control (CDC)
https://www.cdc.gov
	• Provides CEU e-learning courses to introduce public health informatics and specific health informatics career paths (e.g., laboratory informatics)[38]
	• Provides virtual reality laboratory training
	• Runs Informatics and Data Science Workforce Development (IDSWD) programs which offers[39]:
	  ○ Public Health Informatics Fellowship Program (PHIFP)
	  ○ Public Health Analytics and Modeling track for CDC Steven M. Teutsch Prevention Effectiveness fellows
	  ○ Collaborative offerings with the Council of State and Territorial Epidemiologists:
	  ▪ Data Science Team Training Program (DSTT)
	  ▪ Applied Public health informatics Fellowship (APHIF)

Another way of signaling expected competencies for the health informatics workforce, and presumably providing career cachet, is through **certifications.** A 2022 publication examining competencies and curricula across the field of health informatics indicated that:

> *…at this point, it is clear that board certification of physicians is a consideration of hiring physicians for operational clinical informatics roles in healthcare delivery organizations. It is probably more important for those who work in operational than academic or research settings. Nonetheless, clinical informatics certification is a recognition of the field and is probably more important for younger entrants into the field.*[16]

AMIA established the Health Informatics Certification Commission (HICC) to manage the new Advanced Health Informatics Certification (AHIC), targeting a more general health informatician audience.[41] While AMIA can prepare candidates, specific medical boards the American Board of Preventive Medicine or American Board of Pathology,[42] depending on the candidate's credentials, oversee the qualification of applicants, standards of examinations, and the form of the certification. Additionally, AHIMA offers specialized certificates in data management and healthcare privacy and security. HIMSS also provides certifications including:

- Certified Associate in Healthcare Information and Management Systems (CAHIMS) providing a pathway for expanding and diversifying industry knowledge for early careerists and those with more experience.
- Certified Professional in Healthcare Information and Management Systems (CPHIMS) for experienced professionals, acknowledging and honoring their proven expertise and commitment to the field.
- Certified Professional in Digital Health Transformation Strategy (CPDHTS) designed for professionals to demonstrate knowledge and competence in digital health transformation strategy, including person-enabled health, measurement and improvement, strategy, governance, and organizational management.[43]

Both the NLM and ONC have influenced the direction of the health informatics workforce through **training and educational funding**. For example, the ONC recently awarded $75 million in cooperative agreement grants as part of its Public Health Informatics & Technology Workforce Development Program (PHIT Workforce Program).[44] The program aims to train more than 5,000 individuals over four years using an interdisciplinary approach to public health informatics and technology.

HIGHLIGHTING SELECT HIT USERS IN THE HEALTH WORKFORCE

HIT has significantly altered service roles in the healthcare sector. This section concentrates on select health workforce roles especially affected by the ever-increasing use of various HITs, changes in educational pathways, available HIT certifications, and HIT-influenced career opportunities. Our focus does not include users of health information exchange, registration administration, patient financial service, electronic document management, and patient portal HIT.

While we showcase specific professions, we recognize that many occupations in the health workforce interface with HIT (including clinical support staff that often receive on-the-job training in various HITs). Table 2 illustrates the growing expanse, depth, and integration of HIT into each featured occupation or occupational group. Among the many clinician occupations, we highlight physicians and registered nurses (RNs) due to their "front line" accountability to care delivery and patient responsibility using high-level informatics capabilities. The following subsections illustrate some salient points regarding the status of health informatics in the featured roles and provide detail regarding each user group's education and training.

Table 2. Primary HIT Used by Select Healthcare Workforce Roles

Occupation/Occupational Group	How HIT Supports Are Used	Examples of Types of HIT Used [a]
Healthcare Administrators (including Healthcare Informatics Administrators) and HIT Leads	• Making decisions by leveraging aggregated data for quality assurance, outside reporting, and strategic planning • Using population health data for equity initiatives	• Reporting systems and dashboards drawing from EHR and administrative system aggregated data sets • Predictive and decision modeling tools increasingly leveraging analytic advancements in AI and machine learning • Enterprise Resource Planning Systems (ERP) • Situational/role level managerial interfaces associated with other HIT
Clinicians **(focus on Physicians and Registered Nurses)**	• Using platform for care delivery • Accessing and collecting patient history and status • Entering documentation • Receiving evidence-based guidance • Issuing directives/orders	• Electronic Medical Record • Computerized provider order entry (CPOE) • Clinical Decision Support Systems (CDSS) • E-prescription systems • Clinical messaging systems • Point-of-care charting systems • Telemedicine platforms
Pharmacists	• Understanding, reporting, and presenting healthcare data to ensure accurate administration of medication by other healthcare professionals • Establishing medication metrics • Collaborating to optimize the use of technology in medication administration and record-keeping	• Automated dispensing cabinet • Barcode medication administration, or BCMA • CPOE • Electronic medication administration record, or eMAR • Electronic prescribing, or e-prescribing: • Inventory management system • Robotic IV automation (RIVA) • Smart pump • Telepharmacy
Laboratory Professionals	• Reducing transcript errors • Data tracking and workflow management • Supporting integration with other lab systems • Improving regulatory compliance • Managing information in biobanks, biorepositories, and academic research • Recording all test requests • Validating test results • Online, real-time linking to automated analytical instruments	• Laboratory Information Management System (LIMS) • Electronic Lab Notebook (ELN) • Chromatography data systems (CDS) • Scientific Data Management Systems (SDMS) • Inventory management system • Decision support systems to enhance clinical outputs • Data analysis systems for audit, clinical risk management, disease surveillance, and epidemiology

Occupation/Occupational Group	How HIT Supports Are Used	Examples of Types of HIT Used [a]
	• Recording quality control data	
Public Health, Population Health, and Social Service Workers	• Population monitoring • Assessing community needs • Surveilling syndromes • Stratifying risk • Managing disease • Coordinating interventions • Providing essential social services • Facilitating care coordination among organizations providing health and social services	• Surveillance systems • Registries • Analytic, statistic, and data modeling tools leveraging population health data • Electronic lab reporting • Social service program administration programs • Electronic hubs and toolkits of evidence-based resources (e.g., screening tools) and interactive tools that help organizations implement programs to address social determinants of health (SDOH) and assist practitioners in taking action to address them

[a.] *In many cases, two or more of the referenced systems may be integrated.*

Healthcare Administrators/HIT Leads

With varying degrees of influence, healthcare administrators and HIT leads are at the forefront in deciding how to best deploy HIT options in strategic planning. "Deciding where to place 'bets' on technology is doubly challenging for providers because the evidence is mixed or missing to determine which technologies are most effective at achieving better health outcomes and, ideally, lowering costs".[45] In addition, HIT strategic choices impact the workflow and on-the-job skill development of all who may interface with technologies deployed in their organizations.

Value-based care strategies may also rest on the shoulders of healthcare administrators and HIT leads. "The future of value-based care hinges on the use of data, but the implementation of EHRs alone has proven insufficient to improve care and reduce costs," according to the AMIA Policy Committee Chair. "We must better support clinical informatics training programs so that we can collectively extract value from EHRs to benefit patients, payers, and providers."[46] Furthermore, administrators with health informatics training may be exceptionally positioned to initiate and oversee collecting, managing, combining, and analyzing relevant data to address health equity and population health initiatives for the communities they serve.

