Accepted Manuscript online: 2024-10-23 Article published online: 2025-03-05

Building Bridges: Fostering Collaborative Education in Training Dental Informaticians

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Appl Clin Inform 2025;16:205–214.

Abstract

Background Dental informatics (DI) is an emerging discipline. Although the accreditation agency governing dental education programs asserts the importance of informatics as foundational knowledge, no well-defined DI courses currently exist within the standard predoctoral dental curriculum. There is a nationwide lack of DI academic programs. This training gap is due to a lack of qualified dental informaticians to impart knowledge on DI.

Objective This paper aims to introduce a novel conceptual framework for an interdisciplinary DI program in preparing students to become dental informaticians.

Methods In 2023, we developed a standalone graduate certificate program in DI at Indiana University (IU) School of Dentistry (IUSD) in collaboration with IU Luddy School of Informatics, Computing, and Engineering and IU Fairbanks School of Public Health. Feedback was collected through online surveys to assess course quality from students who took Introduction to Health Information in Dentistry. Feedback was analyzed qualitatively, utilizing a thematic analysis approach. Common responses relevant to DI education were grouped into themes.

Results Five major themes emerged during our analysis of the students' feedback: foundational knowledge and skills; experiential learning: learning by doing; access to resources and working on clinical information systems; health promotion through team-based learning; and retention of knowledge assessment and application. A conceptual framework was formulated through these themes as a guideline for future program improvement. This interdisciplinary educational program framework showed how students and faculty from various disciplines could collaborate, learn from each other, and bring in expertise from different domains. The collaboration happens in clinical, laboratory, and virtual settings to acquire hands-on learning through practice and research projects.

Keywords

- dental informatics
- experiential learning
- interdisciplinary
- accreditation standards
- conceptual framework

received
March 27, 2024
accepted after revision
October 15, 2024
accepted manuscript online
October 23, 2024

DOI https://doi.org/10.1055/a-2446-0515.
ISSN 1869-0327.

Georg Thieme Verlag KG, Rüdigerstraße 14, 70469 Stuttgart, Germany

Conclusion The developed conceptual framework aligns with the interdisciplinary nature of DI. It can potentially be adopted by other interdisciplinary informatics programs in health and non-health care disciplines.

Background and Significance

The rapid adoption of electronic dental records (EDRs), alongside other advancements in digital technologies for patient care, led the American Dental Education Association (ADEA) House of Delegates to approve practice management and informatics as a core competency for the new general dentist in 2008.[1] Fifteen years later, in 2023, with the massive footprint of digital dental data and its use to assess outcomes and create artificial intelligence (AI) tools, the Joint Commission on National Dental Board Examinations has added informatics tools as one of the foundational knowledge areas.[2] In addition, the Commission on Dental Accreditation (CODA) requires dental graduates to be competent in evaluating and applying information technology tools for patient care.[3] Despite these requirements, teaching informatics applications in dentistry (hereby referred to as dental informatics [DI]) are yet to become part of the predoctoral and graduate residency dental education programs (DEPs).[3] While dentists are traditionally trained to manage oral diseases and provide treatments effectively, teaching them to analyze and interpret digital health data is essential. AI algorithms provide powerful tools to support informatics work in health care applications and improve clinical care. So, it is essential for dental students and clinicians to be trained to evaluate AI tools appropriately and create high-quality datasets. Moreover, "it is time to reimagine the new dental graduate" and prepare them for an intricate, collaborative interdisciplinary practice by promoting patient-centered care management.[4] CODA continuously monitors and improves the quality of DEPs by developing and implementing accreditation standards based on the needs of students, faculty, and staff.[3,5] Thus, DI must be developed and accredited as a discipline to promote inclusive and person-centered care.

Emergence of Dental Informatics as a Discipline

Dentistry has left its imprint since the inception of medical informatics. One of the forefathers and significant contributors to medical informatics, Dr. Robert S. Ledley, was a dentist who graduated from New York College of Dentistry.[6] DI is a core research subdiscipline of biomedical informatics that applies to advancing oral health through practice and research.[7] It combines clinical dentistry with data science and information technology applications. While informatics has transformed the practice of medicine and proved effective in improving the quality of care, dentistry is lagging behind.[8] A critical barrier is the shortage of trained dental informaticians to impart knowledge on the application of informatics in dentistry and at the intersection of dentistry and other health care disciplines.[9] DI is emerging as a mature discipline intertwined with other disciplines such as computer science, telecommunications, and health technology applications.[10] Similar to the National Academy of Medicine's proposition[11,12] to integrate dentistry with medicine, it is imperative to develop an interdisciplinary program that facilitates communication and continuity of care for the medically compromised population.[13]

