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Integration: a Strategy for Turning Knowledge into Action

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Abstract Within the last decade, there has been increasing interest in transforming undergraduate medical education through integrating basic, clinical, and social sciences. The Hofstra North Shore-LIJ School of Medicine, which graduated its first class in 2015, brought together a group of medical educators to develop a fully integrated curriculum. Here, we describe the "First 100 Weeks" of our curriculum and address the means by which we integrate at the program, course, session, and assessment level. We view integration as a strategy to train physicians to contextualize basic science through application to clinical medicine; to determine if this goal is met requires a novel approach to assessment. In our curriculum, students progress through a series of single courses. Each week's theme is anchored to our problem-based/cased-based learning program, Patient-Centered Explorations in Active Reasoning, Learning and Synthesis (PEARLS), which raises learning issues in biomedical, clinical, and social sciences. All large- and small-group sessions are thoughtfully constructed and positioned to enhance learning from PEARLS without pre-empting or duplicating it. All sessions belong to one of three course components: Mechanisms of Health, Disease, and Intervention; Structure, an integrated anatomy, histology, pathology, imaging and physical diagnosis laboratory; and Patient-Physician and Society, comprised of weekly clinical experiences and skills development, and examination of societal drivers of healthcare. Students complete formative and summative case-based assessments. We describe the details of our curricular and assessment strategies as well as important lessons learned along the way. These include the value of aligning philosophy, organizational structure, integrated content, and assessments.

Keywords Integration · Integrated curriculum · Integrated assessment · Curriculum reform · Case-based · Patient-centered

Introduction

Undergraduate medical education in the 20th century was founded upon the Flexner Report of 1910, which transformed medical education with its recommendation for the 2+2 approach. The continued evolution of undergraduate medical education in the twenty-first century is perhaps best captured by Carnegie's *Call for Reform of Medical Education*, published 100 years later, which recognizes the importance of integrating basic biomedical, clinical, and social sciences [1]. This recommendation is based, in part, on research demonstrating that learners are better motivated to devote the hard work needed to succeed when the relevance of the material is clear [2] and that learner understanding of content is most effective if it is organized in the manner in which it will be used [3]. This has led to the development of the idea that integration provides "cognitive conceptual coherence," which in turn promotes student retention of information and improved ability to apply knowledge to disparate situations [4, 5].

We contend that a common goal of medical educators is to foster the development of conscientious, knowledgeable, and compassionate physicians, who are adept at clinical reasoning founded in the basic sciences. We view "integration" as a strategy to meet this goal, not the goal itself. In this regard, we recognize that integration is frequently used as an operational term and suggest that this definition be further

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expanded. We endorse the idea that true success of integration lies in its ability to improve learning and consider this the value of integration. We hypothesize that anchoring a curriculum to integration produces physicians who are critical thinkers, can explain and apply the how and why of basic science principals to clinical medicine, are skilled at educating both patients and colleagues, and translate this to expert, compassionate care.

Further, we agree with others [5, 6] that integration in medical education must be carefully applied at the program, course, and session levels and extend this to include integrated assessments. Program-level integration involves making key decisions that should be reflected in a school's mission and guiding principles, departmental structure, overall curricular design, and selection criteria for faculty. Importantly, it sets the stage for successful integration at other levels. Course-level integration usually involves basic scientists and clinicians co-designing and co-directing courses, either simultaneously or sequentially such that "horizontal" (concepts connected across different content areas) and "vertical" (concepts connected between different disciplines or bodies of knowledge) integration occurs [5]. Integration at the session level involves the design of pedagogical activities that contextualize the relevance of basic sciences by linking specific concepts and facts to clinical problems. Assessment-level integration requires the creation of tools that enable students to demonstrate knowledge in action. It is important to note that no one, or subset, of approaches has been shown to be most effective at fostering integration and the value of integration has not been thoroughly assessed [5].