Health informatics competencies and curricula. The Master of Health Administration or Healthcare Master of Business Administration degrees have been traditional educational paths toward health administrative roles. Individuals who have management training with clinical health informatics training and education may find a pathway to health informatics management roles such as Chief Medical Informatics Officer and Nursing Informatics Manager. The Commission on Accreditation of Health Management Education (CAHME), which accredits many of these degree programs, has a competency model that references educational programs' facilitation of student competencies in critical thinking, analysis, and problem-solving. Health informatics competencies are not specified, although most degree programs offer at least a survey class on health informatics or offer health informatics concentration options, including dual degrees (e.g., University of North Carolina – Charlotte,[47] Florida International University,[48] Saint Joseph's University[49]). In addition, emerging programs (e.g., Duke University's University Master of Science in Quantitative Management: Health Analytics) integrate content from both health administration and health informatics disciplines in recognition of the increasing role of data analytics, including AI and machine learning, in reporting and strategic management.

Practice-oriented doctorate programs are also starting to emerge for those executive-level professionals seeking a terminal, applied degree in the field of health informatics (e.g., University of Texas – Houston).[50]

Physicians

It is now common to see clinicians including physicians, physician assistants (PAs), and nurse practitioners (NPs) (heretofore we focus on physicians acknowledging the important and similar roles of PAs and NPs) execute their roles in patient care with a computer at hand. The list of HIT accessed by clinicians on tablet, laptop, and desktop computers, as enumerated in Table 2, is long yet not complete. Some clinicians are considering tools like large language models (e.g., ChatGPT - Generative Pretrained Transformer) to serve as a physician's digital assistant, enhance clinical decision support systems, and use in medical education.

Health informatics competencies and curricula. Courses in HIT are not part of traditional competencies or graduation requirements, and HIT inclusion in conventional medical school curricula varies across institutions. Some health informatics leaders feel that health informatics is a core competency that has been neglected[51] because it is not a basic science or a clinical rotation. In response, some members of the American Medical Association (AMA) Accelerating Change in Medical Education Consortium[19] are starting to add "threads" of biomedical and health informatics content that map through multiple courses.[51] Recently, the AMA included "What is biomedical and health informatics?" among its "Covid-19 resources for medical educators"[51] curated from the medical education community.

Furthermore, some medical schools do include health informatics in their curricula. For example, Stanford Medicine requires students to select a Scholarly Concentration—structured coursework consisting of 12 units of study based on individual interest—of which Informatics & Data-Driven Medicine (IDDM) is one among the 19 areas of study. This concentration introduces medical students to fundamental topics such as information management, computational methods of structuring and analyzing biomedical data, and large-scale data analysis (from the analysis and interpretation of new biological datasets to the integration and management of this information in the context of clinical care).[52]

Clinical informatics subspecialty and fellowships. Clinical informatics achieved recognition as a medical subspecialty in 2011. The current certification requirements for a physician sub-specialization in clinical informatics do not call for specific clinical informatics education (i.e., concentration, degree, residency, or fellowship).[53] Candidates can include physicians with informal clinical informatics training who were board-certified in any of the 24 primary ABMS specialties and actively engaged in clinical informatics work.

Health informatics dual degrees (e.g., Florida International University)[54] and Stanford Medicine) and tracks (e.g., Harvard)[55] are emerging. These combined educational programs are for medical students who want more advanced technical skills to use biomedical data to solve challenging problems in biology and medicine. Dedicated health informatics resident and fellowship offerings are the more prevalent routes for physicians wishing to specialize in health informatics. Examples include UCLA's Resident Informaticist program, which provides monthly didactics and a mentored informatics project for 16 to 20 residents per year from a broad diversity of residency programs.[56] An alternative model for informatics education during residency is a specialized clinical informatics track within other specialty residency programs. For example, the psychiatry residency at the University of North Carolina Department of Psychiatry is a three-year longitudinal experience open to residents starting in postgraduate year two, combining informatics service, didactics, and research.[57]

The current "Practice Pathway" allows those without formal fellowship training to take the clinical health informatics board examination, with an expectation that after 2017 physicians would only be able to sit for the board examination after completing a two-year fellowship accredited by the Accreditation Council for Graduate Medical Education (ACGME). However, the Practice Pathway has been extended through the 2025 exam cycle to

recognize “the negative impact the COVID pandemic has had on physicians’ ability to meet eligibility requirements.”[58]

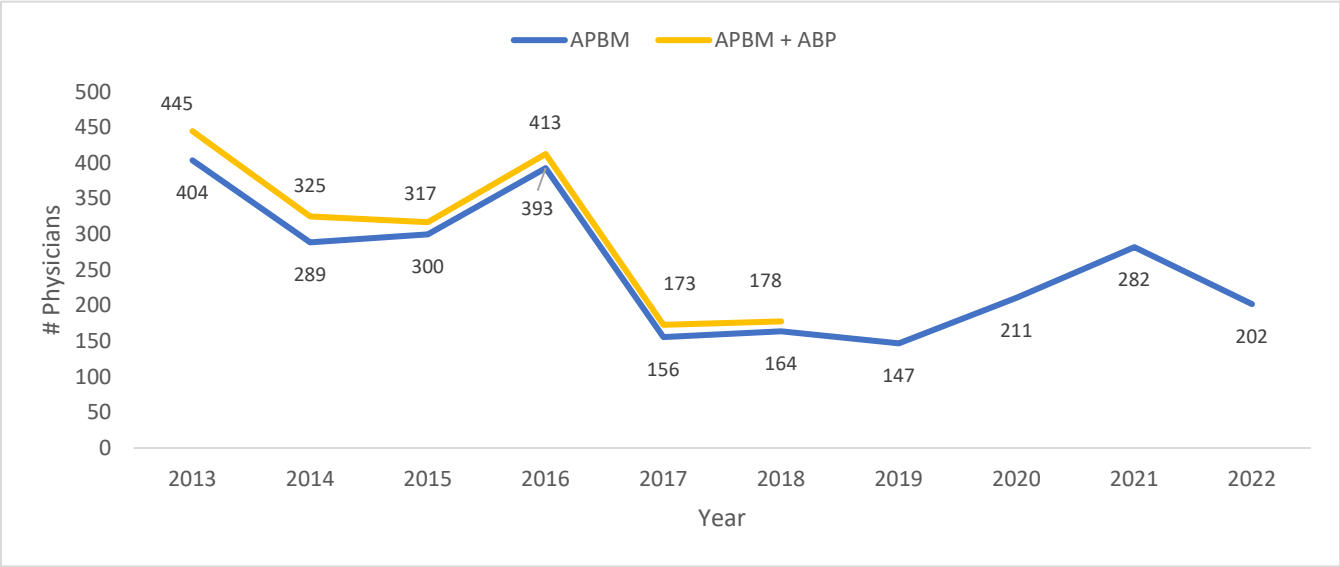
In 2014, the first four fellowship training programs received accreditation from the Accreditation Council for Graduate Medical Education (ACGME).[59] These two-year programs accept physicians of any specialty who will apply information technology to transform healthcare delivery. Specifically, the programs provide additional training in[60]:

- Medical terminology and medical practice
- Information technology terminology
- Analytical tools, databases, and statistics
- Security
- Ethics and professionalism
- Social and behavioral determinants of health
- User-centered design (human factors and socio-technical systems)
- Business aspects of healthcare and healthcare delivery/Quality measures & financial
- Information architecture, predictive analytics
- Artificial intelligence/machine learning
- Evidence-based medicine
- Leadership and collaborative practice
- Project Management