Interdisciplinary Education within Dental Informatics Course

Although the use of health information systems in dentistry (HIS-D) within clinical practice is well-developed, their meaningful use is limited. The use of digital dental radiographs, intraoral scanners, cone beam CT images, and computer-aided design (CAD)/computer-aided manufacturing (CAM) applications generates volumes of data but is seldom shared with other health care professionals.[14,15] The appropriate use of HIS-D will improve clinical care quality, safety, and efficiency in accessing and receiving good oral health care.[14,16,17] As health care systems are fragmented, an interdisciplinary approach that considers health information technology (HIT) could reduce fragmented care, duplication of diagnostic test orders, impart cross-disciplinary knowledge, and establish a foundation for team-based learning that translates to community health settings.[18] Collaborative learning pedagogy within the predoctoral curriculum will promote team-based learning by integrating informatics, information technology, computer science, and other health sciences. The National Academy of Medicine (NAM) supports interdisciplinary health care education and emphasizes that crossing the quality chasm is achievable.[11,12] An interdisciplinary education (IDE) framework is proposed because students from two or more disciplines will collaborate both formally and informally in the same setting.[19] Similar models have been used with nursing, pharmacy, and medical students and have seen positive learning outcomes.[20–24] However, a model consisting of a health care domain such as dentistry, biostatistics, information science, and computer science can help integrate informatics or HIT tools into the clinical workflow to enhance interdisciplinary care and communication.

Objectives

An interdisciplinary DI training course that unifies students from various disciplines such as dentistry, informatics, computer science, and information technology will break barriers and enable an HIT system that promotes integrated care delivery and communication. A future goal is to establish a team-based collaborative learning system that transitions to team-based care in community practices, thus eventually becoming the standard of care. To achieve this goal, we

developed a conceptual framework for IDE within a graduate certificate program in dental informatics (GCDI).

Methods

Development of a Graduate Certificate in Dental Informatics Program

In 2013, Indiana University (IU) School of Dentistry (IUSD) established the DI program focused on research and training. Since then, IUSD introduced a graduate DI certificate program to educate predoctoral and allied dental students and residents. In 2020 and 2023, the DI program offered the Introduction to Health Information Technology in Dentistry (IHIT-D) course (DENT-R 978) to educate health informatics students on applying informatics approaches in dentistry. Due to the ongoing COVID pandemic and faculty shortage, the course was paused in 2021 and 2022. This paper describes the conceptual framework developed with IDE components using the themes developed from enrolled students' responses. This GCDI program aims to prepare participating students from various disciplines to apply informatics approaches in dentistry.

Study Design and Data Collection

The study was reviewed and approved as exempt by the IU Institutional Review Board (approval no.: 22061). Online surveys were distributed to students who took IHIT-D to assess course quality and content. These students were international dental graduates enrolled in the master's program in health informatics at Luddy School of Informatics and taken a few core graduate informatics courses before enrolling in the IHIT-D course. The surveys were administered at the end of each lecture, also called modules, covering 12 topics. An additional survey was taken in 2023 for the teledentistry module. Response to every survey was optional, but completion of some surveys was factored into the participation score of the course. Not all students responded to every question or every module.

The surveys included closed and open-ended questions. Seven questions common to the 13 surveys with free-text responses were analyzed (►**Supplementary Appendix 1** [available in the online version]). Students were asked to rate aspects of each module using a 5-point Likert scale and then enter free-text responses to each survey question taken at the end of the class module (►**Table 1**). Seven most commonly answered questions to 13 surveys with free-text responses were analyzed (►**Supplementary Appendix 1** [available in the online version]). The modules covered HIT's role in dentistry and taught students to analyze data, implement HIT systems, and address challenges with deploying HIT in dentistry.

Questions were on the appropriateness of learning objectives, helpfulness of assignments and activities, the content of the module, new learnings, clarity of assignments and activities, and how the modules could be improved. Only the last responses were included for analysis if a student completed multiple surveys for the same module. Survey questions unique to specific modules or were only asked once during the course offerings were excluded from the analysis. Though students answered favorably to the close-ended questions, there was minimal variation in the ratings, so only free-text responses were used for analyzing themes in this study.

