A Health Informatics Curriculum Congruent with IS 2010 and IMIA Recommendations for an Undergraduate Degree

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Abstract

In addition to being a relevant program for health information technology workers, a recently proposed Health Informatics program was designed with additional objectives in mind: that the program is compatible with the IS 2010 Model Curriculum and that it satisfies the International Medical Informatics Association recommendation for undergraduate curricula. In this paper, we show that the program meets the IS 2010 guidelines based on an analysis of skill expectations for health informatics graduates. We produce a three-way mapping of IS 2010 knowledge and skill sets to IMIA learning outcomes to health informatics course sets. The program is comprised of three course sets: information systems courses, health informatics courses, and courses comprising the clinical environment. Courses in all three sets contribute skills in adequate depth with no gaps in coverage of required skills in either model. The success of the mappings indicates that health informatics should be a robust information systems program that will increase the productivity of individuals and organizations through the application of health information technology. The health informatics curriculum is largely an organizational systems-based program designed to enable new workflow models for health environments.

Keywords: health informatics, IS curriculum, IMIA curriculum, IS skills, organizational productivity, biomedical environment for IS programs, HITECH Act

1. INTRODUCTION

Health Informatics (HI) is a relatively new idea as a program within the information systems (IS) domain. We have developed a curriculum for a proposed Health Informatics degree at our university. The degree program is designed to attract new students to the information systems profession and to meet growing workforce demands in health information technology (HIT). In designing the curriculum, we consulted the recommendations of the International Medical Informatics Association (IMIA) undergraduate bachelors program (Mantas et al., 2010).

Due to the federal initiatives to significantly increase the adoption of information systems in health care, there is an urgency to make significant progress to achieve national goals of the Health Information Technology for Economic and Clinical Health Act (HITECH Act, 2009).

Workforce Needs

According to the United States Department of Health and Human Services, there is a pressing need for workers that are both skilled in the use and management of information systems as well as knowledgeable about the field of healthcare (ONC, 2010). Driven, in part, by government incentives provided by the HITECH Act, interest has been growing among healthcare providers in implementing electronic health record (EHR) systems in their organizations. To accommodate these new enterprise-wide EHR applications, some organizations are replacing their legacy health information systems after finding that they are insufficient for their needs. These widespread investments in EHR's and other health information systems have created a shortage of personnel that are both skilled in information systems and knowledgeable about the healthcare environment (Wager, 2009).

Training programs at the collegiate level have yet to respond to these changes in the healthcare industry. The traditional training model that requires a student to choose between being a healthcare practitioner or a technologist is inadequate since, as noted "a well-trained HIT professional should have knowledge not only of information technology, but also of healthcare, business and management, and other disciplines" (Hersh, 2010 p. 198).

In order to satisfy the workforce needs created by the widespread adoption of health information technology, the Office of the National Coordinator for Health Information Technology (ONC) has created the Health IT Workforce Development Program. Through this program, community colleges and universities have received funding to develop training programs that address six workforce roles identified by the ONC. However, these training programs are not an ideal solution for new students since they focus on training existing IT and healthcare workers and are generally not available for students who don't have a degree and a minimum level of experience (ONC, 2010).

The workforce roles that have been identified by the ONC include:

- Practice Workflow and Information Management Redesign Specialist
- Clinician/Practitioner Consultant
- Implementation Support Specialist
- Implementation Manager
- Technical/Software Support Staff
- Trainer

In order to provide an ongoing supply of qualified workers, it is necessary to train new HIT workers in a program that includes skills in the use and management of information systems set in the healthcare environment, and specifically, enterprise level EHRs.

Proposed Degree Program

After reviewing multiple goals for the curriculum (Campbell et al., 2011) we are convinced that the curriculum is ABET accreditable (ABET, 2010) as an Information Systems program. See Landry et al., (2011) for a detailed analysis of the program against ABET-CAC program criteria. We further believe that that the learning outcomes of the International Medical Informatics Association (IMIA) model map well to IS skill sets described by Landry et al., 2000, and recently by Colvin (2007).

Therefore, the remaining questions we address in this paper are:

- *Is this new Health Informatics curriculum an information systems curriculum congruent with the recommendations of IS 2010 (Topi et al., 2010)?*

- *Is the proposed curriculum simultaneously congruent with the IMIA recommendations for a bachelor's degree in informatics?*

2. BACKGROUND

What is an IS Curriculum?

Ultimately, the nature and quality of any IS program will be determined by the ability of its graduates to achieve and thrive in the workplace as an IS professional. In this spirit, we accept the notion advanced in IS'90 (Longenecker et al., 1990), in IS'95 (Couger et al., 1995), in IS'97 (Davis et al., 1997), in IS2002 (Davis et al., 2002), and in IS 2010 that our graduates must be both confident and competent to execute the skills which define the profession. In addition, they should be able to continue successfully into advanced degree programs.