An unpublished study by a team of health informatics educators and leaders at University of Washington, UCLA, and Boston Children’s Hospital suggests there is an uptick of clinical informatics fellowships[61] and available positions based on 2016 to 2023 data from the Electronic Residency Application Service (ERAS). The number of accredited programs offering fellowships in clinical informatics has grown from 12 to 58 programs (though not all programs participate in the clinical informatics match) and the number of available positions has grown from 28 to 84 positions. While in early years, applicants exceeded available positions, applications are appearing to taper off such that there is an equal number of applicants for available positions. There also appears to be attrition from the ERAS application to successful matches. Potential reasons for this attrition are that some candidates get posts outside of the match while others are recruited to other jobs or training programs.[60] Some speculate that the continued availability of the Practice Pathway is adversely affecting demand for clinical informatics fellowships. [60] In addition, those entering clinical informatics programs are not as diverse such that there are fewer women and individuals from minoritized communities compared to the general medical school population.[61]

To illustrate the trend in the number of physicians certified, data from the American Board of Preventive Medicine (ABPM) and the American Board of Pathology (ABP) shows that the number of physicians certified declined between 2017 and 2019, then rose between 2020 and 2021.[53, 63] We can speculate that the increased use of telemedicine and other HIT among physicians during the COVID-19 pandemic may have influenced this increase.

Figure 3. Physicians Certified in Clinical Informatics, 2013-2022



Source: Desai S, Mostaghimi A, Nambudiri VE. Clinical informatics subspecialists: characterizing a novel evolving workforce. J Am Med Inform Assoc. 2020 Nov 1;27(11):1711-1715; Personal communication with Mia Katzenberger CC. The American Board of Preventive Medicine. March 13, 2023.

Clinical informaticist roles. Clinical informaticists collaborate with other healthcare and information technology professionals to analyze, design, implement, and evaluate information and communication systems. These systems enhance individual and population health outcomes, improve patient care, and strengthen the clinician-patient relationship.[64] In contrast to working with patients individually, clinical informaticists tend to work at a practice or population level. Many solutions developed by informaticians can be transferred to or duplicated at other institutions.[46]

Registered Nurses

Registered nurses (RNs) need critical thinking skills, independent clinical judgment, management and organizational skills, leadership abilities, and technological understanding to practice in various healthcare settings.[65] In addition, RNs interface with multiple technologies to either enter or extract data to aid them in caring for patients. Yet, the literature indicates that "although informatics as a discipline has become ubiquitous in healthcare, nursing schools continue to struggle in their efforts to integrate it into their curricula."[65] Inconsistent infusion and a lack of consensus on how to integrate health informatics into baccalaureate nursing programs are cited issues.

Health informatics training and education. There are many ways outside of academic programs that nurses may gain nursing informatics understanding and skills regardless of whether they intend to transition from a primarily clinical position into a nurse informatics position. Several conferences offer workshops to expand knowledge and network for nursing informatics professionals. One of the largest is the Summer Institute in Nursing Informatics,[66] held annually by the University of Maryland School of Nursing. In addition, HIMSS, ANIA, and AHIMA all hold annual conferences as well as offer online courses. Several private organizations (e.g., Nursing Informatics Learning Center)[67] and academic institutions offer three to 39 hours of continuing education courses tailored to specific topics or individual education needs.

For those desiring a role requiring health informatics proficiency, various graduate degrees or certificate programs in Nursing Informatics exist. Many of these are entirely or partially online, such as the fully online

Post-Professional Certificate in Nursing Informatics at the University of Pittsburgh School of Nursing.[68] Topics covered include:

- Meaningful use
- Using health information technology (HIT) to improve and measure the quality of care
- Adoption of HIT: barriers, challenges, and solutions
- Compliance and the EMR
- Working with EMR vendors
- Patient-centered technologies
- Telehealth systems and applications
- Management of care systems

To achieve Nursing Informatics certification from the American Nursing Credentialing Center (ANCC),[69] candidates must pass a certification exam and (1) have practiced a minimum of 2,000 hours in informatics nursing in the last 3 years or (2) have completed a graduate program in informatics nursing with a minimum of 200 hours faculty-supervised practicum, or (3) have completed a graduate program in informatics nursing containing a minimum of 200 hours of faculty-supervised practicum in informatics nursing.[62, 69] Applicants who meet eligibility and practice requirements and successfully pass an examination are awarded the 'Informatics Nursing Certification Registered Nurse – Board Certified (RN-BC)' credential for five years. Table 3 compares certification processes for nurses to that of physicians.

Table 3. Comparison of Informatics Certification Processes for Registered Nurses and Physicians

	Nursing Informatics Certification Informatics Skills/Competencies References	Clinical Informatics Board Certification for Physician (American Board of Preventive Medicine and American Board of Pathology) Informatics Skills/Content Outline
Skills and competencies	Scope of nursing informatics practice: Foundational knowledge of metastructures, concepts, and tools, functional areas of nursing informatics; evolution of informatics competencies, ethics, the future of nursing informatics including trends in practice roles, technology, regulatory changes, quality standards, care delivery models, and innovation. Standards of nursing informatics practice: assessment, diagnosis, problems, and issues, outcomes identification, planning, implementation, evaluation. Standards of professional performance for nursing informatics: ethics, education, evidence-based practice and research, quality of practice, communication, leadership, collaboration, professional practice evaluation, resource utilization, environmental health	Informatics competencies as listed on the outline for board certification: leading and managing change, health information systems, fundamentals of informatics, clinical decision making and care process improvement, legal, ethical, and regulatory issues

	Nursing Informatics Certification Informatics Skills/Competencies References	Clinical Informatics Board Certification for Physician (American Board of Preventive Medicine and American Board of Pathology) Informatics Skills/Content Outline
Eligibility	Eligibility is limited to nurses with a baccalaureate degree in nursing; current RN license; two years' experience practicing as a Registered Nurse; experience practicing as an informatics nurse and/or graduate level practicum hours in informatics	Eligibility is limited to physicians with MD or DO degree; current, unrestricted medical license in the U.S.; current American board certification in primary clinical discipline or pathology
Practice requirement	ANCC certification requires up to 2000 hours of experience in informatics nursing. Practicum hours in a graduate nursing informatics program may also be used to satisfy the practicum requirement.	Accredited fellowship: 2 years Practice Pathway (25% time spent in informatics-related activities for at least 36 months in the 5 years or acceptable 24-month informatics master or fellowship prior to taking the examination)
Validation domain	Certification validates knowledge pertaining to the informatics nurse role; informatics nurse specialists, those with graduate degrees in informatics, practice at higher levels than that implied by certification	Board certification validates practice-based training and experience and/or formal training in clinical informatics (either advanced degrees or fellowships)
Duration of validity	Board certification valid for five years	Board certification valid for 10 years
Recertification	A minimum of 30 hours continuing education in informatics required for initial certification. Continuing education also required for re-certification.	Continuing education required for maintenance of certification; examination required once every 10 years

Reprint of Table 3 from Cummins MR, Gundlapalli AV, Murray P, Park HA, Lehmann CU. Nursing Informatics Certification Worldwide: History, Pathway, Roles, and Motivation. *Yearb Med Inform*. 2016;(1):264–271.