Table 1 List of modules for the course, Introduction to Health Information Technology in Dentistry

Modules included in the course IHIT-D
1. Introduction and Overview of Health Information Technology
2. Electronic Dental Records
3. Computer Representation of Dental Data
4. Dental Care Workflow and Analysis
5. Controlled Vocabularies, Terminologies, and Ontologies
6. Using Electronic Dental Record Data for Research to Evaluate Process and Treatment Outcomes
7. User-centered Design Methods to Evaluate Clinical Systems and Enhance Decision Making
8. Rapid Implementation of a Patient-Centered Teledentistry Program
9. Extracting and Analyzing Data from Biomedical Literature and Clinical Notes
10. Failures in Health Information Technology
11. Privacy, Confidentiality, and Security
12. Requirements Analysis and Technology Evaluation

Abbreviation: IHIT-D, Introduction to Health Information Technology in Dentistry.

Thematic Analysis

A generic qualitative framework was utilized to analyze and interpret the data.[25] This method was utilized because it is well-suited to analyze data from fully structured questionnaires with mixed closed and open-ended responses while examining the broad opinions of students' experience in our informatics courses.[25] A descriptive qualitative approach[26] and an inductive analysis, followed the steps outlined by Percy et al (2015) and Saldana (2013).[25,27] Free-text responses were first reviewed, then empty text fields and null responses, such as "N/A," were removed and the Likert scale responses were analyzed as an initial summary of the data. A research member (J.M.M.) performed an initial manual coding round using Microsoft Excel. In vivo coding, also known as verbatim coding[27] was utilized to generate an initial list of codes using the verbatim text of the student's responses. Next, two health/DI researchers (S.L. and G.G.F.G.) reviewed the initial codes, identified the most common codes, merged and categorized similar codes, performing focused coding[27] on the responses. The responses were clustered, highlighting illustrative examples, and used to develop a set of themes focused on DI education, with results reviewed by another health/DI researcher (T.P.T.). The resulting themes were mapped to the competencies developed in the CODA accreditation standards for informatics and the foundational domains that were established by the American Medical Informatics Association (AMIA).[3,28,29]

The Commission on Accreditation for Health Informatics and Information Management Education (CAHIIM) Health Informatics (CAHIIM-HI) accreditation standards are based on these foundational domains.[28,29] All authors reviewed and discussed the results to ensure consistency and sensibility.

Results

Nineteen students who were international dental graduates and enrolled in the master's program in Health informatics at IU participated in the two IHIT-D sessions. They provided 453 free-text responses to seven survey questions, out of which 350 were valid free-text responses. Five themes emerged upon mapping the responses to CODA DEP standards and CAHIIM-HI's foundational domains.[3,28,29] The competencies of a dental student, in conjunction with informatics education, were assessed and evaluated based on knowledge, skills, values, and attitudes. Only a small subset of student responses is provided within the text box below the themes with DEP standards and foundational domains.[3,28,29]

Theme 1—Foundational Knowledge and Skills

Students reported that lecture recordings, tutorials, and hands-on training activities were helpful for their learning (►Table 2). They also mentioned that the information and technological tools relevant to dentistry aligned with the expectations and learning needs. Students stated that the learning objectives for each module in ►Table 1 were appropriate, clear, informative, and valuable. With all of them having a dental background, students realized the importance of teledentistry. Although they are currently taking courses related to health informatics, they indicated there was new learning in each class on this course. Establishing precise knowledge acquisition is a preamble for both dental and informatics education because gaining foundational knowledge and skills is a core requirement for dental education programs [DEP 2-1; 2-4; 2-11][3] and for informatics education [foundation domains F1, F2, F4].[28,29] The graduate certificate course was administered to dental graduates with previous knowledge about oral health or acquiring knowledge of oral health. So, the informatics domain helps them to have a foundational knowledge of concepts, methods, and tools to identify the gaps in delivering oral health care services by assessing the clinicians' needs in a real-world clinical setting [F1, F2, F4].[28,29]

Theme 2—Experiential Learning: Learning by Doing

Students recognized the importance of assignments and activities provided in the modules (►Table 3). They felt that activities that assessed the skills they had learned were helpful. Through assignments and activities, students understood the use of HIT in a clinical setting. Students also reported the benefits of including lectures on navigating the EDR (for example, axiUm®), digital radiograph software such as MiPACS, and providing video recordings as well [DEP 2-8].[3] Further, one stated that learning about heuristic design principles and applying them by evaluating usability problems was both enjoyable and filled with knowledge [F4, F5].[28,29] Critical thinking and problem-solving [DEP 2-10][3] are some of the foundational standards to attain competencies. Activities and assignments encouraged them to think and apply them in real-world scenarios. A graduating DI student can apply the experiences from group projects to work in a collaborative practice environment [F9].[28,29] The hands-on learning with EDR and other dental clinical systems will be helpful for students entering into practice-based settings and future dental informaticians [DEP 2-19, 2-20].[3]

