Trends in Basic Sciences Education in Dental Schools, 1999-2016

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Abstract: The purpose of this study was to examine data published over the past two decades to identify trends in the basic sciences curriculum in dental education, provide an analysis of those trends, and compare them with trends in the basic sciences curriculum in medical education. Data published from the American Dental Association (ADA) Surveys of Dental Education, American Dental Education Association (ADEA) Surveys of Dental School Seniors, and two additional surveys were examined. In large part, survey data collected focused on the structure, content, and instructional strategies used in dental education: what was taught and how. Great variability was noted in the total clock hours of instruction and the clock hours of basic sciences instruction reported by dental schools. Moreover, the participation of medical schools in the basic sciences education of dental students appears to have decreased dramatically over the past decade. Although modest progress has been made in implementing some of the curriculum changes recommended in the 1995 Institute of Medicine report such as integrated basic and clinical sciences curricula, adoption of active learning methods, and closer engagement with medical and other health professions education programs, educational effectiveness studies needed to generate data to support evidence-based approaches to curriculum reform are lacking. Overall, trends in the basic sciences curriculum in medical education were similar to those for dental education. Potential drivers of curriculum change were identified, as was recent work in other fields that should encourage reconsideration of dentistry's approach to basic sciences education. This article was written as part of the project "Advancing Dental Education in the 21st Century."

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In his 1926 report *Dental Education in the United States and Canada,* Dr. William J. Gies forcefully supported a strong education in basic sciences in dental schools as foundational to the practice of dentistry and made the case for the importance of scientific discovery for the vitality of a profession.[1] He stated, "Without the stimulating influence of recurrent discoveries in a profession, ignorance, discouragement, inefficiency, and stagnation impair the usefulness of those who seek to exemplify its best service." In line with Gies's vision for the role of basic sciences in dental education and practice, the 1995 Institute of Medicine (IOM) report *Dental Education at the Crossroads* recommended specific steps in a process to align science and practice in dental education (summarized in Recommendation 4).[2] These steps were as follows: "design an integrated basic and clinical sciences curriculum that provides clinically relevant education in the basic sciences and scientifically based education in clinical care; incorporate in all educational activities a focus on outcomes and an emphasis on the relevance of scientific knowledge and thinking to clinical choices; shift more curriculum hours from lectures to guided seminars and other active learning strategies that develop critical thinking and problem-solving skills; identify and decrease the hours spent in low priority preclinical technique, laboratory work, and lectures; and complement clinic hours with scheduled time for discussion of specific diagnosis, planning, and treatment-completion issues that arise in clinic sessions."

The IOM Committee on the Future of Dental Education, the group that prepared the 1995 IOM report, envisioned a "post-reform" dental curriculum that educates dentists who use their knowledge of science in the daily planning and delivery of oral health care, who recognize and keep current with the scientific discoveries that support the practice of "state-of-the-science" dentistry, and who incorporate the rigorous methods of scientific thinking and problem-solving into their practice of dentistry.[2] The committee particularly advocated for the use of scientific knowledge and thinking in making clinical choices, such as those necessary to arrive at a diagnosis or to select among treatment options.

This article was written as part of the project "Advancing Dental Education in the 21st Century." We were tasked with identifying trends that have emerged in basic sciences education in dental education over the past two decades, comparing them with those in medical education over the same period, and presenting a "snapshot in time" view of the current state of basic sciences education in dental education with recommendations for areas in need of further investigation. We were also tasked with assessing dental education's progress toward implementing the recommendations made for the basic sciences curriculum in the 1995 IOM report. Finally, we present some perspectives gained from work in other fields that may have important implications for how we think about and offer basic sciences education in dental education going forward.

Methods

Data for this report were obtained from numerous sources. For dental education, data gathered in the American Dental Association (ADA) Surveys of Dental Education (SODE) and published biennially in Volume 4, Curriculum (1999-2000, 2001-02, 2003-04, 2006-07, 2008-09, 2010-11, 2014-15, and 2015-16) as well as data from two reports summarizing the results of dental curriculum surveys were used to assess curriculum change in dental education.[3-12] These surveys were selected for comprehensive analysis because they had response rates of at least 80% from U.S. dental schools. It should be noted that the Group IV questions on the ADA SODE (the responses to which provide the data published in Volume IV, Curriculum) were updated after administration of the 2010-11 survey and that no curriculum survey information was published by the ADA between the 2010-11 and 2014-15 survey reports.[8,9] We used data reported in the American Dental Education Association (ADEA) Surveys of Dental School Seniors (SDSS) regarding students' perceptions of the appropriateness of time devoted to various areas of education and training.[13-22]