Results from a 2020[70] HIMSS survey showed that the percentage of nurse respondents who have a master's degree or PhD in nursing informatics declined from 37% in 2014 to 31% in 2017. On-the-job training saw a downward trend, with 54% of respondents reporting they engaged in it in 2020, compared with 56% in 2017 and 58% in 2014. Survey respondents with a certificate in nursing informatics rose from 20% in 2017 to 25% in 2020. In a new question added to the 2020 survey, 15% of respondents reported completing a vendor/supplier certification. The number of respondents with any certification increased from 49% in 2017 to 58% in 2020. In another new question from the 2020, 49% of respondents reported that enhanced credibility and marketability was a top reason to pursue certification followed by personal satisfaction (45%). When asked about the perceived value of certification, these answers also topped the list, although personal satisfaction (81%) edged out enhanced credibility and marketability (78%).

Nursing informaticist roles. In the 2020 HIMSS nursing informaticist survey,[70] nearly a third (31%) reported having more than 10 years of experience in nursing informatics, with no difference among respondents from a previous survey conducted in 2017. The top job responsibilities of nurse informaticists were systems implementation (44%) and utilization/optimization (41%). While systems development was still in the top three job responsibilities, only 34% of respondents report "currently working in this area." The 2020 question about job responsibilities included two new categories: project management (30% of respondents) and change/control management (26% of respondents). About a third (36%) of respondents managed at least one direct report, with 19% managing between one and five employees. Another 8% managed six to 10 employees.

Pharmacists

Pharmacists should be familiar and skilled with the tools, software, systems, and technological practices common to the field. Among other things, HIT allows for streamlined communication between pharmacists and other prescribers (e.g., physicians, PAs, NPs). Information sharing helps to prevent errors and expedite pharmaceutical services. As illustrated in Table 2, pharmacists may use multiple technologies to carry out their duties.

Health informatics curricula and competencies. The health informatics curricula within a traditional pharmacy educational route are evolving slowly. A 2017 survey of pharmacy curriculums in the US showed that only 36% included an informatics course, which was not much of an improvement from 10 years before.[71] A Pharmacy Doctorate (PharmD) coupled with a health informatics program is a suggested educational path for a pharmacy[72] informaticist. The American Society of Health-System Pharmacists (ASHP) recognizes the following competencies for pharmacy informaticists:

- Data, information, and knowledge management
- Information and knowledge delivery
- Practice analytics
- Applied clinical informatics
- Leadership and management of change[71]

A limited number of universities offer degrees in pharmacy informatics, including the University of Kansas,[73] Regis University,[74] and Samford University.[75] However, it is more common for pharmacists interested in informatics to gain skills through on-the-job experience, working alongside nonpharmacy clinical informatics colleagues, education provided by information system vendors, attending public interest conferences, or continuing education.[71] Additional pharmacy informatics educational opportunities are needed to enable a shift to more technologically supported pharmacy practices. In the coming years, pharmacy informaticists may be essential to developing and adopting artificial intelligence tools to ensure that data currently captured and used for computation are meaningful and accurate.

Pharmacy informaticist roles. Pharmacy informaticists' roles concentrate primarily on using HIT and telecommunications to enhance factors associated with medication administration and resulting patient outcomes.[71] As with physician informaticists, pharmacy informaticists' may share their innovations across organizations. There are a few specializations within the field of pharmacy informatics, including:

- **Pharmacy informatics technicians** who are responsible for inputting data, dispensing medications, and maintaining the computer systems used in pharmacies or other healthcare facilities.
- **Drug safety specialists** who help to monitor drug safety by tracking the administration and use of medications, generating medical reports, and auditing medication inventories.
- **Clinical data analysts** who analyze pharmacy data to ensure the effective use of information and develop or modify systems to process pharmacy data.[72]

Laboratory Professionals

HIT is rapidly evolving the laboratory professional role. Laboratory professionals use technologies to store data as well as for data analysis. Rapid innovation has made laboratory equipment more interactive, allowing laboratory services to collect, analyze and share data. Laboratory informatics is a term that covers the usage of a variety of technology tools for data collection and analysis in a laboratory setting.

Health informatics training and education. Although a call for academic concentrations exists, there are relatively few academic educational pathways dedicated to laboratory informatics.[24] Those without specialized academic education seem to attain their laboratory informatics skills by "grafting on" generalized health informatics degrees or training through health informatics professional education programs or vendor training (e.g., EPIC Beaker Training). In an email correspondence describing the training programs for laboratory informatics students, Donna M. Wolk, MHA, PhD, D(ABMM), Professor, Geisinger Commonwealth School of Medicine, referenced many forms of training and education outlets identified earlier in this report and mentioned the need for learnings to be pulled together to make a cohesive whole:

> *At Geisinger, we have deployed ongoing training for several job descriptions. We are training doctoral medical and scientific directors (clinical), retired doctoral staff [four people presently in the program] who want to continue to perform translational research, medical laboratory scientists (one manager), and healthcare epidemiologists with laboratory backgrounds. Most of our training is with our microbiology research program. Our program is focused on quality projects and documentation of value-based care: experimental design; creation of data sets for analytics, analytics and biostatistics, trend analysis, and dashboarding. In addition, half of our clinical doctoral directors (4/7) are in the process of taking the Epic Builder course for traditional clinical informatics related to the electronic health record and Epic Beaker. We also have several CLS/IT staff (50% I.T., 50% laboratory time) trained by IT on Epic build for new tests, interfaces, etc.- these are half from clinical laboratory and half from traditional IT.*
>
> *I deliver formalized didactics and project-specific training and tape for future training. In addition, there is a book club (reading via group book purchases on Kindle), formal training as a master in public health and a master in health administration for experimental design, and online training programs for data science (Google training, Linkedin, and Coursera).*[76]

As referenced in Table 1, the CDC offers Continuing Education Units (CEUs) dedicated to laboratory informatics.[38] The CDC laboratory informatics introductory programs focus on data science skills and pathways and reference: data relationships, data quality and standards, and the generation and flow of information as a specimen progresses through the pre-analytic, analytic, and post-analytic phases, the characterization of the recipients of laboratory data, data and results storage, and the communication of data and results (especially electronically) to various stakeholders.[77, 78]

While the American Society for Clinical Pathology does not offer a professional certificate in laboratory informatics, their Lab Management University (LMU) Fundamentals and LMU Advanced Certificates call out health informatics topics in their curriculum. One of their LMU Contemporary Issues programs, New Technologies and Distanced Team Management,[79] focuses on the new technologies introduced into laboratory informatics. While a published competency model for laboratory informatics could not be identified, the curricula details in the LMU programs provide some insight. The Contemporary Issues program focuses on new technologies, as does the LMU Fundamentals, which includes objectives related to assessing and selecting a new laboratory system. The LMU Advanced Certificate covers the following topic: "harnessing automation and informatics to improve quality, efficiency, and turnaround time in the clinical laboratory."