Theme 3—Access to Resources and Working on Clinical Information Systems

Each student was given access to axiUm®, the EDR system used in IUSD, and assigned activities and assignments to

Table 2 Theme 1—Foundational knowledge and skills

Theme 1—Responses
• "Tutorial videos are really helpful to recapitulate things when missed or confused." • "The addition of videos and readings in the modules are really augmenting the learning." • "The learning activities (activities, assignments, class discussions, etc.) associated with the module were helpful." • "The Axium portal was very new to me, and I learned a lot about various concepts of EDR." • "More material can be provided to understand the various workflow models with examples of scenarios, as this was very new and a little difficult to understand at once."
Dental education program standards (https://coda.ada.org/about-coda)
• Standard 2-1 instruction: "written information on the goals, requirements, course content, methods of evaluation, grades must be provided." • Standard 2-4 Curriculum management: "preparation of graduates with knowledge, skills and values" • Standard 2-11 Self-assessment: "graduates must demonstrate ability to self-assess and have capacities associated with self-directed, lifelong learning"
Foundational domains (https://academic.oup.com/jamia/article/25/12/1657/5145365)
• F1 Health: "Describe data, information used, produced, challenges in health science, healthcare delivery, personal health" • F2 Information Science and Technology: "identify concepts, methods, and tools to manage data, information, knowledge, terms, concepts, information security, and user information needs assessment methods." • F4 Health Information Science and Technology: "identify health information science and technology methods and tools for solving health information problem dependent on the area of the training program."

Abbreviation: EDR, electronic dental record.

Table 3 Theme 2—Experiential learning: learning by doing

Theme 2 Responses
• "The in-class activities are fun and helpful to understand the concepts." • "These assignments make more sense when you start doing it and I honestly enjoyed the learning part while doing the assignments." • "A small quiz on the topic would be helpful." • "The lecture videos made Axium training easy" • "I was made to explore the MiPACS in the previous lab session, I could easily access the panoramic radiograph and could give my responses to the questions asked. I feel like this is the correct way of learning something that I haven't done before."
Dental education program standards (https://coda.ada.org/about-coda)
• Standard 2-8 Curriculum management: "incorporation of emerging didactic and clinical technologies" • Standard 2-10 Critical thinking: "use teaching and learning methods that support the development of critical thinking and problem-solving skills." • Standard 2-19 Practice management and health care systems: "apply basic principles and philosophies of practice management, models of oral health care delivery" • Standard 2-20 Practice management and health care systems: "communicating and collaborating with other members to coordinate patient care"
Foundational domains (https://academic.oup.com/jamia/article/25/12/1657/5145365)
• F4 Health Information Science and Technology: "Consider advantages and limitations of information science and technology usage to solve health information problems based on the needs of stakeholders" • "Design solutions to health information problems by applying information science and technology" • F5 Human factors and Sociotechnical Systems: "Design and evaluation of information systems and technology" • "Respect the role of users in the design and application of information systems and technology" • F9 Interprofessional Collaborative Practice: "team dynamics to solve complex health and health information problems". • "Responsive and responsible team approach to solve complex health and health information problems" • "Recognize the importance of mutual respect and shared values as well as one own role"

assess its functionalities. One foundational standard is providing access to learning resources [DEP 4-5].[3] Students expressed that access to the EDR system made them respond effectively and stated that it was a proper way of learning something they had not done before (►Table 4). Findings from a mixed methods study with senior allied health students showed that access to electronic medical records helped them develop competencies for preparing for clinical practice.[30] Allowing students to wear an information designer hat enabled them to understand the features and functions of EDRs for oral health care delivery.

New technology and tools evaluated based on evidence-based research should address the needs of patient-centered care [DEP 5-2; 6-1].[3] Access to data is inevitable for a training informatician, and this resource helps them procure clinicians' information needs to attain informational knowledge in health information science and technology [F2].[28,29] Clinical engagement activities were conducted ethically [DEP 2-21],[3] and Health Insurance Portability and Accountability Act (HIPAA) training was provided during the class sessions [F8].[28,29]

Theme 4—Health Promotion through Team-based Learning

Students reported that discussing peer-reviewed published articles in the class helped them gain more insights into the module topic (►Table 5). One of the standards expected from students is that they should be able to communicate and collaborate [DEP 2-20].[1,3,31] The competencies obtained through the DI program will enable graduating students to understand the value of shared goals among multiple disciplines to provide oral care [F9].[28,29] Students mentioned enjoying class discussions and sharing thoughts, assignments, and activities, which helped them learn and engage actively. Class sessions on privacy, confidentiality, and security standards proposed by the U.S. Department of Health and Human Services for protecting personal health information were provided. Students can potentially identify HIPAA violations and apply what they have learned in dental practice and informatics-related research.