We feel it is important that our graduates are equipped to accomplish the mission of information systems as expressed by McNurlin and Sprague (2006): *"To improve the performance of people in organizations through the use of IT. The objective is the improvement of the enterprise, not IS, so, ideally, IS performance is based on business outcomes and business results."*

We currently have a successful IS program that is ABET accredited. In our Health Informatics program, however, we have instituted several significant changes (Campbell et al., 2011) which replace programming courses with health informatics courses and change the environment from business to a clinical environment. We argue that these changes should be compatible with ABET IS accreditation (Landry et al., 2011) and with the specification for IS 2010 (Topi et al., 2010). See discussion below.

What is IS 2010?

IS 2010 is the current version of the model curriculum for undergraduate programs of information systems. It is a systems-based curriculum developed from prior models: IS'90, IS'95, IS'97, and IS2002. IS 2010 defines a core of courses common to most degree programs, and suggests that there will be many variations among new IS programs that will determine additional courses that complete the major. IS 2010 relaxes the programming requirement of IS2002 by removing the IS2002.5 and IS2002.9 courses from the new core. It also relaxes the mathematics requirements. The program can be completed with ten courses in keeping with a business school environment.

IS 2010 utilizes three knowledge and skill areas for assessing its degree requirements (Topi et al., 2010 p. 19). We have used these definitions of the curriculum to assess our new program (See discussion below):

1.0 IS Specific Knowledge and Skills
2.0 Foundation Knowledge and Skills
3.0 Domain Related Knowledge and Skills

3. HEALTH INFORMATICS IN THE IS 2010 MODEL

IS 2010 curriculum guidelines (Topi, 2010) define an IS bachelor's degree program in terms of knowledge and skills. Also, it describes the characteristics IS graduates should possess. Furthermore, it is appropriate that there be some alignment between IS 2010 core courses and the proposed health informatics course set.

Description of How Proposed Curriculum Meets IS 2010 Requirements

Specifically, any information systems program must provide answers to the details of the three areas. The details of the specification are contained in IS 2010:

1.0 Information Systems Specific Knowledge and Skills
2.0 Foundation Knowledge and Skills
3.0 Knowledge and Skills Related to Domain Fundamentals.

It is further expected that knowledge and skills are achieved by completing certain course sequences. IS 2010 provides a relatively flat sequence of seven core courses, along with suggested electives, as an example of course sets which meet the spirit of the information systems specific knowledge skill requirements. Instead of looking at IS 2010 prescribed courses and comparing them literally to our HI courses, we chose to follow a methodology of mapping our courses to knowledge and skill expectations of the specification. Curriculum mapping has been useful for expressing knowledge and skills at different levels of abstraction and for assessing the breadth and depth of curricula. Mapping can be useful for identifying gaps in knowledge and skill areas, and demonstrating a curriculum's adherence to prescribed guidelines. IS 2010 provides three broad knowledge and skill areas for graduates. These categories are

helpful to any organization attempting to verify that its courses match the expectations of the curriculum developers.

Category 1.0 criteria are:

1.1 Identifying and designing opportunities for IT-enabled organizational improvement
1.2 Analyzing trade-offs—(alternate solutions, feasibility, use of decision criteria)
1.3 Designing and implementing information systems solutions
1.4 Managing ongoing information technology operations

Tables 1 through 8 are contained within the Appendix section of this document.

In Table 1, the courses of our degree program are mapped to the four IS specific skill categories of IS 2010. Our program uses 12 courses to attain the IS major specification. These courses contain the desired level of IS skill content.

Category 2.0 defines foundational skills that may be provided by courses other than the information system course set. IS 2010 identifies foundational knowledge and skills that are not unique to IS programs, yet which are of significant importance to IS professionals. This knowledge and skills come from general education courses and IS courses as well.

These foundational skills include:

2.1 Leadership and collaboration (teams, organizational structuring)
2.2 Communication (listening, observing, writing, presenting, and collaboration tools)
2.3 Negotiation (internal organizational, external providers, facilitation)
2.4 Analytical and critical thinking (breaking down systems, relationships, problem solving, ethical/legal implications, qualitative analysis, enhancing innovation and creativity)
2.5 Mathematical foundations (specialty related, statistics, algorithmic thinking)

Table 2 demonstrates our compliance with IS 2010 by showing foundation courses selected for the health informatics program.

Knowledge and skills related to the domain of health informatics are different from the usual IS/business environment. Table 3 details the courses relevant to the clinical domain. They involve a mix of basic medical sciences courses in anatomy and physiology, as well as a breadth of allied health introductory courses related to the clinical environment. Table 4 presents detailed descriptions of these courses so that the reader may appreciate the "ecosystem" of these biomedical specialties.