For medical education, we examined data available in the Curriculum Inventory and Reports section of the Association of American Medical Colleges (AAMC) website.[23] Report data were derived from the Liaison Committee on Medical Education's Annual Medical School Questionnaire Part II.[24]

Results

Trends in Basic Sciences Education in Dental Education

Instructional time. Table 1 presents a summary of clock hour data reported by U.S. dental schools in eight ADA SODEs conducted between 1999 and 2016.[3-10] These data suggest that the mean total clock hours of instruction increased steadily at a rate of 2% or less between the 1999-2000 and 2010-11 surveys, increased 6.8% between the 2010-11 and 2014-15 surveys, and increased 1.7% between the 2014-15 and 2015-16 surveys. The net increase in mean total clock hours of instruction from 1999 to 2016 was about 11%.

Table 1. Mean total curriculum clock hours and basic science clock hours of instruction, 1999-2016

ADA Survey	Mean Total Clock Hours	Total Hours Range	Mean Basic Science Clock Hours	Basic Science Hours Range	Number of Schools
1999-2000	4860	3409-6352	839	544-2160	55
2001-02	4889	3094-6435	826	544-2160	54
2003-04	4924	3311-6259	810	501-2046	54
2006-07	4908	2704-7212	859	478-1780	56
2008-09	4888	3531-6954	831	452-1455	56
2010-11	4961	3335-7451	811	446-1455	56
2014-15	5296	3342-7503	NA	NA	65
2015-16	5384	3242-7678	NA	NA	65

Note: Number of schools includes only those schools with enrollment in all classes.

NA=not available

Sources: American Dental Association. Survey of predoctoral dental education, volume 4: curriculum. Chicago: American Dental Association, 1996-2016.

From 1999 to 2011, the last survey year for which these data are available, the mean clock hours of instruction for the basic sciences increased by 2.4% between the 1999-2000 and 2006-07 surveys and then decreased 5.6% between the 2006-07 and 2010-11 surveys.[3,6,8] Schools reporting the highest numbers of clock hours of instruction in the basic sciences decreased them by about one-third (from 2,160 to 1,455 clock hours) in the years between the 1999-2000 and 2008-09 surveys.[3,7]

Instruction in the basic sciences represented on average 16-18% of the total clock hours of instruction between 1999 and 2011.[4-8] The average distribution of basic sciences clock hours between didactic and laboratory instruction remained relatively constant at ~75% didactic hours and ~25% laboratory hours between 1999 and 2011, although the distribution of didactic and laboratory hours across the different teaching areas varied considerably among schools (data not shown).[3-8] The teaching areas of physiology and pathology reported the largest number of didactic clock hours of instruction, and gross and microscopic anatomy reported the largest number of laboratory clock hours of instruction. These data suggest that there was great variability in both the total clock hours of instruction (1999-2016) and the total clock hours of basic sciences instruction (1999-2011) reported by U.S. dental schools (Table 1).[3-10]

Curriculum integration. The reports by Kassebaum et al. in 2004 (survey conducted in 2002-03) and Haden et al. in 2010 (survey conducted in 2009) described curriculum structure and changes in dental education using data collected from surveys sent to the academic deans at all U.S. and Canadian dental schools.[11,12] The response rate was 87% (48 U.S. and eight Canadian dental schools) for the 2004 report and 86% (50 U.S. and five Canadian dental schools) for the 2010 report. Both studies requested information in four broad areas: curriculum format, curriculum assessment, curriculum innovation, and resources needed for curriculum enhancement. In the domain of curriculum format, the authors presented findings regarding the extent of curriculum integration overall and in the basic sciences (2010 report only), the basic science curriculum format (2010 report only), the use of problem-based learning (PBL) and case-based/case-related learning (CBL) outside of the clinic setting, and the extent to which dental students took courses with students enrolled in other health professions education programs (2010 report only).