Laboratory informaticist roles. As one article described, "Informatics[80] has become one of the key pillars of pathology, and the requirement for skilled informaticists in the laboratory has quickly grown." The growth of the field has been attributed to the need for more automation in laboratories, the need to comply with stringent regulatory measures, and the demand from academic research institutes.[81] Roles focused on laboratory informatics include:

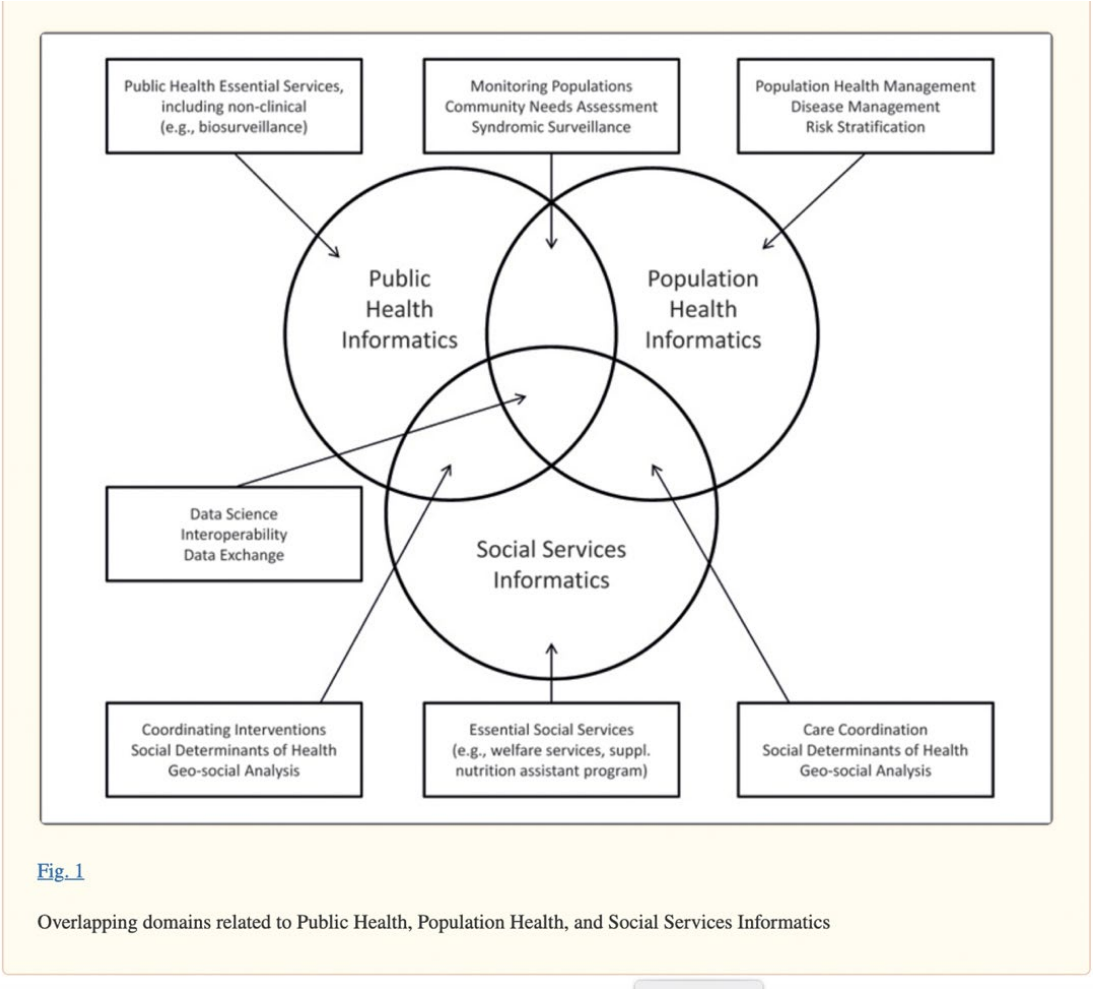
- Laboratory Applications Specialist
- Quality Control Laboratory Informatics
- Laboratory Information Scientist
- Clinical Informatics Analyst - Laboratory
- Clinical Informatics Specialist – Laboratory
- Laboratory Informatics Manager
- Automated Laboratory Technician[82]

Public Health, Population Health, and Social Services Workforces

Public health agencies increasingly use informatics and big data tools, which has occurred apart from the healthcare electronic data infrastructure.[1] The public health HIT uses include evaluation of surveillance practices, surveillance methods, interoperable health information infrastructure, mobile health, social media, and population health. Social service agencies are increasingly using informatics to manage service programs and often provide platforms that allow recipients to register for services and review their service accounts. Health systems also have a growing interest in monitoring and managing population health, which can be attributed to managed-care contracts, value-based care models, and pressures to consider patients' social determinants of health (SDOH).[83] These and other dynamics create a need for informatics competencies within these domains. Figure 4 conceptualizes the public health, population health, and social service informatics domains.

Health informatics curricula and competencies. The COVID-19 pandemic and an increasing spotlight on healthcare inequities and the impact of social factors on physical health have fueled the compelling case to increase health informatics competencies and enhance HIT tools in the public health, social service, and population health subdomains.[84] This need has spawned ONC funding for public health informatics training and education. The ten consortia recipients of this funding have the charge to "develop curricula, recruit and train participants, secure paid internship opportunities, and assist in career placement at public health agencies, public health-focused non-profits, or other public health-focused organizations."[85] In addition to increasing the number of public health professionals trained in public health and informatics during the grant period and beyond, the funding has a health equity call to increase the capacity of minority-serving institutions to create sustainable pathways to careers in public health informatics for underrepresented minority (URM) students. The hope is that through representation, URM students and professional trainees can harness the power of public health data to develop disease-prevention and well-being improvement initiatives with their communities.[86] Not all the educational opportunities funded under this award are dedicated to public health informatics programs or tracks. For example, Alcorn State University School of Nursing[44] is using funding for a nursing informatics education. The University of Minnesota, School of Nursing Population Health Informatics Certificate program, emphasizes population health. While not explicitly stating social services/ social informatics, a few seem to focus on social informatics (e.g., Bethune-Cookman University) developing a health informatics and health equity curriculum.[85]

Figure 4. Public Health, Social Services, and Population Health Informatics



Source: Reprint of Figure 1 from Gamache R, Kharrazi H, Weiner JP. Public and Population Health Informatics: The Bridging of Big Data to Benefit Communities Yearbook of medical informatics. 2018;27(1):199-206. doi:10.1055/s-0038-1667081

Regarding fellowships, the CDC runs multiple recognized public health informatics programs.[39] The long-standing Public Health Informatics Fellowship Program (PHIFP) provides on-the-job training for professionals to apply expertise in information science, computer science, and information technology to address current and future informatics needs in global, national, state, and local public health contexts. The Public Health Analytics and Modeling track offers CDC Steven M. Teutsch Prevention Effectiveness Fellowships. Collaborative offerings with the Council of State and Territorial Epidemiologists include:

- Data Science Team Training Program (DSTT) which provides on-the-job training for state, territorial, local, and tribal public health agencies.
- Applied Public Health Informatics Fellowship (APHIF), where recent graduates work closely with informaticians, epidemiologists, and public health practitioners at the state, territorial, local, and tribal levels and collaborate with CDC.