Theme 5—Retention of Knowledge Assessment and Application

Regarding instructions on assignments, students felt instructions on completion of activities and assignments were clear but they lacked clarity on submitting assignments. Students reported office hour sessions as helpful in completing assignments (►Table 6). Students mentioned that the readings provided in the modules helped them understand the lectures and complete assignments [F8].[28,29] Lecture recordings and tutorial video sessions helped revisit the information taught. Some felt that videos helped them understand more easily than theoretical learning [DEP 2-5].[3]

Conceptual Framework Model for the Graduate Certificate in Dental Informatics Program

With the themes generated, we propose the following conceptual framework model based on competencies proposed by nationally recognized accreditation committees. The IDE set of

Table 4 Theme 3—Access to resources and working on clinical information systems

Theme 3 Responses
• "Totally new experience to electronic dental records." • "The axiUm portal was very new to me, and I learned a lot about various concepts of EDR." • "It was interesting to use the axiUm." • "More focus on EDR could be helpful."
Dental education program standards (https://coda.ada.org/about-coda)
• Standard 2-21 Ethics and professionalism: "know how to apply principles of ethical decision making and profession responsibility." • Standard 4-5 Facilities and resources: "provide adequate and appropriately maintained facilities and learning resources in conformance with applicable regulations." • Standard 5-2 Patient Care Services: "using evidence to evaluate new technology and products to guide patient diagnosis and treatment decisions" • Standard 6-1 Research Program: "scientific inquiry in the development and dissemination of new knowledge"
Foundational domains (https://academic.oup.com/jamia/article/25/12/1657/5145365)
• F2 Information Science and Technology: "familiarity with basic computer science terminology and concepts related to information systems, computer programming, information retrieval, ontologies, analytics, user interface" • F8 Professionalism: Emphasis on preserving the confidentiality, privacy, and security of patient, health data and information".

Abbreviation: EDR, electronic dental record.

competencies in a team-based collaborative environment is based on standards from CODA and CAHIIM.[3,5,31,32] There is an overlap in the standards from the three councils (CODA, CAHIIM, ADEA) that oversee the abilities necessary for the growth of students to sustain independently in a work environment.

Knowledge acquisition, application of new knowledge, retention of knowledge, effective communication, critical

Table 5 Theme 4: Health promotion through team-based learning

Theme 4 Responses
• "I love and enjoy the in-class discussions and activities. They help in improving the engagement to the topic being discussed." • "The assignments and discussions are a very effective way of learning many things." • "Discussing peer reviews also helped in gaining extra knowledge from their point of view." • "Having networking opportunities would be very beneficial for obtaining real-world experience." • "Enjoy the in-class discussions and the course content"
Dental education program standards (https://coda.ada.org/about-coda)
• Standard 2-20 Practice management and Health Care Systems: "communicating and collaborating with other members to coordinate patient care."
Foundational domains (https://academic.oup.com/jamia/article/25/12/1657/5145365)
• F9 Interprofessional Collaborative Practice: "Recognize the importance of mutual respect and shared values as well as one own role"

Table 6 Theme 5: Retention of knowledge assessment and application

Theme 5 Responses
• "All the assignments were clearly explained, and I was provided with the required readings and recordings to guide me through." • "The extra zoom section for assignment really helped me to complete this assignment. However, I have missed attending the zoom but the video recording helped" • "The video of how Heath Information Technology (HIT) works was great." • "May be such videos can be a best method of learning and was very easy to understand than explaining theoretically."
Dental education program standards (https://coda.ada.org/about-coda)
• Standard 2-5 Educational program: "Assessment should measure not only retention of factual knowledge, but also development of skills, behaviors, attitudes for education and practice."
Foundational domains (https://academic.oup.com/jamia/article/25/12/1657/5145365)
• F8 Professionalism: "able to demonstrate the value of information literacy and lifelong learning, maintain skills and professional excellence."

thinking, collaborative practice, access to resources, information management, and health promotion are the overarching standards for IDE that we have included in our framework. The primary foundational standard on knowledge and skills required by accreditation standards is acquired through topics related to dentistry and through courses that will introduce students to successfully use and implement HIT in clinical practice and research. We expect that students' understanding of HIT applications and expertise in clinical dentistry will help them develop algorithms for clinical decision support systems (CDSSs). This competency parallels Theme 1 from our students on acquiring knowledge and skills.