Since these studies included both U.S. and Canadian dental schools, the results cannot be directly compared with data obtained in the ADA SODEs, which publish data only from U.S. schools; however, the reports can be used together to identify trends. The data suggest that some progress has been made in integrating dental curricula particularly in the past five years (Table 2). Although nearly half of dental schools reported in 2015-16 that only a few of their courses were integrated, the percentage of U.S. dental schools reporting no integrated courses decreased from 10% in the 2010-11 survey to 2% in 2015-16 survey, and the percentage of U.S. dental schools reporting integration of at least one major curriculum component increased from 16% (2010-11 survey) to 45% (2015-16 survey) in the same time frame.[8,10] Concurrently, the percentage of schools reporting that their entire curriculum was integrated (17%, ten schools) in the 2010-11 survey decreased substantially (5%, three schools) in the 2015-16 survey. Results of a recent study suggested that about three-quarters of U.S. dental schools presented biomedical and clinical sciences instruction in separate courses,[25] but further studies are needed to confirm those findings.

The survey conducted by Haden et al. asked schools to report the extent to which their basic sciences curricula were integrated.[12] About 20% of the 55 schools responding reported that their basic sciences curricula were entirely discipline-based; 47% were primarily discipline-based with a few interdisciplinary components; 6% reported equal division between discipline-based and interdisciplinary courses; and 27% were primarily interdisciplinary with a few purely discipline-based courses. In terms of organizational strategies used in basic sciences instruction, 24% of schools reported that students learned normal structure in discipline-based courses followed by exposure to pathophysiology in an organ system format; 17% reported their students learned basic sciences in an interdisciplinary format based on organ system pathophysiology; 33% reported their basic sciences courses were conducted independently by departments but with some topic coordination; and 14% reported the same but with no topic coordination. Finally, when asked what curriculum organization they most preferred for instruction in the basic sciences, 53% of these academic deans responded that they most preferred an organ system format.

Curriculum integration has been considered a desirable goal because it is presumed to hold the

Table 2. Curriculum integration reported by dental schools, 2004-16, by percentage of schools responding in each category

Level of Integration	Kassebaum et al. 2004 n=56[a]	ADA Survey 2006-07 n=56	ADA Survey 2008-09 n=57	Haden et al. 2010 n=55[b]	ADA Survey 2010-11 n=58	ADA Survey 2014-15 n=62[c]	ADA Survey 2015-16 n=65
No integration	14%	14%	11%	12%	10%	3%	2%
Few courses integrated	63%	57%	56%	49%	57%	45%	49%
At least one major component integrated[d,e]	16%	20%	21%	25%	16%	39%	45%
Entire curriculum integrated	7%	9%	12%	14%	17%	9%	5%

Note: The n is number of dental schools with any classes enrolled. The Kassebaum et al. survey was conducted in 2002-03 and was published in 2004; the Haden et al. survey was conducted in 2009 and was published in 2010.

[a]48 U.S. and eight Canadian dental schools.
[b]50 U.S. and five Canadian dental schools.
[c]62 of the 65 schools responded to this question.
[d]This choice in the 2014-15 survey was "major integration: 2 or more components integrated into thematic units without disciplines."
[e]This choice in the 2015-16 survey was "major integration: multiple curriculum components integrated into thematic units without disciplines."

Sources: Kassebaum DK, Hendricson WD, Taft T, Haden NK. The dental curriculum at North American dental institutions in 2002-03: a survey of current structure, recent innovations, and planned changes. J Dent Educ 2004;68(9):914-31; American Dental Association. 2006-07 survey of predoctoral dental education, volume 4: curriculum. Chicago: American Dental Association, 2008; American Dental Association. 2008-09 survey of predoctoral dental education, volume 4: curriculum. Chicago: American Dental Association, 2010; Haden NK, Hendricson WD, Kassebaum DK, et al. Curriculum change in dental education. J Dent Educ 2010;74(5):539-57; American Dental Association. 2010-11 survey of dental education, volume 4: curriculum. At: www.ada.org/SDE4_2010-11_final2.xlsx. Accessed 15 Oct. 2015; American Dental Association. 2014-15 survey of dental education, volume 4: curriculum. At: www.ada.org/SDEA_2014-15_public_final.xlsx. Accessed 1 June 2016; American Dental Association. 2015-16 survey of dental education, volume 4: curriculum. At: www.ada.org/SDEA_2015-16_SDE4_final.xlsx. Accessed 12 Dec. 2016.

promise of clarifying relationships between diverse disciplines and programmatic areas important in providing patient care. Recommendation 4 in the 1995 IOM report called for integration of instruction not just across the basic sciences, but across instruction in the basic, behavioral, and clinical sciences.[2]

Instructional methods and strategy. The 1995 IOM report recommended that dental schools shift more curriculum hours from lectures to guided seminars and other active learning formats, so that learning experiences not only convey the knowledge base to students in an integrated fashion but help them develop critical thinking and problem-solving skills.[2] Two active learning strategies that have received considerable attention in dental education are PBL and CBL, which support integration of learning of the basic, behavioral, and clinical sciences and provide students with the opportunity to practice applying basic science concepts to the solution of clinical problems (reviewed by Nadershahi et al.[26]).