The Informatics Academy at the Public Health Informatics Institute (PHII) published an updated applied public health informatics competency model in 2016 that includes the following components[87]:

- Standards and interoperability

- Project management
- Information systems
- Policy
- Communication
- Analysis, visualization, and reporting
- Evaluation
- Principles and strategy

We do not yet have competency models explicitly for social service informatics or population health informatics. However, it seems most, if not all, competencies in the PHII model apply to these subdomains. In addition, those working in social services or population health informatics require a deep understanding of the SDOH, the digital tools that collect and analyze SDOH data from patients, and how to work with local and national government datasets.[84]

Public health, population health, and social service informatics roles. Common trends in the socio-technical infrastructure of the subdomains represented in Figure 4 that provide insight into workers' functions include big data platforms, SDOH, geographical information systems, novel data sources, and new visualization techniques. A common thread connects workforce, governance, and sustainability: "to proactively identify, monitor, and improve a range of medical, environmental, and social factors relevant to the health of communities. These efforts show significant growth in a range of population health-centric information exchange and analytics activities."[1]

Several HITs help workers in these subdomains improve processes and bridge connections. Digital tools, including *NowPow*, *WellSky*, *Pieces*, *UniteUs*, *SignifyHealth*, *Rx.Health* and *Innovancer*, provide personalized referrals by connecting health organizations to community-based resources and building community-referral platforms and networks in partnerships. Most of these platforms aim to bridge gaps in care and integrate SDOH efforts into existing healthcare workflows. As a result, these platforms and networks integrate with EHRs, Health Information Exchanges (HIEs), patient portals, and care/case management systems to support referrals as part of various service provider workflows. In addition, some platforms use advanced analytics and AI to help automate the screening process and address SDOH issues (e.g., *Pieces* and *Rx.Health*). For example, *Pieces* uses predictive modeling to identify at-risk patients in the EHR system using their relevant SDOH information. Some platforms (e.g., *SignifyHealth*) mention creating value-based care as a goal. Other platforms emphasize building community care providers' networks (e.g., *UniteUs*, *NowPow*, and *WellSky*).

FACILITATING HEALTH EQUITY THROUGH HEALTH INFORMATICS

Factors such as the COVID-19 pandemic have stressed the urgent need to build and develop stronger, more resilient, and rapidly responsive data infrastructures and health systems. In addition, underlying inequities and disparities require a population health view.[88] Frameworks to address disparities suggest four broad intervention strategy concepts to confront disparities: 1) influencing social hierarchies, 2) reducing exposures, 3) decreasing vulnerabilities, and 4) preventing unequal consequences of ill health.[89]

Informatics innovations introduce many important possibilities in leveraging data to benefit both individuals and communities directly related to preventing unequal consequences of ill health (and arguably other strategies), such as:

- Applying a community/population perspective to clinical practice as well as a clinical lens to community/population health.
- Identifying health needs both at the individual and community/population levels.
- Systematically addressing the determinants of health, including the social and structural ones.

- Reaching the goals of population health and well-being, especially for socially vulnerable, underserved communities.
- Better coordinating and integrating the delivery of healthcare.
- Strengthening health promotion, health protection, and health equity.
- Closing gender inequality and other (ethnic and socio-economic) disparities and gaps.[90]

The possibilities align within and across the public health, population health, social service (including social welfare and community health), and consumer health domains, as illustrated in Table 4.

While HIT provides possibilities to address inequities, concerns remain regarding the potential for intervention-generated inequality resulting from bias in applying machine learning and other data science methods to healthcare. Specifically, health informatics interventions are at risk of reinforcing health disparities by disproportionately benefiting nonmarginalized groups that already possess health-related advantages.[91, 92] We provide a closer look at health equity through the lens of health informatics by discussing status, issues, and innovations within the health informatics subdomains particularly relevant to the healthcare workforce.

Table 4. Informatics Domains, Health Equity Challenges, and Informatics Strategies

Informatics Domains	Health Disparities Elimination and Health Equity Achievement Challenges	Information Technology Tools, Data Sources, and/or Strategies
Public Health Informatics	• Establish national guidelines, standards, and objectives for health disparities and health equity (e.g., Healthy People 2010 objective) • Foster timely translation of research evidence into practice through national health information clearinghouses • Evaluate state and local health department health disparities and health equity policy and practices	• National surveillance and disease registries • State and local health department surveys • Public health program reporting • Public health research data hubs
Population Health Informatics	• Foster equitable and empowering patient-provider communication • Emphasize primary care and preventive care and reduce the use of emergency care use for non-emergencies • Increase coordination of care through the use of Patient-Centered Medical Homes (PCMHs)	• Electronic Health Records (EHR) • Health Information Exchanges (HIEs) • Clinical data warehouses • Regional research data collaborations • Hospital-based event and disease tracking through registries (e.g., medical errors, quality, safety)
Community/Social Service Health Informatics	• Leverage community-based participatory research hubs and community partnerships • Establish multi-organizational coalition network partnerships	• Community Health Needs Assessments (CHNA) • Community health worker summaries

	(e.g., community, academic, corporate, and government) to address large-scale collective challenges	• Community-based knowledge exchange networks
Consumer Health Informatics	• Access to internet • Increase health literacy • Increase access to care • Increase emphasis on patient self-management and shared decision making	• Patient-reported outcomes • Patient health surveys • Patient advocacy (e.g., lay health advisors, social workers) • Electronic patient portals • Patient Health Records (PHRs)

Source: Reprint of Table 1 from Carney TJ, Kong AY. Leveraging health informatics to foster a smart systems response to health disparities and health equity challenges. J Biomed Inform. 2017;68:184-189.

Public Health, Population Health, and Social Service Informatics

As evidence mounts showing the associations between social factors and health outcomes, medical organizations, including the American Academy of Family Physicians and the National Association of Community Health Centers, have come out in favor of screening patients for SDOH. And federal agencies such as ONC have thrown their support behind efforts to boost technology systems' ability to integrate SDOH data.[93]

Various HIT resources help organizations develop digital platforms, collect data, implement programs to address SDOH needs, and assist healthcare providers in taking action to address SDOH. Some resource hubs are specific to rural communities by providing guidelines, toolkits, screening tools, and other resources for developing community health programs. A variety of groups have developed resources such as the Health Resources & Services Administration's *Rural Health Information Hub*, American Medical Association's *STEPSforward* toolkit, and the Association of Asian Pacific Community Health Organizations' (AAPCHO) *PREPARE Implementation and Action Toolkit*. AAPCHO was initiated as a way to develop a national voice to advocate for the unique and diverse health needs of Asian American, Native Hawaiian, and Pacific Islander communities and the community health providers that serve their needs. The National Alliance to Impact the SDOH (NASDOH) resource toolkit builds a cross-sector value proposition for addressing social needs.

A number of private companies have also developed resources targeting population health and social services. *WellSky* has curated and vetted databases for over 420,000 resources nationwide. The *NowPow* platform provides different types of referrals to manage self-care and support people's needs through personalized referrals, including self-care and caregiving needs at all ages, stages, and challenges. The configurable functionality of *NowPow* aims to fit the vast array of self-care workflows present in a system or across a community. The *ACT.md* platform allows healthcare providers to manage patient needs and care with community partners by sharing tasks, messages, and data across organizations. Care teams can see patients' unmet social needs and collaborate with community organizations to address those needs.

Clinical Health Informatics

Social service informatics elements are being introduced into EHR workflows. For example,[94] CMS has mandated (voluntary in 2023 and will be required by 2024) Special Needs Plans to include questions regarding social needs factors (e.g., housing instability, food insecurity, and housing) in Health Risk Assessments (HRAs) to help identify and address these nonmedical needs in a clinical setting. Clinical health informatics might be better poised to address health inequities if SDOH were universally and consistently collected and used as part of clinical care.[95, 96] Training tools such as *SDOH Challenge*, *SDOH Sim*, *VARIAT Sim,* and *Stand Up for Health* aim to raise provider awareness of patients' SDOH challenges and provide sensitivity training. The overarching goal of these apps is to

enable providers to identify and assist those with social needs. In general, content includes patient interaction scenarios and some broader SDOH ideas. However, each SDOH tool has nuances in key messaging and means of presentation. For example, the *SDOH Challenge* app facilitates learning how to navigate conversations around SDOH effectively. The goal of *SDOH Sim* is to emphasize the importance of understanding the patient as an individual and showing compassion for the patient. *VARIAT Sim* incorporates contextual, experiential learning in a gamified environment to improve awareness of implicit biases among Medicaid providers, educate on how biases and SDOH needs may lead to inequitable care, and offer strategies and resources to minimize health disparities.