Indeed, domain skills are covered within the Health Informatics courses as well. The context of the clinical environment itself is set in the language of the biomedical sciences as well as medicine. It is not our intention to create either a medical or biomedical science degree through the courses offered. Rather, it is suggested that these courses define and encompass the areas for the IS Health Informatics Degree Program. We do not believe that the set of allied health courses are an absolute specification. Instead, we suggest that a broad selection of basic courses will provide a rich environment for the informatics professional.

What is the IMIA Health Informatics Degree Recommendation?

IS Skills		IMIA Outcomes (see Table 5)		
IS Skills - Industry Analysis (Colvin 2007)		Total Count	Count in Basic IS Courses	Count in Advanced IS Informatics Courses
1.1	Software Development	5	1	4
1.3	Database	4	2	2
1.4	Systems Integration	4	1	3
1.5	Info Security Assurance	1	0	1
2.1	Business Fundamentals	5	2	3
2.2	Individual & Teams	3	3	0
3.1	Org Sys Development	17	7	10
3.2	Project Management	1	0	1
8	Total	40	16	24

Table 0. Relationship of IMIA Outcomes to IS Skills.

Mantas et al., (2010) reports that health and medical informatics are well known areas, but federal performance requirements are placing a large demand on community, four-year, and advanced degree programs, many of which do not exist. The report contains the

recommendations of a large task force knowledgeable of the needs and requirements for health informatics programs.

Significant in the Mantas presentation is a table of knowledge and skill expectations for a bachelor's degree program. In order to understand the outcomes presented this table, we have mapped each IMIA outcomes to IS Skills (Landry et al., 2000; and Colvin, 2007). Simultaneously, we mapped the outcomes to one of the collections of courses. Table 0 demonstrates the numbers of IMIA outcomes to IS skills. Table 5 shows the mapping to both skills and course areas.

A large percentage of the total number of IS skills are supplied in the organizational systems development category, business fundamentals and database categories of skills. In addition, there are more objectives focused in the advanced area of the curriculum. The level of expected skill is higher in more advanced courses.

Table 6 represents IMIA outcomes from the basic information systems area while Table 7 shows the outcomes associated with the advanced IS skills. Clearly the more advanced outcomes result from the more advanced section of the curriculum. Using the depth levels of the IMIA model, application skills are reached in the advanced courses. The lower level courses introduce materials (note the outcomes with level 1 and 2 skills) whereas the upper level outcomes (levels 2 and 3) occur primarily in the advanced courses.

Interestingly, Table 8 shows that the clinical disciplines also furnish material directly related to the IMIA as well as the IS skill outcomes.

While we might have tried to map the IMIA outcomes to individual courses, we argue that the courses are already known (to us and ABET). We were not starting at the beginning to design new courses. Rather, we feel that in aggregate, each course set must eventually satisfy the IMIA outcomes, as well as the skills.

Benefits for Students and Programs

It is our perception that the Health Informatics program will afford new opportunities for our students. Allied health and nursing students who are interested in information systems will have a simple migration pattern to this degree program. They will stand a great chance of being hired because of their joint clinical and information systems specialties.

IS students who have an interest in health care will receive specialty training appropriate to their being productive in a clinical environment. In our area we can place students we graduate, and they will be able to pursue meaningful careers.

Drawbacks for Students and Programs

Some students may be more interested in the technological side of health informatics but uncertain of their commitment to working in the healthcare domain. These students may choose to either major in HI or IS. If they enroll in HI, they may add courses in application development and/or business. This route is a good one, particularly if they already have completed or nearly completed the clinical environment. The second option would be to enroll in the existing IS program, where they might also choose the health informatics certificate by completing the four course sequence in HI. This second option is a better fit with HIT workforce needs for software engineers.

If a traditional IS student wished to achieve the informatics degree, they may have elected biomedical science courses they really did not appreciate. Their fallback position will be to add business courses (2 courses) and programming (3 courses) for which they may spend additional time.

4. DISCUSSION

Our analysis of our proposed program reveals that the Health Informatics program is an IS degree program fully compatible with the IS 2010 guidelines. It also is very clear, because of the clinical environment requirement for the Health Informatics degree, that the junior year becomes determinant for course selection and commitment by students.

Our proposed clinical environment gives a very rich eco-system of courses for the future Health Informatics professional. With a firm understanding of the work environment, enterprise exposure to information systems relevant to electronic medical records, and experience developing work-flows involving patient care, our graduates will be more

professionally prepared for the HIT workforce than a traditional IS graduate.

Our clinical environment was chosen by studying the first courses of the many disciplines that make up our Allied Health and Nursing Colleges. We are not committed to a specific set of courses. At our institution, the department of Biomedical Sciences offers two introductory courses that have no biology or chemistry prerequisites. These courses are used by Allied Health professions departments. This special relationship makes it easy for our Health Informatics students to take a laboratory science that is general, yet focused in a direction preliminary and prerequisite to the clinical environment courses we have selected.