Here, we describe the first 2 years of a program, the First 100 Weeks (FOW), created in accordance with a proposed framework for organization of integration. As a new medical school, having just graduated our first class in 2015, we embarked upon the process of building a fully integrated curriculum and assessing our learners with a deliberate focus on the value of integration. We describe here how we integrated our curriculum at the program, course, and session levels and designed and executed a complementary assessment system. We also provide examples of how we attempt to determine the value of this integration through assessments that require students to demonstrate integrated understanding of material. Finally, we share both our challenges and lessons learned from this exciting endeavor.

Integration at the Program Level

Prior to creating our curriculum, we spent a significant amount of time strategizing how best to address integration at the program level. Visiting a variety of medical schools and reviewing the literature allowed us to identify at least five significant barriers to integration at the program level. These barriers and our approach to overcoming them are listed as follows.

Mission Statement and Guiding Principles Lend Purpose to Integration

As discussed by Goldman and Schroth [6], the first step in constructing an integrated curriculum is to align the institutional mission statement and its related goals with the desired outcome. Our mission statement and guiding principles were created with this in mind and include the following:

- Cultivating the personal transformation of our students into physicians through … a curriculum embedded in the student doctor-patient relationship
- Fostering the courage and intellectual climate to see beyond "what is," and developing the leaders to take us there
- Valuing conceptual knowledge in action, not memorizing facts
- Building upon experiential and active small group case-based learning
- Emphasizing scholarship, critical thinking, and lifelong learning
- Focusing on learning rather than teaching
- Creating an "adult learner" environment that values independent study and self-directed learning
- Allowing assessment to drive learning
- Enabling reflection, assessment, and transformation
- Creating a fully integrated, developmental, 4-year science and clinical curriculum

Using these statements to guide every step of our program development paves the way for an integrated community and curriculum to be actualized. Specifically, they move us beyond simply training doctors, to our goal of creating physicians who are internally driven to be lifelong learners and critical thinkers who use rigorous science to solve patient-centered clinical problems.

Breaking Down Barriers Between Basic and Clinical Sciences

A fully integrated curriculum requires contributions from basic scientists and clinical faculty. However, differing work priorities and responsibilities between the two groups can foster a division between them, hindering the open communication needed to build and maintain the complexities required of an integrated curriculum [7, 8]. Our status as a new school allowed us to create a single Department of Science Education and recruit science and clinical faculty who embrace our philosophy and whose professional goals are aligned with our mission. Full-time support of our educators within this department is critical to the success of our integrated curriculum.

Organizing Principles Must Support Integration

Successful integration depends upon the selection of an organizing principle for curricular design (e.g., competencies, organ systems) that lends itself to the examination of basic, clinical, and social sciences [6]. We organized our curriculum around weekly curricular themes anchored in our small group, problem/case-based learning program, Patient-Centered Explorations in Active Reasoning, Learning and Synthesis (PEARLS). PEARLS cases prompt students to develop biomedical, clinical, and social science objectives that are explored in small group discussions as well as in complementary sessions, including large groups, labs, and multidisciplinary practice-based initial clinical experiences (ICE). During ICE, students are able to practice applying the weekly goals under the guidance of clinical preceptors from five core disciplines: medicine, surgery, obstetrics/gynecology, pediatrics, and psychiatry. Students spend time in the office that is most relevant to that week's curricular content and are asked to relate their basic science studies to the care of patients. ICE patients are often discussed in PEARLS where, as a group, students explore the scientific principles underlying their clinical cases. This organizational framework is applied to our student-centered curriculum in which we limit required curricular contact time to approximately 22 h/week and expect students to be prepared for sessions, ready to apply knowledge. By doing so, the majority of curricular sessions can apply material across disciplines, enabling students to accomplish learning they would not have otherwise achieved.

Thus, through the blend of PEARLS, other complementary sessions, and ICE, students come full circle by starting with a patient in a case, delving into the basic sciences, and synthesizing this information through real patient experiences. We use this model throughout the FOW, where we apply this organizing framework to all disciplines and have found that it promotes integration.