In Kassebaum et al.'s 2004 report, 59% of dental schools reported using PBL as an instructional method in either individual courses or components of some courses, and 5% (three schools) reported that all of their courses used PBL.[11] The ADA SODE began asking schools to report the use of PBL and CBL in their programs in the 2006-07 iteration of the survey, as did the survey used in Haden et al.'s 2010 report.[6,12] There was little change in the percentage of schools using PBL as a learning strategy between 2004 and 2011: 59-68% of responding schools reported using PBL in some courses or some course components, 27-36% reported that they did not use PBL, and 3-5% reported using PBL in all of their courses (Table 3).[6-8,11,12] The 2014-15 and 2015-16 ADA SODE reports did not ask dental schools about their use of PBL in this format; however, in these surveys on average, one-quarter of schools reported using PBL to deliver content to support development of some of the clinical competencies required by the Commission on Dental Accreditation (CODA) (Section 1) and one-quarter to one-third reported using PBL as an instructional method to ensure integration of instruction (Section 3) in the biomedical, behavioral, and clinical sciences (FK statements 1-10).[9,10,27]

In contrast, CBL has been used extensively in dental education for some time. Kassebaum et al. reported in 2004 that 93% of the schools responded that CBL was used as an instructional method in some courses or course components.[11] In the 2006-07 ADA SODE report, that number increased to 96.4% of schools reporting, and in both the 2008-09 and

2010-11 SODE reports, that number increased to 100% of schools reporting.[6-8] Haden et al. reported in 2010 that 89% of dental schools stated that they used CBL as an instructional method in some courses or course components, 4% used it in all courses, and 7% did not use it in any of their courses (U.S. dental schools comprised 91% of the sample in this study).[12] The 2014-15 and 2015-16 ADA surveys did not ask dental schools about their use of CBL in this format; however, on average, about three-quarters of schools reported using CBL to deliver content to support development of some of the CODA clinical competencies (Section 1) and about two-thirds reported using CBL as an instructional method to ensure integration of instruction (Section 3) in the biomedical, behavioral, and clinical sciences (FK statements 1-10).[9,10,27]

In Kassebaum et al.'s 2004 report, 55.4% of the schools noted that they had already incorporated increased educational collaborations with other campus schools, and 51.8% reported that they planned to increase educational collaborations with other campus schools over the next four years.[11] It is not clear, however, if these collaborations with other schools created interprofessional education (IPE) experiences or courses. Beginning with the 2006-07 ADA SODE, schools were asked to report their participation in IPE courses by type of course. These data suggest that there was little variation in engagement of schools in IPE courses by type between 2006 and 2011 (Table 4).[6,8] Corroborating the findings of the 2008-09 and 2010-11 ADA SODE reports, Haden et al. noted in 2010 that about 35% of the schools reported that some of their basic science curricula included students from other health professions schools.[7,8,12] While no questions on the 2014-15 or 2015-16 ADA SODEs specifically asked schools to report their participation in IPE courses,

Table 3. Use of problem-based learning (PBL) as an instructional strategy in dental schools, by percentage of schools reporting

Survey, Year	All Courses Use PBL	Some Course or Course Components Use PBL	No Courses Use PBL
Kassebaum et al., 2004	5%	59%	36%
ADA survey, 2006-07	3.6%	66.1%	30.3%
ADA survey, 2008-09	3.5%	64.9%	31.6%
Haden et al., 2010	4%	68%	27%
ADA survey, 2010-11	3.4%	65.5%	31%

Note: The Kassebaum et al. survey was conducted in 2002-03 and was published in 2004; the Haden et al. survey was conducted in 2009 and was published in 2010.

Sources: Kassebaum DK, Hendricson WD, Taft T, Haden NK. The dental curriculum at North American dental institutions in 2002-03: a survey of current structure, recent innovations, and planned changes. J Dent Educ 2004;68(9):914-31; American Dental Association. 2006-07 survey of predoctoral dental education, volume 4: curriculum. Chicago: American Dental Association, 2008; American Dental Association. 2008-09 survey of predoctoral dental education, volume 4: curriculum. Chicago: American Dental Association, 2010; Haden NK, Hendricson WD, Kassebaum DK, et al. Curriculum change in dental education. J Dent Educ 2010;74(5):539-57; American Dental Association. 2010-11 survey of dental education, volume 4: curriculum. At: www.ada.org/SDE4_2010-11_final2.xlsx. Accessed 15 Oct. 2015.