Our proposed program is structured to prepare graduates to be able to "hit the ground running" without a health science degree background and experience of on the job training that might otherwise be necessary for an IS graduate. While traditional IS graduates could overcome the limitations of not knowing the environment of the Health Informatics discipline, they would be at a disadvantage in this increasingly important biomedical environment.

It was interesting that the IS skills map to the IMIA outcomes. The reality of the mapping suggests how the clinical environment plays an important and significant part in understanding the relative richness of the skills and outcomes. Likewise, that the IS skills can be mapped to the IMIA BS requirements, supports the strong relationship of the HI model to the IS profession.

Mapping to both IS and HI model curricula at once enables a richer evaluation of our proposed program than if we had mapped to one or the other, or both separately. In effect, the triple-mapping enables a kind-of cross-checking to take place. A mapping decision might result in a confirmation of the relationship between two skills, or else point out a contradiction that leads to further analysis. Such an analysis was useful for us in making decisions to include or exclude courses in the proposed HI program. We have not validated our mappings at this time; we expect to go to this step within the next year, particularly as we expect to develop a standardized exam to measure program and individual success.

An additional design criterion we imposed upon ourselves was to allow for degreed Nursing or other Allied Health professionals to take our Health Informatics courses with no additional prerequisites. The five HI courses and be elected by a health care professional, and when completed will result in a Certificate in Health Informatics. We have elected to take this approach based on the recommendations of EHR vendors in our area who are willing to hire immediately our certificated individuals into meaningful careers. Normally, assumptions are made about the necessity for programming and other IS skills as prerequisite to systems analysis and database courses. However, we are confident that a mature individual can complete these more "advanced courses" with no additional prerequisites. Indeed we have experience in the success of such individuals. In fact, some of the highest scores in these classes have come from several nurses who have scored on top of the class!

5. CONCLUSIONS

We have presented the details of a Health Informatics program, and have shown, using the technique of curriculum mapping, that it covers the breadth and depth of knowledge and skills of an IS program within the guidelines of IS 2010. Further, we have shown that the same program maps well to the International Medical Informatics Association outcome criteria for a bachelor's degree in Health Informatics. In addition, we feel based on input from our advisory group that graduates of the degree will find it possible to work in the informatics field or go on for additional graduate studies.

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Appendix

IS 2010 Program Knowledge and Skills Produced by Courses

Knowledge and Skills Criteria

1.1 Identifying and designing opportunities for IT-enabled organizational improvement
1.2 Analyzing trade-offs—(alternate solutions, feasibility, use of decision criteria)
1.3 Designing and implementing information systems solutions
1.4 Managing ongoing information technology operations

IS Knowledge and Skills Criteria > **IS Courses in Degree Program**	1.1	1.2	1.3	1.4
CIS 245- IS in Organizations	*	*		
CIS 272- Systems Organization	*	*		
CIS 321- Data Communications & Networking	*	*		
CIS 324- Database Design	*	*	*	
CIS 360- Analysis and Design	*	*	*	
ISC 462- IS Strategy and Policy	*	*	*	*
CIS 495- IT Project Management	*	*	*	
HI 300- Health Informatics Clinical Environment	*			
HI 410- Health Informatics	*	*		
HI 450- Health Systems Analysis and Design	*	*	*	*
HI 455- Health Decision Support Systems	*	*	*	
HI 496- Health Informatics Internship			*	*

Table 1: Providing Skills Through IS Course Work as Specified by IS 2010

	-------Skills Produced by Courses-------				
Foundational Skills Criteria 2.1 Leadership and collaboration (teams, organizational structuring) 2.2 Communication (listening, observing, writing, presenting, and collaboration tools) 2.3 Negotiation (internal organizational, external providers, facilitation) 2.4 Analytical and critical thinking (breaking down systems, relationships, problem solving, ethical/legal implications, qualitative analysis, enhancing innovation and creativity) 2.5 Mathematical foundations (specialty related, statistics, algorithmic thinking)	2.1	2.2	2.3	2.4	2.5
EH 101- Composition I		*			
EH 102- Composition II		*			
CA 110- Public Speaking		*			
MA 112 or higher				*	*
MGT 345 Statistics 1				*	*
MGT 355 Statistics 2				*	*
PSY 120 General Psychology		*	*		
ISC 360 Analysis and Design	*	*	*	*	
ACC 211 Accounting Principles I	*	*			*
MGT 300 Management Theory and Practice	*	*			
ISC 462- IS Strategy and Policy	*	*	*	*	
CIS 495- IT Project Management	*	*	*	*	
HI 300- Health Informatics Clinical Environment	*	*	*	*	
HI 450- Health Systems Analysis and Design	*	*	*	*	*
HI 455- Health Decision Support Systems	*	*	*	*	*
HI 496- Health Informatics Internship	*	*	*	*	*

Table 2. Courses that Supply Foundation Skills for the Health Informatics Program.