Anchoring Content in a Spiraled, Single Curricular Component Helps Define the "What, When, and Where?" of Integration

Goldman and Schroth [6] identify several crucial elements to be considered when developing an integrated curriculum. These include defining the purpose, content, and environments in which integration will take place. In our curriculum, the purpose of integration is to prepare students to turn knowledge into action. During the FOW, we create a consistent balance of basic, clinical, and social science content by enrolling students in a single course at a time, grounded in PEARLS and consisting of three curricular components. These include the following: mechanisms of health, disease and intervention (MHDI), structure, and patient, physician and society (PPS). MHDI includes physiology, pathophysiology, and interventions such that students learn normal, abnormal, and therapeutics simultaneously. Structure uses both nonlaboratory and laboratory formats to simultaneously integrate gross anatomy, histology, pathology, embryology, medical imaging, clinical reasoning, and physical diagnosis. PPS is comprised of two components. The first encompasses classroom and simulation-based sessions tied to the School of Medicine's themes (communication, professionalism, and physical diagnostic skills) and drivers (continuum of care, decision making and uncertainty, social context/responsibility, quality and effectiveness, and scientific discovery). The second component of PPS is the ICE.

We organize much of the content of our FOW program using a spiraled, longitudinal approach, in which curricular content is learned and revisited over time, with the complexity and/or clinical application of content advancing each time it is reintroduced. In the first course, "From the Person to the Professional: Challenges, Privileges, and Responsibilities (CPR), " students survey the major systems of the body while becoming licensed EMTs. In doing so, they experience translating knowledge into action from the outset. CPR also introduces students to health care systems through the lens of various medical professionals and patients, thereby forming the foundation of future clinical experiences [9]. All content covered in CPR is reintroduced in the subsequent series of five 12–15-week integrated courses.

An Integrated Curriculum Requires an Integrated Faculty, Careful Bookkeeping, and Vigilance

We identified three common barriers related to faculty challenges when creating a fully integrated curriculum. First, course directors need to be aware of content covered in all other courses to prevent redundancy and ensure revisited topics are covered at the appropriate level and context [10]. Next, Bandiera et al. [11] describe tension regarding allocation of curricular time to basic versus clinical sciences during preclinical training. Finally, the literature describes what we call "curricular, drift" defined here as gradual regression to traditional educational approaches [12].

To address these issues, the School created the position of Dean for Curricular Integration and developed two unique subcommittees of our Curriculum Committee: the FOW subcommittee and the Curriculum Integration and Innovation subcommittee. The FOW subcommittee is comprised of course directors representing all three curricular components, other full-time science educators, our Education Deans, and curriculum support staff. This group meets on a bi-weekly basis to review details of current curricular content, discuss coverage of this content elsewhere in the curriculum, and collectively wrestle with "special topics" that arise as a result of running a fully integrated curriculum. The FOW group tracks curricular mapping, both in real time during these weekly meetings, as well as at defined intervals.

The Curriculum Integration and Innovation subcommittee is responsible for maintaining integration homeostasis with a constant eye on opportunities for innovation. The committee is comprised of basic and clinical science faculty from the First and Second 100 weeks as well as our Education Deans. It grapples with difficult questions such as those related to program evaluation in an integrated curriculum and measurement of student achievement in all curricular components. This committee has been instrumental in the development of our innovative assessment approach (described below). Additionally, we have discovered that a fully integrated curriculum sometimes pushes educators beyond their comfort zones and this committee helps uphold our guiding principles, thereby preventing curriculum drift.

Integration at the Course Level

Three closely related issues have been identified as barriers to successful integration at the course level [11, 13]. These include (a) achieving collaborative interdisciplinary course leadership; (b) balancing basic, clinical, and social science content; and (c) integrating longitudinal curricular content while maintaining a curricular theme. To begin addressing these obstacles, our courses are directed by teams of physicians and scientists who collectively represent our three curricular components. This helps build collaborative leadership and ensure that MHDI, Structure, and PPS content are balanced (Fig. 1). Course directors identify the weekly theme to which the content of each curricular component is tied. The establishment of three curricular components, each comprised of multiple longitudinal content areas overseen by a limited number of people, ensures that only longitudinal content appropriate to the week's theme is used to build the week. As an example, the third course in the FOW, Fueling the Body (FTB), is comprised of biochemistry and gastrointestinal basic and clinical science (Table 1). Three of the weekly themes (PEARLS cases indicated parenthetically) in this course include: Fuel to Energy (Toxicity and Mitochondrial Myopathy), Glucose Homeostasis Gone Awry (type 1 diabetes and type 2 diabetes), and Liver in Health and Disease (alcoholic liver disease and cirrhosis). After establishing the foundational LOs in the PEARLS cases, LOs related to that content, but specific to each of the curricular components, drives the creation of other sessions. In this way, individual weeks collectively form a course in much the same way as chapters form a book.