Our framework also includes how the modules are delivered to students to acquire new knowledge and how they are applied to research and practice. Critical thinking and problem-solving skills are foundational for dental accreditation standards. Courses and modules through the GCDI will actively engage students in teaching and learning, which will allow students to be competent in analyzing problems, developing solutions, and enhancing decision-making skills. The above competencies align with Theme 2, where our students felt the importance of applying what they learned.

Theme 3 is more related to the availability of facilities and access to resources to create purposeful learning and apply the scenarios in real-life settings. Some institutional standards are central to teamwork, collaboration, and communication.[1,3,31] These standards are expected in a health care environment to promote good oral health. So, our Theme 4 on team-based learning approaches is as per the expected standards.

Further, Theme 5 curated retention of knowledge through lectures and recordings, which were assessed through assignments and activities. Short-term assessments were done in this course. Midterm and final exams intermittently assessed knowledge. There is a need to develop a long-term assessment of retaining knowledge through the course after graduation.

The schematic diagram (►Fig. 1) illustrates DI as a subdiscipline through the intersection of two distinctive disciplines of dentistry and informatics. The GCDI program requires 15 credit hours provided through courses at IUSD, Luddy School of Informatics, and Fairbanks School of Public Health from IU. The list of coursework for GCDI is included in ►Table 7. Students are allowed to choose either INFO-B-530 or INFO-B-535 under informatics and INFO-B-518, PBHL-B-551, or PBHL-B-561 for biostatistics.

Within this framework, predoctoral, allied dental students, residents from dental schools, and graduate students with informatics backgrounds are eligible to enroll in the GCDI program. Accepted applicants can complete the certificate program in 1 year (full-time) or 2 years (part-time). Students can formulate a study plan based on their academic interests, availability, and minimum required credits by semester.

The topics of EDR, dental care workflow and analysis, dental vocabularies, terminologies, ontologies, and teledentistry were discussed in the course offered by IUSD, while topics such as health informatics and biostatistical methods are from the informatics discipline. These required courses will provide students with theoretical foundations and help them develop critical thinking and problem-solving skills in DI. The standards that will be met through the course curriculum in this framework, including competencies on foundational knowledge and skills, critical thinking, problem-solving, access to learning resources,[30] and team-based