		Domain Skills Produced by Courses		
3.1 Basic Medical Sciences 3.2 Health Informatics Clinical Environment 3.3 Health Informatics Courses				
IS Courses in Degree Program	**IS Skills Criteria**	3.1	3.2	3.3
3.1	BMD 114 Human Anatomy and Physiology I	*	*	
	BMD 115 Human Anatomy and Physiology II	*	*	
	BMD 210 Infectious Diseases in Health Care	*	*	
3.2	NU 311 Clinical Nursing Skills		*	
	NU 325 Health Assessment		*	
	HSC 342 Clinical Pharmacology		*	
	RAD 101 Principles of Radiographic Exposure		*	
	OT 201 Introduction to Occupational Therapy		*	
	CRC 330 Cardio-respiratory Care Assessment		*	
3.3	HI 300- Health Informatics Clinical Environment		*	*
	HI 410- Health Informatics		*	*
	HI 450- Health Systems Analysis and Design		*	*
	HI 455- Health Decision Support Systems		*	*
	HI 496- Health Informatics Internship		*	*

Table 3. Courses that Define Domain Skills for the Health Informatics Program

Courses	Catalog Description
BMD 114 Human Anatomy and Physiology I	This is the first of a two-course sequence that covers an introduction to basic human anatomy and physiology, including the study of the structure and function of the normal human body. Included is a study of basic principles of chemistry related to human physiology, a study of cells and tissues, metabolism, joints, the integumentary, skeletal, muscular and nervous systems, and the senses.
BMD 115 Human Anatomy and Physiology II	A continuation of BMD 114. Topics include nervous, cardiovascular, lymphatic, immune, respiratory, digestive and urinary systems. Additional topics may include blood, metabolism, immunology and reproduction.
BMD 210 Infectious Disease in Health Care Environments	This course introduces the fundamental concepts of host-parasite relationships involved in infectious diseases. Included are virulence characteristics of microbes and mechanisms of host defenses. Principles of microbial physiology, genetics and antimicrobial therapy are provided as background. Specific infectious diseases of various anatomical systems are emphasized
NU 311 Clinical Nursing Skills	The purpose of this course is to provide students the opportunity to acquire basic nursing care skills. The emphasis is on the responsibilities of the professional nurse in ensuring quality and safety. Students are introduced to simulation as an approach to sharpen clinical reasoning and communication skills in a safe environment
NU 325 Health Assessment	The purpose of the course is to provide students the opportunity to acquire basic nursing assessment skills. The emphasis is on the assessment skills of the whole person, including physical, psychological, socio-cultural, and spiritual aspects of persons from all stages of life. Students will learn skills associated with obtaining a health history and performing health assessments across the lifespan.
HSC 343 Clinical Pharmacology	The purpose of the course is to provide the student with the opportunity to acquire information related to the clinical application of drug therapy and the concepts relating to the mechanisms of drug actions, interactions, and adverse reactions, including the immunologic-idiosyncratic-allergic responses. Emphasis is on the current evidence related to pharmacokinetics, dosage, methods of administration, and adverse effects of major classifications of drugs to inform nursing care.
RAD 101 Principles of Radiographic Exposure	A beginning study of the principles involved in image formation including radiographic films, film processing, and exposure factors affecting film quality.
OT 201 Introduction to Occupational Therapy	An introduction to the occupational therapy profession and the scope of occupational therapy practice. Includes self-assessment and development strategies to enhance students' readiness for the professional component of the occupational therapy curriculum. Familiarizes students with the functions, policies and services of the University, College and Department and includes an exploration of related allied health professions.
CRC 330 Cardio-respiratory Care Assessment Skills	A presentation of patient assessment skills to prepare for subsequent courses in the curriculum. Modules included are chart review and history, vital signs, physical assessment of the chest, chest radiography, laboratory assessment, bedside pulmonary function testing, electrocardiography, and cardiopulmonary resuscitation. Students are prepared to function in a

	problem-based learning curriculum.
MGT 300 Management Theory and Practice	Theories of organizational structures, practices, and behavior, and the effective leadership and management of organizations. Emphasis on leadership and developing patterns and strategies of organization management in a dynamic environment as affected by the interaction of material and human resources using the technique of applied social and management sciences.
MGT 325 Operations Management	Addresses concepts, problems, and managerial approaches applicable to the management of manufacturing and service operations. The course will examine the strategic and tactical considerations that are involved in creating a systematic framework that supports the creation of competitive advantages through effective operations and the production of high quality products. Topics covered include the role of operations in the overall organization, operations strategy development and implementation, product design and process selection, location and capacity planning, facilities' layout, quality management, inventory management, production planning, scheduling and control, and project management. An important component of the overall course is the incorporation of computer applications for problem solving and decision making in operations.