Integration at the Session Level

Working from clearly articulated goals and LOs, our Science Education faculty develops sessions that synchronously and sequentially integrate basic and clinical sciences. The development of such sessions has been described as a barrier to integration [5, 14]. We believe the means by which we integrate content at this level is best illustrated by examining a sample week from our FTB course during the week entitled "Glucose Homeostasis Gone Awry" (Table 1). The MHDI directors for this course include a biochemist (PhD), molecular biologist (PhD), and an endocrinologist (MD). The first PEARLS case presents a patient with type 1 diabetes with the goals of having students understand glucose homeostasis in the absence of insulin and how exogenous insulin therapy seeks to mimic endogenous insulin secretion. The second PEARLS case, which focuses on a patient with type 2 diabetes, promotes student understanding of the pathophysiology of type 2 diabetes and the hyperosmolar hyperglycemic nonketotic state. Additional pharmacologic goals include indications for and risks associated with using insulin sensitizers, DPP-4 inhibitors, and SGLT2 inhibitors. Embedded within each case are prompts that allow students to recognize some of the LOs to be explored in the Structure and PPS sessions of this week. Students use these patient-centered cases to explain and relate all aspects of patient history, physical examination, laboratory data, diagnostic workup, clinical course, and pharmacologic therapies to the basic sciences underlying them. PEARLS groups of nine students and a process facilitator meet three times weekly; the first meeting of the week is dedicated to deriving LOs from the cases. Students have a significant amount of time allocated to self-directed learning each week (Fig. 1), during which they research their PEARLS LOs and complete assigned pre-work for the other sessions. In preparing for PEARLS discussions, students are required to create new, thought-provoking questions and scenarios to explore their PEARLS LOs. These "triggers" are presented to their group during the next PEARLS session.

Learning in PEARLS is supported by the MHDI large group sessions that complement the PEARLS cases. In our sample week, there are three MHDI sessions (Table 1). "Glucose Regulation and Pregnancy" exemplifies our spiral curriculum, as students build upon knowledge obtained in the prior course regarding the physiologic changes of pregnancy and relate it to the new concept of glucose regulation. "Glucose Homeostasis and Insulin" illustrates the application of basic science to clinical scenarios, as students apply biochemical pathways involved in maintaining glucose homeostasis to explain clinical findings in patients. "Type 2 Diabetes Therapeutics" demonstrates knowledge in action because students are challenged to select antidiabetic agents and insulin regimens. An obstetrician,