Moreover, clinical informatics work can facilitate identifying patients with emerging disabilities using EHR data,[97] evaluating interventions to increase the use of preventative services,[98] and improving access to care for rural populations.[99] For example, American Indian/Alaska Native patients have some of the highest morbidity and mortality rates among any ethnic group in the US. The Indian Health Service (IHS) provides care to these populations who often live in remote and under-resourced communities. The IHS is currently assessing its Resource and Patient Management System (its legacy HIT system) for opportunities to reimagine and redefine HIT that supports health equity as its end goal rather than continue to focus on the traditional applications of HIT.[100]

In another example, the Veterans Health Administration (VHA) provides a methodological framework called Relative Housing Stability in Electronic Documentation (ReHouSED) to study long-term housing stability among Veterans.[101] Unfortunately, measuring the long-term housing stability of veterans who receive assistance from the VHA is difficult due to a lack of standardized structured documentation in the EHR. However, the text of clinical notes often contains detailed information about veterans' housing situations that may be extracted using natural language processing.

While housing stability is commonly considered an essential SDOH, deciding what and which social conditions are most useful for the care of patients depends upon many contextual factors and will be the subject of future debate. One study characterized the use of psychosocial information such as mental health status, financial strain, and other life stressors in outpatient diabetes care, demonstrating that its use may be related to adaptations to care plans for patients experiencing psychosocial challenges.[95]

Consumer Health Informatics

While not a focus of this brief, consumer health informatics interventions (apps, websites, home monitoring) provided by health systems and outside vendors have grown dramatically in recent years. These tools are designed to reduce vulnerability to disease (e.g., enhancing the psychological resource of self-efficacy, increasing physical activity, encouraging screening for early disease detection) or reduce the negative consequences once a disease has developed (e.g., developing disease management or coping strategies, monitoring biometrics such as blood glucose at home, text-based medication, or health management reminders).[89] Part of the goal of these tools is to enable and empower patients/health consumers by enhancing self-care and data collection opportunities.

Unfortunately, many existing consumer health informatics interventions do not specifically address differences in vulnerability or consequences for marginalized groups but instead focus on consumer/patient groups in general. Furthermore, many interventions assume computer or Smartphone access. This assumption carries some irony as access to the internet, and possibly smartphones, may itself be construed as a SDOH given the proliferation of medical data shared and provider communication transmitted electronically. In addition, opening the door to social service and population health informatics as well as emphasis on SDOH data and analysis, raises critical new issues as to how to best support the consumer and their dependents, including

issues of information sharing, service coordination, sharing of meaning and objectives, and respect for autonomy.

Potential opportunities to address health equity in consumer health informatics include understanding and addressing algorithmic biases[102] in health and healthcare, disparities in the use of digital platforms,[103, 104] and the role of technologies in fostering resilience among marginalized people and communities.[105] Furthermore, health administrators and HIT leads may be able to influence bringing health equity to patient-facing digital health tools, as enumerated in a recent JAMA publication, by:

- Investing and implementing patient portals and mobile health apps that address the needs of underserved populations.
- Tracking digital health access and usage across sociodemographics, including race/ethnicity and language, to prevent the worsening of digital divides.
- Focusing on patient training in the deployment of new technologies to account for varied digital literacy levels and ensuring security and privacy of patient data.
- Developing workflows that allow clinical teams to engage with diverse patients across digital health platforms, such as telehealth.[106]

BARRIERS AND GAPS

Multiple barriers and gaps exist in capitalizing on health informatics tools and cultivating the workforce that develops or interacts with them.

Evolving Definitions and Scope of the Field

While medicine evolves, health informatics is exploding. Shards of innovation in computer science, healthcare process, or human capabilities (e.g., digital intelligence) can cut through, create, or expand recognized subdomains. The US government's effort to promote EHRs, including recent expansions in telehealth due to COVID-19, are recognizable examples. The impact of AI and machine learning on health informatics is still unfolding, and seemingly accelerating with emerging chatbots such as OpenAI's *ChatGPT*, Microsoft's *Bing Chat* and Google's *Bard*. Taken as a whole, the breadth and depth of the health informatics field is complex and morphing, making it challenging to detail what one means when referencing health informatics without a specific context.

Furthermore, connections among the technologies within and across subdomains do not always come together to form a sum greater than siloed tools. Within clinical informatics, health information exchange challenges persist. There is a need for better data collection and integration of public health and population health into clinical informatics to address SDOH. Digital records in social care are increasing, and require investment and support to harmonize social services received with healthcare delivery.[107] Likewise, despite the proliferation of technology in the laboratory and pathology domain, influencing organizations like AMIA do not yet report an obvious "category" for laboratory informatics.[76]

Evolving Roles

Tracking an all-encompassing "health informatics" workforce from development to implementation to the evaluation of HIT becomes a daunting quandary of "how do you define" and "where do you draw the line." The field's interdisciplinary nature has blurred the lines between traditional IT workers and the health workforce. The field is evolving so quickly that many new and emerging occupations are not yet captured by common employment data sets collected by the US Bureau of Labor Statistics and the Census. For example, the 2018 Standard Occupational Codes (SOC), a national system classifying occupations, do not include common occupation titles such as Nurse Informaticist, Clinical Informatics Specialist, and Chief Medical Information

Officer. Without standardized occupation codes, tracking the supply, distribution, and characteristics of the health informatics workforce at a national level remains a challenge.

With HIT innovation comes the need for additional knowledge and skill building, propelling the workforce into rapid changes in their roles as well as requiring new workers. Healthcare providers (e.g., doctors, RNs, pharmacists) are increasingly interfacing with technologies (and the number of technologies) as part of their everyday practice, inadvertently becoming part of the health informatics workforce. With appropriate training, the health informatics workforce is well-positioned to identify best use cases for AI-related tools such as improving medical decision making and integrating disparate health record systems. This also requires partnerships between the health informatics workforce and other IT fields developing the technologies to ensure that emerging technologies meet the needs within the healthcare field. Without clear roles and boundaries, it becomes tough to track the status of the health informatics workforce and to identify the education and career pathways needed to prepare healthcare workers for these roles. For example, challenges for laboratory informatics include no job descriptions outside of research, no formal categorization for clinical lab specialist (CLS) training or board certification for health informatics, a national CLS staffing shortage, no additional paygrades, leakage to industry once trained, limited bandwidth in CLS areas, and the limited ability of traditional IT to describe processes in the language used by CLS.[76]

Uncertain Balance of Supply and Demand

There are indications that the field is growing, though without adequate tracking systems for the health informatics workforce, the current numbers may be an undercount. Also, there are signs of trouble in growing the health informatics workforce. Where the Bureau of Labor Statistics collects data on the health informatics workforce, they project growing demand:

- Health Information Technologists and Medical Registrar: Number of jobs in 2021: 39,900; Employment is projected to grow 17 percent from 2021 to 2031, much faster than the average for all occupations. About 3,400 openings for health information technologists and medical registrars are projected each year, on average, over the decade.
- Computer[108] and Information System Manager: Number of jobs in 2021: 509,100; Employment is projected to grow 16 percent from 2021 to 2031, much faster than the average for all occupations. About 48,500 openings for computer and information systems managers are projected each year, on average, over the decade. Notably, it is unclear how many of these individuals the healthcare section will need.