Table 4. Course Descriptions Demonstrating a Clinical Environment for Health Informatics

Information Systems Skills (Colvin, 2007; Landry et al., 2000)		International Medical Informatics Association (IMIA) Expected Skills for BS Degree in Informatics (Mantas et al., 2010)		IMIA Skill Level	3--NatSci/Math 5-PreMajor CE-ClinicalEnv IS-Area HI-HealthInfo
1.1	Software Development	3.01	**Basic informatics terminology** like data, information, knowledge, hardware, software, computer, networks, information systems, information systems management	3	IS
1.1	Software Development	3.04	Methods of **practical informatics**/computer science, especially on programming languages, software engineering, data structures, database management systems, information and system modeling tools, information systems theory and practice, knowledge engineering, (concept) representation and acquisition, software architectures	3	IS
1.1	Software Development	3.10	**Mathematics:** algebra, analysis, logic, numerical mathematics, probability theory and statistics, cryptography	2	3
1.1	Software Development	1.05	**Information literacy:** library classification and systematic health related terminologies and their coding, literature retrieval methods, research methods and research paradigms	2	HI
1.1	Software Development	3.14	Usability engineering, **human-computer interaction**, usability evaluation, cognitive aspects of information processing	2	IS
1.3	Database	1.11	Appropriate documentation and **health data management principles** including ability to use **health and medical coding systems,** construction of health and medical coding systems	3	HI
1.3	Database	1.12	Structure, design and analysis principles of the **health record** including notions of data quality, minimum data sets, architecture and general applications of the electronic patient record/electronic health record	3	HI
1.3	Database	1.16	**Ethical and security issues including** accountability of health care providers and managers and BMHI specialists and the confidentiality, privacy and security of patient data	2	5
1.3	Database	1.14	Principles of **data representation and data analysis** using primary and secondary data sources, principles of data mining, data warehouses, knowledge management	2	CE
1.4	Systems Integration	3.07	Methods of **interfacing and integration** of information system components in health care, interfacing standards, dealing with multiple patient identifiers	2	HI
1.4	Systems Integration	1.10	Methods and approaches to **regional networking and shared care** (e-Health, health telematics applications and inter-organizational information exchange)	2	IS
1.4	Systems Integration	3.06	Methods of **technical informatics**/computer science, e.g. network architectures and topologies, telecommunications, wireless technology, virtual reality, multi-medias	2	IS
1.4	Systems Integration	3.13	Basic concepts and applications of **ubiquitous computing** (e.g. pervasive, sensor-based and ambient technologies in health care, health enabling technologies, ubiquitous health systems and ambient assisted-living)	1	HI

1.5	Info Security Assurance	3.05	Methods of **theoretical informatics**/computer science, e.g. complexity theory, encryption/security	2	HI
2.1	Business Fundamentals	2.04	**Organization of health institutions** and of the overall health system, inter-organizational aspects, shared care	3	CE
2.1	Business Fundamentals	1.08	**Management of information systems** in health care (health information management, strategic and tactic information management, IT governance, IT service management, legal and regulatory issues)	3	HI
2.1	Business Fundamentals	1.09	Characteristics, functionalities and examples of **information systems to support patients and the public** (e.g. patient-oriented information system architectures and applications, personal health records, sensor-enhanced information systems)	2	HI
2.1	Business Fundamentals	1.07	**Architectures of information systems** in health care; approaches and standards for communication and cooperation and for interfacing and integration of component, architectural paradigms (e.g. service-oriented architectures)	2	IS
2.1	Business Fundamentals	2.05	**Policy and regulatory frameworks** for information handling in health care	1	CE
2.2	Individual & Teams	3.02	**Ability to use personal computers,** text processing and spread sheet software, easy-to-use database management systems	3	5
2.2	Individual & Teams	3.03	**Ability to communicate electronically,** including electronic data exchange, with other health care professionals, internet/intranet use	3	5
2.2	Individual & Teams	1.04	**Use of personal application software** for documentation, personal communication including Internet access, for publication and basic statistics	2	5
3.1	Org Sys Development	1.06	Characteristics, functionalities and examples of **information systems in health care** (e.g. clinical information systems, primary care information systems, etc.)	3	HI
3.1	Org Sys Development	3.08	Handling of the **information system life cycle**: analysis, requirement specification, implementation and/or selection of information systems, risk management, user training	3	HI
3.1	Org Sys Development	3.12	Methods for **decision support** and their application to patient management, acquisition, representation and engineering of medical knowledge; construction and use of clinical pathways and guidelines	3	HI
3.1	Org Sys Development	3.11	**Biometry, epidemiology,** and **health research methods**, including study design	2	5
3.1	Org Sys Development	1.13	**Socio-organizational and socio-technical issues,** including workflow/process modeling and reorganization	2	CE
3.1	Org Sys Development	2.03	Principles of **clinical/medical decision making** and diagnostic and therapeutic strategies	2	CE
3.1	Org Sys Development	2.07	**Health administration, health economics,** health quality management and resource management, patient safety initiatives, public health services and outcome measurement	2	CE
3.1	Org Sys Development	1.02	**Need for systematic information processing** in health care, benefits and constraints of information technology in health care	2	HI
3.1	Org Sys Development	1.03	Efficient and responsible **use of information processing tools,** to support health care professionals' practice and their decision making	2	HI
3.1	Org Sys Development	1.17	**Nomenclatures, vocabularies,** terminologies, ontology's and taxonomies in BMHI	2	HI