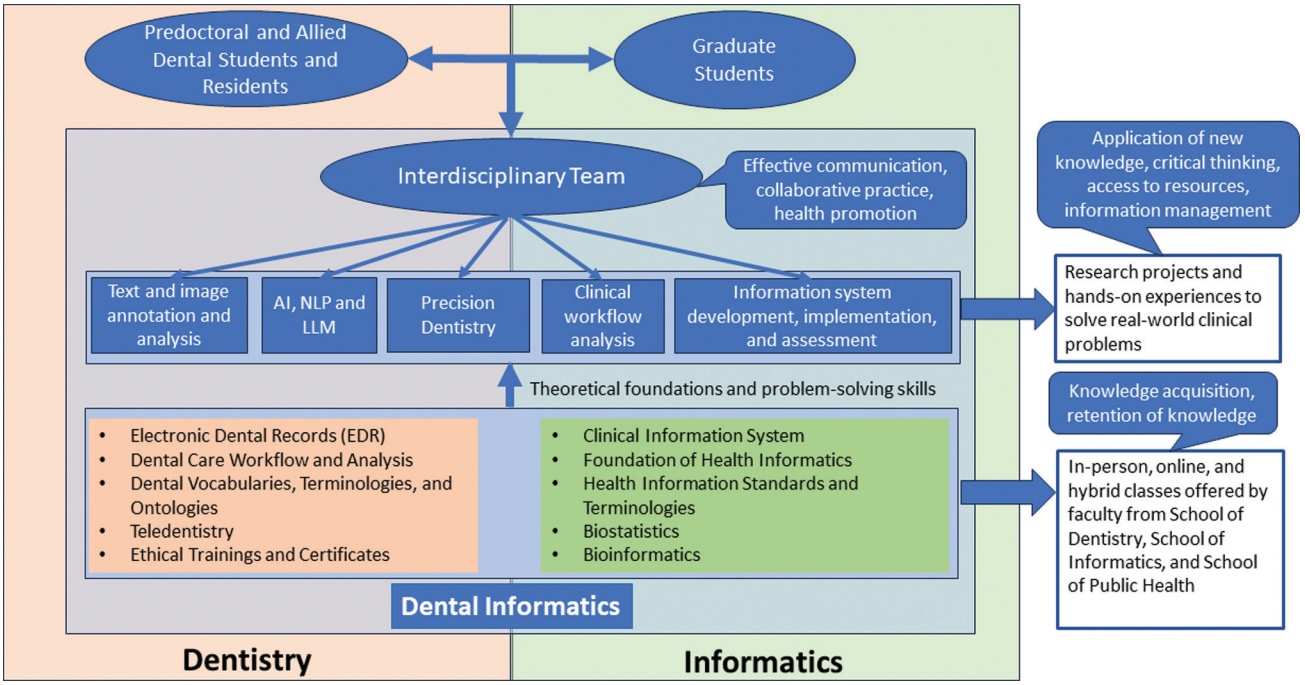

Fig. 1 Conceptual interdisciplinary education (IDE) model framework for the GCDI program. AI, artificial intelligence; GCDI, graduate certificate program in dental informatics; LLM, large language model; NLP, natural language processing.

Table 7 List of coursework for the GCDI[a] program

Academic unit	Course name and number
IUSD	Introduction to Health Information Technology in Dentistry (DENT-R 978)
	Introduction to Research (DENT-R 957)
Informatics [b]Public Health	Health Informatics Standards and Terminologies (INFO-B 581)
	Foundations of Health Informatics (INFO-B 530) or Clinical Information Systems (INFO-B 535)
	Applied Statistical Methods for Biomedical Informatics (INFO-B 518) or Introduction to Biostatistics 1 (PBHL-B 551)[b] or (PBHL-B 561)[b]

Abbreviation: IUSD, Indiana University School of Dentistry.
[a]Graduate certificate Program in dental informatics.
[b]Public Health.

learning [DEP 2-4; DEP 2-10; DEP 4-5; DEP 2-20],[3] highlight the interdisciplinary nature of the DI discipline.

Students will have the opportunity to join a research team to work on DI projects such as, but not limited to, text and image annotation and analysis, AI, natural language processing (NLP) and large language model (LLM), precision dentistry, clinical workflow analysis, and information system development, implementation, and assessment. Through such research projects, students can apply the DI knowledge and skills they have learned and developed in their coursework to solve real-world clinical problems in dentistry. This allows students to gain experience in using and evaluating new technologies in clinical practice. The knowledge, skills, and experiences that the students acquired through the certificate program are very well-aligned with CODA Standard on evidence-based patient care integrating research evidence and patient values (Standard 5-2)[3] and CAHIIM 2022 Graduate HI Standards on IDE (Standard 10).[33]

Discussion

We developed the conceptual IDE framework based on the themes generated through our students' responses. It is highly likely that students from other disciplines with a U.S. or international dental degree will join the DI program. International dentists who elect to distinguish themselves in advanced education are intensely interested. Developing the program to integrate with a master's or doctoral program is in the pipeline.

Training future dental informaticians through a team-based learning environment involving students from various disciplines is a pedagogical innovation to impart real-world skills. Our current IDE framework applies to all dental and informatics academic programs with students interested in learning and pursuing careers in DI. In-person didactic training, combined with the self-instructed administration of videos, was a practical and effective approach to elicit interest in this level of learning. We started the program with a hybrid approach to collect students' feedback on the courses. The course modules are presented to students in person, asynchronously, and online. Students preferred to have recordings of both in-person and synchronous online courses. A fully online format as a video recording was also deemed beneficial to students as they indicated they could replay specific sections multiple times for closer understanding. Although our conceptual framework is applicable for various modes of delivery, for a fully online asynchronous GCDI course, it is vital to have a virtual discussion board setup and provide technical resources and community engagement opportunities to avail hands-on activities. Since this is a higher learning course with independent and motivated students, establishing connectedness among students and faculty would be a pedagogical learning approach suitable for fully online courses asynchronously.[20,34] We will be considering offering the course in a fully online format as we do not have any barriers in transferring the course materials to this option. Teams working on case scenarios within the dental setting with groups of students from various disciplines will have an exchange of expert information, promoting a comprehensive approach to learning. One form of experiential learning used is to assess the use of technological tools within a clinical dental setting. This gives a bird's eye view approach to a clinical case scenario with a lens from various perspectives, backgrounds, and disciplines.

Though all students were dental graduates in a master's level informatics program, none reported having any practical, hands-on experience working with a clinical information system, such as an electronic health record or EDR system. This might be due to their international dental training with limited access to EDRs. In general, they have shown a strong interest in learning and using an information system that is actively used to support clinical operation and clinical data management. Providing access to resources and support helped students explore axiUm training with case scenarios as it is done for a new U.S. dental student. Clinical dental knowledge was not found to be a limiting factor in completing assignments related to DI courses.