Among clinical informaticists, as described earlier, while the number of clinical informatics fellowships and positions is growing, the applicant pool appears to be shrinking. Some attribute this to awareness and promotion, stating that clinical informatics urgently needs robust marketing to enhance interest among medical students and residents, with continued emphasis on women and persons of color. In addition, efforts should include strong informatics curricular opportunities for medical students and residents.[109] Others indicate that "the sustainability and growth of this new and promising medical subspecialty —and its effect on care delivery— are threatened by outdated and inconsistent funding models that fail to support clinical informaticians' education and professional growth when compared with other clinical specialties."[46] Fostering an interest in health informatics needs to begin earlier in medical school or even before. As the landscape of the medical field changes, failure to emphasize critical skills needed to navigate the future of medicine early on may be a significant barrier.

Glimpses of tensions and gaps exist among different health professions that reference HIT as part of their duties or managing those that are involved in using HIT. For example, when asked about challenges to the success of

HIT tools in 2020, 21% of nurse informaticians respondents chose IT priorities as the top barrier, followed closely by organizational structure (20%).[70] The priorities changed from responses in earlier surveys conducted in 2014 and 2017, where lack of administrative support and a lack of staffing resources were cited as the top barriers.

Multiple Educational Pathways

The degree requirements to pursue a career in health informatics are not always consistent or clear. For example**,** *JobMine* reports that 47.5% of clinical informatics professionals hold a bachelor's degree, while only 23.4% hold a master's degree.[110] Overall, those interested in careers emphasizing health informatics are presented with many possible pathways that are not cleanly defined for many targeted roles. Offerings can range from on-the-job training to CEUs, to dedicated or general degrees as a generalized health informatics offering or targeting a specific area (analytics) or role (nursing informatics). Of the roles we showcased, there seems to be a limited number of dedicated education and training offerings tailored to those interested in laboratory and pharmacy informatics.

Nursing informatics degrees (typically graduate programs) seem to be one of the more defined pathways aligned to a particular set of health informatics roles, and often requiring a bachelor's degree in nursing. However, from a recent literature review,[65] there remains a lack of clarity on how to integrate informatics competencies into the curricula, for example faculty many lack familiarity with the TIGER competencies framework and report. Lack of support and training on how to implement informatics into the curriculum was cited as a barrier as well as the lack of concrete examples on how or where to bring a wide range of informatics competencies into the curricula and lack of collaboration with other nursing instructors to efficiently and effectively incorporate informatics due to faculty resistance and/or discomfort with technology. Though not in nursing, recent efforts funded by the ONC to expand public health informatics education appear to be addressing some of these issues through a public health informatics education consortium model that may align curriculums and promote sharing.

Equitable Access to and Use of Data

New policy and payment models that incentivize equity initiatives, such as the collection and response to SDOH data, will increase the availability of social data. Interest is growing in integrating these data into EHRs and implementing social care interventions that address identified risks.[111]

To the consumer, real personalization is delivering integrated support services to maintain their health and well-being, particularly when managing chronic illness and frailty. There are continued IT challenges to make meaningful connections of information streams across healthcare fields that are otherwise working hard to integrate such as primary care with behavioral health or primary care with oral health. In addition, integrating health and social care support has been identified as a key yet challenging step. Health informatics decision makers can either reinforce the isolation of silos of care and thus fragmentation of service or seek to become a unifying agent through thoughtful and considered development of HIT tools and the data they generate.[112]

Even if data are collected and used equitably, efforts are needed to overcome the current inadequacy of most systems and processes surrounding these data to achieve advances and insights. As explained in a recent article:

> *While data on social conditions, such as lack of access to adequate food, housing, and transportation, may be obtained during clinical encounters, they can also be derived from nonclinical sources such as local and national government dataset…Once these data are incorporated into the healthcare system, they facilitate the NASEM report's recommendation of increasing the health sector's awareness of social risks of patients and populations…Regardless of their source, social data are neither uniformly collected nor commonly captured in EHRs in a structured format.*[111]

CONCLUSION

The health informatics workforce plays a critical role in improving patient health by leveraging big data and harnessing the power of machine learning and AI, among other tools. Pushed forward initially by the adoption of EHRs and now with rapidly emerging innovations, the health informatics field needs integrated leadership and investments to ensure that the collective health informatics workforce has the necessary skills and competencies to manage HIT and that a sufficient pipeline exists to keep up with technological advancement and employer demand. While there are many pathways to join the health informatics workforce, the level of education to obtain an informatics-oriented job in the field tends to be at the master's level, which may be a barrier for many individuals, particularly from historically marginalized populations, due to the high cost of education and the inability to take time off work to pursue additional education. Ensuring a diverse health informatics workforce is important to reducing bias currently embedded in many existing HIT systems and developing HIT tools that meet the needs of the community.

This brief aimed to provide a landscape view of the complex and evolving health informatics workforce. Many healthcare workers are currently interacting with HIT with varying levels of intensity. Future research is needed to better understand the current gaps in knowledge and training around HIT among healthcare workers, especially in lower skilled jobs such as medical assistants, who play important supportive roles in healthcare delivery and could benefit from leveraging HIT as part of patient care. Opportunities for expanding health informatics training to support integration of health care services such as primary care with behavioral health should be explored. Also, with recent attention on the power of chatbots such as ChatGPT in synthesizing information, including for medical decision making, and the ethics surrounding the use of these tools, additional work is needed to understand how AI-based systems may be helping or harming the daily activities of healthcare workers and support the functioning of the current healthcare system.

Health informatics has considerable potential to improve health, and we are only scratching the surface of its possibilities. Combining clinical and public health knowledge with computer science and related technical skills is increasingly critical to make sense of the ever-growing body of data emerging at every point in life toward not only answering questions about individual health but also how to move the needle on health inequities. Cultivating the health informatics workforce through identification of clear career pathways and competencies, combined with structural supports such as educational financing and on-the-job training opportunities, will be important steps to move the field forward.

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APPENDIX A: DEDICATED HEALTH INFORMATICS DEGREE AND ROLES

Degree	Job Title	Description	Estimated Salary
Associate Degree	Health Information Technologist and Medical Registrar	• manage health databases • maintain patients' medical records • require knowledge of medical data software	$55,560
Bachelor's Degree	Computer and Information Systems Manager	• install new computer systems • keep operating costs low • orchestrate I.T. functions • find new ways to improve current computer systems	$159,010
Health Informatics Post Graduate Certificates	Role and position title may vary. On example is a health data analyst.	• Varies according to specialty skill attained through certification.	$73,012*
Master's Degree	Clinical Informatics Specialist	• requires expertise in healthcare management and computer science • resolves software and hardware issues while planning facility-wide system changes.	$78,210
	Pharmacy Informatics Coordinator	• trained in latest standards and pharmaceutical laws • Maintain pharmacy databases • Implement, creates relevant software	$98,260
	HIT Consultant	• advise clients on how to set up I.T. systems • requires significant specialization in computer science	$78,990
Doctoral Degree	Leadership Roles in Health Informatics (e.g., Chief Medical Information Officer)	• run entire medical programs within organizations • manage informatics budgets, personnel, work models	$298,490
	Health Informatics Academics Research specialist	• Teaching, planning projects, implementing new technologies, conducting research • Specialization varies	$101,310

*Based on data analyst using Indeed.com

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