3.1	Org Sys Development	1.19	**Evaluation and assessment** of information systems, including study design, selection and triangulation of (quantitative and qualitative) methods, outcome and impact evaluation, economic evaluation, unintended consequences, systematic reviews and meta-analysis, evidence-based health informatics	2	IS
3.1	Org Sys Development	2.01	Fundamentals of **human functioning** and biosciences (anatomy, physiology, microbiology, genomics, and clinical disciplines such as internal medicine, surgery, etc.)	1	CE
3.1	Org Sys Development	2.02	Fundamentals of **what constitutes health,** from physiological, sociological, psychological, nutritional, emotional, environmental, cultural, spiritual perspectives and its assessment	1	CE
3.1	Org Sys Development	2.06	Principles of **evidence-based practice** (evidence-based medicine, evidence-based nursing, …)	1	CE
3.1	Org Sys Development	1.01	**Evolution of informatics** as a discipline and as a profession	1	HI
3.1	Org Sys Development	1.18	Informatics methods and tools to **support education** (incl. flexible and distance learning), use of relevant educational technologies, incl. Internet and World Wide Web	1	HI
3.1	Org Sys Development	1.15	Biomedical **modeling and simulation**	1	IS
3.2	Project Management	3.09	Methods of **project management and change management** (i.e. project planning, resource management, team management, conflict management, collaboration and motivation, change theories, change strategies)	3	HI

Table 5. Mapping of IMIA Outcomes to Health Informatics Program Areas, and to IS Skills

Courses that Satisfy the Information Systems Area
ISC 245 Information Systems in Organizations
ISC 272 Systems Architecture
CIS 321 Data Communications and Networking
CIS 324 Database Design, Development, and Management
ISC 360 Information Systems Analysis and Design (W)
ISC 462 Information Systems Strategy and Policy

International Medical Informatics Association (IMIA) Expected Skills for BS Degree in Informatics (Mantas et al., 2010)		IMIA Skill Level	Information Systems Skills (Colvin, 2007; Landry et al., 2000)	
1.07	**Architectures of information systems** in health care; approaches and standards for communication and cooperation and for interfacing and integration of component, architectural paradigms (e.g. service-oriented architectures)	2	2.1	Business Fundamentals
1.19	**Evaluation and assessment** of information systems, including study design, selection and triangulation of (quantitative and qualitative) methods, outcome and impact evaluation, economic evaluation, unintended consequences, systematic reviews and meta-analysis, evidence-based health informatics	2	3.1	Org Sys Development
1.15	Biomedical **modeling and simulation**	1	3.1	Org Sys Development
3.01	**Basic informatics terminology** like data, information, knowledge, hardware, software, computer, networks, information systems, information systems management	3	1.1	Software Development
3.04	Methods of **practical informatics**/computer science, especially on programming languages, software engineering, data structures, database management systems, information and system modeling tools, information systems theory and practice, knowledge engineering, (concept) representation and acquisition, software architectures	3	1.1	Software Development
3.14	Usability engineering, **human-computer interaction**, usability evaluation, cognitive aspects of information processing	2	1.1	Software Development
1.10	Methods and approaches to **regional networking and shared care** (eHealth, health telematics applications and inter-organizational information exchange)	2	1.4	Systems Integration
3.06	Methods of **technical informatics**/computer science, e.g. network architectures and topologies, telecommunications, wireless technology, virtual reality, multimedia	2	1.4	Systems Integration

Table 6. Courses, IMIA and IS Skills for the Health Informatics Information Systems Area.