One of the pressing concerns is the absence of accreditation standards for DI within DEPs. This might be because of limited trained dental informaticians in the field. The solution is to train dental informaticians and bring them into academic settings for training future generations. Dental education standards require institutions to inculcate education and scholarship so that students are competent to practice independently. DI as a specialty is needed to promote standards for establishing a learning health care system

for institutional effectiveness. Although dental students will be more interested in providing direct patient care, including DI in the curriculum will help them understand the role of informatics in improving patient care and outcomes.

The influence of AI has rapidly pervaded all facets of society today. The convergence of DI and AI will reshape the practice of dentistry.[35] While the growth of AI applications in health care has added enormous breakthroughs to provide value-based care, they have seen more limited usage in dentistry.[35] As the amount of data generated in academic and dental practice settings grows exponentially, AI applications in dentistry will positively impact oral care delivery. It can revolutionize the use of patient portals for screening risk for diseases as well as diagnosing and providing treatment planning by using clinically recorded data, notes, and images.[36,37] Generating appropriate clinical data in a standardized format is essential for AI applications.[35,38] So, it is inevitable that dental clinicians need to be educated on entering valid data and procuring meaningful information. Students need to understand, use, evaluate, and implement technological applications used in providing dental care. Combining skills developed from informatics learning and their domain knowledge in dentistry will enable students to be able to develop CDSSs that effectively utilize a broad digital body of knowledge. So, clinical guidelines could be implemented for access by dental clinicians through an integrated CDSS, which can improve the quality of dental care and patient outcomes.

One of the limitations of this study is that only students with an informatics background and an international dental education have participated in the program until 2023. Dental students may respond to our course differently, as their backgrounds and learning priorities may differ from those of informatics/computer science students. In addition, dental students may not have enough time to invest in non-clinical informatics research due to a lack of knowledge and emphasis on informatics. The GCDI program is flexible with online/in-person/and hybrid options to fit students from different backgrounds of career interests. Also, courses are offered in the evening through the School of Informatics and have both in-person and online options for the same course. DI must be included as a distinct form of training within the dental curriculum with future considerations as a specialty. Another drawback of the study is that the survey feedback from students was collected to evaluate course quality and measure teaching effectiveness. So, their responses will not entirely reflect on the development of the GCDI program.

Conclusion

The proposed conceptual framework with an interdisciplinary team will promote a supportive learning environment. The interdisciplinary educational approach in the DI certificate course will enhance knowledge and skill sharing between and among students and faculty from various disciplines. The framework can be adopted by other health and non-health care disciplines to educate and train students to become domain-specific informaticians. Bringing predoctoral students, allied dental students, and residents, including practicing dental professionals, within their informatics training programs will increase qualified dental informaticians. Our current framework model will evolve to include not only dental students and dentists but also those from other disciplines.

Clinical Relevance Statement

An interdisciplinary graduate certificate in DI program will enable future dental clinicians and allied dental health professionals to provide comprehensive oral health care through a collaborative approach.

Multiple-Choice Questions

1. What are the three major themes that were extracted from students' feedback?
   a. Foundational knowledge and skills
   b. Health promotion through team-based learning
   c. Experiential learning: learning by doing
   d. All of the above

   Correct Answer: The correct answer is option d. Five major themes emerged during our analysis of the students' feedback: foundational knowledge and skills; experiential learning: learning by doing; access to resources and working on clinical information systems; health promotion through team-based learning; and retention of knowledge assessment and application. Critical thinking skills are one of the foundational standards to attain the required competencies for our interdisciplinary educational framework but not a major theme from students' feedback.

2. Who are included within the interdisciplinary team framework for DI training?
   a. Dental students and faculty
   b. Informatics students and faculty
   c. Neither a nor b.
   d. Both a and b.

   Correct Answer: The correct answer is option d. For the proposed framework, one of our goals is to establish an interdisciplinary learning and research environment. Both the courses and the research projects in our proposed framework are taught or guided by faculty members from the IU School of Dentistry, Luddy School of Informatics, Computing, and Engineering, and Fairbanks School of Public Health. Both dental and informatics students can take the courses and enroll in the program.

Protection of Human and Animal Subjects

The study was performed in compliance with the World Medical Association Declaration of Helsinki on Ethical Principles for Medical Research Involving Human Subjects and was reviewed and approved as exempt by the IU Institutional Review Board (no.: 22061).

Funding
None.

Conflict of Interest
None declared.

Acknowledgments
We thank students who provided feedback for the course, IHIT-D (DENT-R 978). We also thank the faculty who were part of this course.

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