Table 4. Interprofessional courses reported by dental schools by percentage of schools reporting, by area

Area	2006-07 ADA Survey	2008-09 ADA Survey	2010-11 ADA Survey
No interprofessional courses	32.1%	43.9%	34.5%
Basic science courses	41.1%	36.8%	37.9%
Behavioral, communications, ethics, or professionalism courses	25.0%	29.8%	24.1%
Clinical courses	30.4%	19.3%	25.8%
Other courses	25.0%	19.3%	22.4%

Sources: American Dental Association. 2006-07 survey of predoctoral dental education, volume 4: curriculum. Chicago: American Dental Association, 2008; American Dental Association. 2008-09 survey of predoctoral dental education, volume 4: curriculum. Chicago: American Dental Association, 2010; American Dental Association. 2010-11 survey of dental education, volume 4: curriculum. At: www.ada.org/SDE4_2010-11_final2.xlsx. Accessed 15 Oct. 2015.

about one-fifth of schools on average reported (Section 3) using an IPE team to ensure integration of instruction in the biomedical, behavioral, and clinical sciences.[9,10] Results of a recent study suggest that up to 90% of U.S. dental schools may be including IPE in their curricula,[25] but further studies are needed to confirm those findings.

Instructional unit. Table 5 summarizes data from the 2001-02 and 2010-11 ADA SODEs (the last year for which these data are available) about the school that provided instruction in the basic sciences for dental students.[4,8] Reporting options were as follows: dental school only provides this instruction, medical school only provides this instruction, provision of instruction is shared in some way with another unit, or some other arrangement. In both survey reports, instruction in the areas of gross anatomy (including head and neck anatomy), physiology, and general pathology accounted for nearly 50% of the mean total clock hours of basic sciences instruction. We used data compiled for these teaching areas to identify trends related to which units provided basic sciences instruction for dental students. The data suggest that there was little difference in the mean total number of clock hours of instruction reported in any of these teaching areas in the nine-year interval between the 2001-02 and 2010-11 surveys.[4,8]

What changed (dramatically in some cases) was the extent to which the dental school or medical school provided this instruction and the extent to which dental schools shared this instruction with other units. In the case of instruction in anatomy and pathology, dental schools reporting that their medical school provided this instruction decreased by 50% or more. For all three disciplines (anatomy, physiology, and pathology), it appears that dental schools affected by those instructional decreases were teaching this material themselves and/or sharing the teaching with other units on campus.

As noted above, since such reporting began (2006-07 ADA SODE), just over one-third of dental schools have reported that their students participated in IPE courses that included the basic sciences (Table 4).[6] It may be that IPE courses accounted for some of the increases in sharing of instruction in the basic sciences with units on campus other than medical schools reported in the nine-year interval between 2002 and 2011.

Current status: summary of key findings. The mean clock hours of instruction in dental schools increased nearly 11% between 1999 and 2016, and most of this increase occurred between 2010 and 2016 (Table 1). Little change in clock hours of instruction was seen in the basic sciences between 1999 and 2011,[3,8] the last year for which these data are available, so it is not known whether there was an increase between 2010 and 2016 that parallels the one that occurred in the curriculum as a whole.[8-10] However, increased density in the curriculum ("curriculum creep") in dental education programs could impact learning in the basic sciences whether or not the basic sciences were directly involved as it has been reported in medical education.[28] The reasons for the sharp increase in mean total clock hours of instruction over the past five years in dental education programs are unclear and should be investigated.

The variability reported by dental schools in total clock hours of instruction (most recently >100%; Table 1) and in clock hours of instruction in the basic sciences (most recently >300%) is too great to be accounted for by the unique missions of individual dental schools. It raises concerns about

Table 5. Instructional unit providing basic sciences instruction for dental schools for 2001-02 and 2010-11 academic years

	Mean Clock Hours of Instruction		% Dental School Only		% Medical School Only		% Shared	
Subject	2001-02	2010-11	2001-02	2010-11	2001-02	2010-11	2001-02	2010-11
Gross anatomy (including H&N)	192	193	38.0%	32.7%	30.6%	12.0%	29.6%	51.7%
Physiology	109.5	97.1	27.7%	36.2%	35.2%	24.1%	35.2%	34.5%
Pathology	101.3	95.9	40.7%	46.5%	27.7%	13.8%	29.6%	34.5%

Note: The percentages in the shared column do not total 100% because the few schools who identified "other or independent" arrangements for providing basic sciences instruction were not included in this table.