Courses That Satisfy the Health Informatics Area

ISC 300 Health Informatics Clinical Environment
ISC 410 Health Informatics
ISC 450 Health Sys Analysis and Design
ISC 455 Health Decision Support Sys
ISC 475 Information Systems Project Management
CIS 496 Computer and Information Sciences Internship

International Medical Informatics Association (IMIA) Expected Skills for BS Degree in Informatics (Mantas et al., 2010)		IMIA Skill Level	Information Systems Skills (Colvin, 2007; Landry et al., 2000)	
1.08	**Management of information systems** in health care (health information management, strategic and tactic information management, IT governance, IT service management, legal and regulatory issues)	3	2.1	Business Fundamentals
1.09	Characteristics, functionalities and examples of **information systems to support patients and the public** (e.g. patient-oriented information system architectures and applications, personal health records, sensor-enhanced information systems)	2	2.1	Business Fundamentals
1.11	Appropriate documentation and **health data management principles** including ability to use **health and medical coding systems,** construction of health and medical coding systems	3	1.3	Database
1.12	Structure, design and analysis principles of the **health record** including notions of data quality, minimum data sets, architecture and general applications of the electronic patient record/electronic health record	3	1.3	Database
3.05	Methods of **theoretical informatics**/computer science, e.g. complexity theory, encryption/security	2	1.5	Info Security Assurance
1.06	Characteristics, functionalities and examples of **information systems in health care** (e.g. clinical information systems, primary care information systems, etc.)	3	3.1	Org Sys Development
3.08	Handling of the **information system life cycle**: analysis, requirement specification, implementation and/or selection of information systems, risk management, user training	3	3.1	Org Sys Development
3.12	Methods for **decision support** and their application to patient management, acquisition, representation and engineering of medical knowledge; construction and use of clinical pathways and guidelines	3	3.1	Org Sys Development
1.02	**Need for systematic information processing** in health care, benefits and constraints of information technology in health care	2	3.1	Org Sys Development
1.03	Efficient and responsible **use of information processing tools,** to support health care professionals' practice and their decision making	2	3.1	Org Sys Development
1.17	**Nomenclatures, vocabularies,** terminologies, ontology's and taxonomies in BMHI	2	3.1	Org Sys Development
1.01	**Evolution of informatics** as a discipline and as a profession	1	3.1	Org Sys Development
1.18	Informatics methods and tools to **support education** (incl. flexible and distance learning), use of relevant educational technologies, incl. Internet and World Wide Web +	1	3.1	Org Sys Development
3.09	Methods of **project management and change management** (i.e. project planning, resource management, team management, conflict management, collaboration and motivation, change theories, change strategies)	3	3.2	Project Management
1.05	**Information literacy:** library classification and systematic health related terminologies and their coding, literature retrieval methods, research methods and research paradigms	2	1.1	Software Development
3.07	Methods of **interfacing and integration** of information system components in health care, interfacing standards, dealing with multiple patient identifiers	2	1.4	Systems Integration
3.13	Basic concepts and applications of **ubiquitous computing** (e.g. pervasive, sensor-based and ambient technologies in health care, health enabling technologies, ubiquitous health systems and ambient assisted-living)	1	1.4	Systems Integration

Table 7. Courses, IMIA and IS Skills for the Health Informatics Environment

Courses that Satisfy the Clinical Environment
BMD 210 Infectious Disease in Health Care Environments
NU 311 Clinical Nursing Skills
NU 325 Health Assessment
HSC 343 Clinical Pharmacology
RAD 101 Principles of Radiographic Exposure
OT 201 Introduction to Occupational Therapy
CRC 330 Cardio-respiratory Care Assessment Skills
MGT 300 Management Theory and Practice
MGT 325 Operations Management

International Medical Informatics Association (IMIA) Expected Skills for BS Degree in Informatics (Mantas et al., 2010)		IMIA Skill Level	Information Systems Skills (Colvin, 2007; Landry et al., 2011)	
2.04	**Organization of health institutions** and of the overall health system, inter-organizational aspects, shared care	3	2.1	Business Fundamentals
2.05	**Policy and regulatory frameworks** for information handling in health care	1	2.1	Business Fundamentals
1.14	Principles of **data representation and data analysis** using primary and secondary data sources, principles of data mining, data warehouses, knowledge management	2	1.3	Database
1.13	**Socio-organizational and socio-technical issues,** including workflow/process modeling and reorganization	2	3.1	Org Sys Development
2.01	Fundamentals of **human functioning** and biosciences (anatomy, physiology, microbiology, genomics, and clinical disciplines such as internal medicine, surgery, etc.)	1	3.1	Org Sys Development
2.02	Fundamentals of **what constitutes health,** from physiological, sociological, psychological, nutritional, emotional, environmental, cultural, spiritual perspectives and its assessment	1	3.1	Org Sys Development
2.03	Principles of **clinical/medical decision making** and diagnostic and therapeutic strategies	2	3.1	Org Sys Development
2.06	Principles of **evidence-based practice** (evidence-based medicine, evidence-based nursing, …)	1	3.1	Org Sys Development
2.07	**Health administration, health economics,** health quality management and resource management, patient safety initiatives, public health services and outcome measurement	2	3.1	Org Sys Development

Table 8. Courses, IMIA and IS Skills for the Health Informatics Clinical Environment.