Sources: American Dental Association. 2001-02 survey of predoctoral dental education, volume 4: curriculum. Chicago: American Dental Association, 2003; American Dental Association. 2010-11 survey of dental education, volume 4: curriculum. At: www.ada.org/SDE4_2010-11_final2.xlsx. Accessed 15 Oct. 2015.

adequacy of instruction at the low end and efficiency of instruction at the high end. It also suggests that dental schools have not reached consensus regarding the optimal length of the curriculum. All accredited dental education programs graduate students who are deemed competent for entry into the independent practice of dentistry. Could dental schools collaboratively develop a basic sciences curriculum that efficiently and effectively supports the development of competent dental graduates?

Interestingly, according to data from the ADEA SDSS for graduating classes from 2002 to 2015 in which senior students at U.S. dental schools were asked to rate as inadequate, appropriate, or excessive the curriculum time devoted to selected areas of their education and training, about 20% of responding seniors consistently rated the amount of instruction they received in the basic sciences as excessive.[13-22] This area received the highest percentage rating of excessive of any of the 20-35 selected areas listed in the surveys.

During this time frame, many schools were engaging in curriculum reform efforts that should have highlighted the relevance, importance, and use of the basic sciences in dental practice—for example, major curriculum integration and implementation of active learning methods of instruction. Therefore, it is somewhat surprising that student perceptions remained unchanged regarding the excessive time devoted to instruction in the basic sciences. The reasons for these findings should be further investigated.

The participation of medical schools in the basic sciences education of dental students decreased dramatically over the past decade. In some basic sciences disciplines, the percentage of dental schools reporting that their medical school provided instruction in that discipline for dental students decreased by as much as two-thirds, and dental schools alone or in collaboration with other campus units reported picking up the difference. The reasons for these changes are not clear but should be further investigated. They are concerning because of the significant decrease in the basic sciences faculty at dental schools reported over the past decade.[29] Has the decreased participation of medical schools in the basic science education of dental students and/or the decrease in basic science faculty at dental schools impacted dental students' ability to learn and apply the basic sciences in practice? In general, dental schools have made modest progress over the past two decades in implementing some of the curriculum changes recommended in the 1995 IOM report.[2]

Trend Comparisons: Dental and Medical Education

We also examined trends in the basic sciences curriculum in medical education related to integration of instruction and adoption of PBL, CBL, and IPE. The curriculum report developed from the Liaison Committee on Medical Education's (LCME) Annual Medical School Questionnaire, Part II captures information related to curriculum integration in the basic sciences, by discipline, in medical education.[24] These data are available online for some components of annual surveys conducted between 2006 and 2015 in the Curriculum Reports section of the AAMC's website.[23]

The data shown in Table 6 were collected in response to the question "For each topic area listed, check if the topic is taught as a separate independent course or as part of an integrated course." Although data are reported for a number of the basic sciences topic areas, we are summarizing here the data for instruction in anatomy, physiology, and pathology, the same topic areas we selected to highlight in dental education.

About half of the medical schools reporting in the 2010-11 and 2013-14 questionnaires (the latest data available) indicated that instruction in anatomy, physiology, and pathology was provided in independent courses (data not shown).[23] The data suggested that, increasingly, schools were including content in anatomy, physiology, and pathology in integrated courses (Table 6). Some schools apparently presented anatomy, physiology, and pathology subject matter in both independent and integrated courses, although the number (or proportion) using both instructional formats, if captured, was not published in the report. The data did not include an analysis of all of the topic

Table 6. Percentage of U.S. medical schools including anatomy, physiology, or pathology instruction as part of an integrated course

Topic	2010-11	2013-14
Anatomy	61%	76%
Physiology	62%	80%
Pathology	70%	84%

Note: Data suggest that some schools reported that the topic was presented in both independent and integrated courses.

Source: Association of American Medical Colleges. Curriculum inventory and reports. At: www.aamc.org/initiatives/cir/curriculumreports/. Accessed 21 Oct. 2015.

Table 7. Percentage of U.S. medical schools reporting use of selected learning formats in anatomy, physiology, and pathology

Topic	Learning Format	2010-11	2013-14
Anatomy	CBL	0	58%
	TBL	29%	34%
	PBL	0	26%
Physiology	CBL	0	71%
	TBL	21%	33%
	PBL	0	40%
Pathology	CBL	0	75%
	TBL	24%	35%
	PBL	0	33%

CBL=case-based learning; TBL=team-based learning; PBL=problem-based learning

Source: Association of American Medical Colleges. Curriculum inventory and reports. At: www.aamc.org/initiatives/cir/curriculumreports/. Accessed 21 Oct. 2015.

areas contributing to integrated courses, so it is not possible to determine whether the integrated courses were within the basic sciences alone or were integrated across basic, behavioral, and clinical sciences.

The data shown in Table 7 summarize changes in the extent to which medical schools reported in the 2010-11 and 2013-14 questionnaires using active learning methods to deliver instruction in the basic sciences (represented by anatomy, physiology, and pathology).[23] The data suggested that the use of active learning methods in basic sciences instruction (anatomy, physiology, and pathology) increased dramatically between 2011 and 2014.

The percentage of medical schools offering required education sessions that bring together students from different health education programs (IPE) increased gradually over the past eight years from 44% of schools responding to the 2006-07 LCME Annual Medical School Questionnaire, Part II to 92% of schools responding to the 2014-15 questionnaire (data not shown).[23] Over the four years of the most recent reports, the percentage of medical schools reporting that dental schools participated with them in these required IPE experiences increased from 21% (2011-12) to 29% (2014-15). Based upon the number of responding medical schools (nearly 100% of MD-granting institutions), these percentages corresponded to ~28 dental schools (2011-12) and ~41 dental schools (2014-15), which would represent a 46% increase in the number of dental schools engaged in IPE with medical schools over this time frame. Overwhelmingly, allied medical education programs were reported by medical schools to comprise the largest group participating in IPE experiences with baccalaureate nursing (78% of reporting schools), pharmacy (70%), and physical and occupational therapy (51%) the most highly engaged according to the 2014-15 report.

It appears that, for both dental education and medical education, stakeholder organizations in the respective professions have played significant roles in encouraging curriculum change. ADEA (especially through the work of its Commission on Change and Innovation in Dental Education) has played a significant role in encouraging curriculum change in dental education.[30] Substantial revisions to the CODA standards in 2014, development of the document "Foundation Knowledge for the General Dentist" by the Joint Commission on National Dental Examinations' Committee for an Integrated Examination (JCNDE CIE), revisions made to the ADA SODE curriculum-related questions and to the ADA SODE Volume 4 reports, and the development and approaching implementation of the Integrated National Board Dental Examination (INBDE) support recommendations made in the 1995 IOM report and strongly encourage development of curricula that are integrated, use active learning methods, require application of science in practice, and develop students' critical thinking and problem-solving skills.[2,9,10,27,31,32]

In medical education, the AAMC—through its collaboration with the Howard Hughes Medical Institute (HHMI), for example—has played a significant role in encouraging curriculum change in medical education.[33] Both the LCME accreditation process (analogous to the CODA accreditation process) and the United States Medical Licensing Examination (USMLE, analogous in part to the NBDE) appear to have encouraged curriculum change, particularly curriculum integration.[34,35] The LCME 2016-17 Data Collection for Full Accreditation Surveys asks schools to provide information about integration of instruction in the basic sciences.[24] It also asks schools to document instruction in and assessment of content related to the scientific method and to include in the documentation any hands-on or simulated exercises in which medical students collect or use data to test and/or verify hypotheses or to experimentally study biomedical phenomena.

The USMLE Step 3 Foundations of Independent Practice examination, which is usually taken by physicians near the end of the first year of

postgraduate training and which assesses readiness for independent practice, was recently revised to include an expanded range of competency-based content including applying foundational sciences, biostatistics, epidemiology/public health, interpretation of the medical literature, and social sciences, including communication and interpersonal skills, medical ethics, and systems-based practice/patient safety to patient care.[35] It also includes item formats based on scientific abstracts and pharmaceutical advertisements, which require applying basic science concepts to the practice of medicine. Thus, it appears that the intention of the redesign of this component of the USMLE Step 3 examination was similar to the intention articulated by the JCNDE CIE in creating the INBDE, "to create a new examination that would integrate the basic, behavioral, and clinical sciences to assess entry level competence" in dentistry.[32]

For the most part, changes in basic sciences education in medical education in the areas of curriculum integration, use of active learning strategies, and engagement in IPE parallel the changes occurring in dental education. It appears that dental education implemented some active learning strategies in basic science education (use of CBL and PBL) earlier and more widely than did medical education. Conversely, it appears that medical education has implemented IPE more fully than has dental education, but the extent to which these learning experiences involve education in the basic sciences is unclear. There was little change reported in the use of IPE courses by dental schools between 2006 and 2011 and an increase (21 to 29%) in the percentage of medical schools reporting engagement with dental schools in IPE experiences between 2011 and 2015.[6-8,23]

Perspectives from Recent Work in Other Fields

Outcomes of recent work in other fields may have important implications for dental education. We briefly discuss three of them here. In 2009, a committee formed by the AAMC and the HHMI published "Scientific Foundations for Future Physicians," which defined science competencies for premedical and medical education.[33] Science competencies define how science and its methods are applied in practice. This work has had broad impact in both medical and premedical education. It provided the framework for development of a new Medical College Admissions Test, and it is helping to shape medical and premedical education.[34,36,37]

The foundation knowledge statements contained in "Foundation Knowledge for the General Dentist" published by the JCNDE CIE can be thought of as science competencies, although they are not defined as such in the document.[27] In order to demonstrate attainment of science competencies, dental students would have to show that they use science and its methods in their practice of dentistry in much the same ways that they currently demonstrate attainment of clinical competencies. More than that, using science competencies has the potential to emphasize and elevate the position of basic sciences in the hierarchy of learning for dental students, since attaining both basic sciences and clinical competencies would be required for graduation.[27,31]

The Carnegie Foundation for the Advancement of Teaching funded both the 1910 Flexner and 1926 Gies reports.[1,38] The foundation's Preparation for the Professions Program, a decade-long comparative series of studies that concluded in 2010, examined the preparation (education) for five professions in the U.S.: law, engineering, the clergy, nursing, and medicine.[39] Findings that emerged from examining data from these five professions were 1) that the most overlooked aspect of professional preparation in all five was professional identity formation (PIF), and 2) the proposition that PIF plays a significant role in integrating the academic knowledge base (scientific foundations) with the skills of practice.[39,40] These findings may have important implications for education in all professions including dentistry.

The notion that integrating science and practice may require the development of "professional values and capacities" on the part of the learner (and CODA Standard 2-10) suggests that applying science to practice is not just an academic issue, but an ethical issue that must be addressed in the curriculum and culture of professional schools.[31,40,41] Doing so would be no small undertaking. Importantly, this notion raises the possibility that working at the level of curriculum structure and delivery (curriculum integration, active learning methods, etc.) alone may be insufficient to bring about transformative change in the learner for whom applying science to practice must be accepted as a professional responsibility and therefore should become a habit of practice. It also suggests that dental educators and other stakeholders should be open to a major reconsideration of the steps we have been taking, recommended in the 1995 IOM report, to graduate dentists who use their knowledge

of science in the daily planning and delivery of oral health care and who recognize and keep current with the scientific discoveries that support the practice of "state-of-the-science" dentistry across their professional lifetimes.[2]

Conclusion

The curriculum surveys and reports we reviewed for dental education presented almost exclusively data that summarized what dental schools self-reported was being taught (topic areas and clock hour reports), who did the teaching, the extent to which instruction was discipline-based and/or integrated across disciplines or programs (basic, behavioral, and clinical sciences), and whether schools used specific instructional methods.[3-12] While such data are relatively easy to collect and do afford dental schools the ability to compare the content, structure, and methods of instruction used nationally, they offer no information about the effectiveness of that instruction in bringing about desired learning outcomes. Effectiveness data can only be obtained by examining the impact of educational programs on student learning outcomes and perhaps patient care outcomes at the dental school and beyond.

We believe that there is an urgent need for studies to determine whether specific educational interventions, such as integrating curriculum, using active learning strategies, etc., result in improved student learning outcomes such as increased use of basic science knowledge and its methods in the practice of dentistry. The results of such studies across the curriculum could provide evidence to help us identify best practices in dental education, assist programs in reaching consensus about curriculum time, emphasis, and methods, and help decrease the great variability in curriculum length (as measured in clock hours of instruction) among dental education programs. Dental graduates are expected to be able to identify and use the best possible evidence when making clinical decisions—that is, to engage in evidence-based practice. Educational research is needed to generate the evidentiary base to allow dental educators to make evidence-based decisions about how to best educate the next generation of dentists.

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