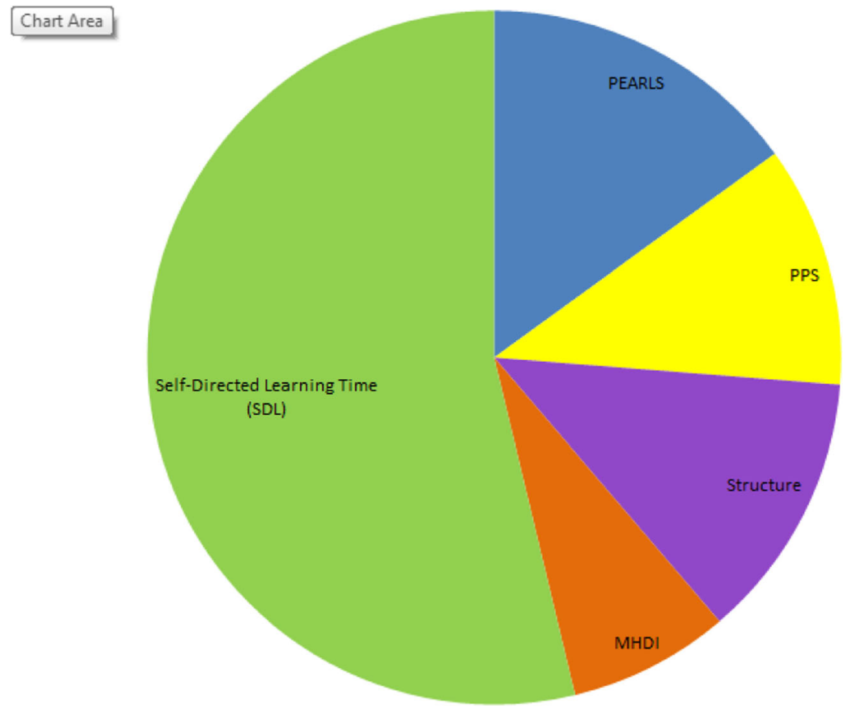

Fig. 1 Relative distribution of SDL, PEARLS, MHDI, Structure, and PPS within a week

endocrinologist, and biochemist collaborate to create the content of these sessions around multiple clinical scenarios; two examples are listed in Table 2. To successfully participate in the week's MHDI application based sessions, students use their understanding of physiology, pathophysiology, pharmacology, and biochemistry, acquired through PEARLS as well as assigned pre-work.

Structure sessions also support learning in PEARLS. In our example week, the Structure session's goal is for students to understand the systemic impact of diabetes as a chronic

Table 1 Sample week: Glucose Homeostasis Gone Awry

Week 4: Glucose Homeostasis Gone Awry

	Monday	Tuesday	Wednesday	Thursday	Friday
8:00am	PEARLS Case: Type 1 Diabetes	Standardized Patient Encounters	PEARLS Case: Type 1 Diabetes	Lab: The Structure of Diabetes & Ophthalmic Exam	PEARLS Case: Type 2 Diabetes
9:00am	PEARLS Case: Type 2 Diabetes				
10:00am	Glucose Regulation and Pregnancy		Chronic Disease Management: Diabetes as a Paradigm		Glucose Homeostasis and Insulin
11:00am	Obesity as an Epidemic				Type II Diabetes: Complications and Therapeutics
12:00pm					
1:00pm					
2:00pm					
3:00pm					
4:00pm					

The relationship of the three curricular components (MHDI, Structure, and PPS) and their related content to the weekly theme is shown

Table 2 MHDI large groups—session-level integration

Case scenarios from MHDI large group sessions	Questions posed	Disciplines integrated at the session level
Ms. B is a 52-year-old woman with a BMI of 32 and a 5-year history of type 2 diabetes; blood pressure is 140/90.	What is the most appropriate treatment for her and why? What are the potential side effects and how do those relate to the mechanism of action of the medications? What are the risks, benefits and relative costs of those treatments?	Biochemistry Clinical medicine Physiology Pathophysiology Pharmacology Behavioral sciences
Mr. R has no prior history of diabetes and is admitted to the hospital for surgery to repair an aortic aneurysm. He is given nothing to eat after midnight. The next morning his case is delayed into the afternoon. He remains without eating and his fingerstick log is as follows: day 1: 11 pm=160 mg/dL, day 2: 6 am=121 mg/dL, 12 pm=116 mg/dL, 5 pm=100 mg/dL	How would you interpret the lab results? Why didn't he become hypoglycemic overnight? Throughout the following day? What were his fuel sources? If he did not eat for 2–3 days, what would be his source of fuel and how would it be produced?	Biochemistry Clinical medicine Physiology Pathophysiology

disease. This lab is comprised of three stations through which all students rotate. Each station is facilitated by one or two faculty members, including anatomists, pathologists, ophthalmologists, endocrinologists, and emergency medicine physicians. The stations are organized around the structural complications encountered in patients with diabetes: peripheral vascular disease, diabetic nephropathy, and diabetic retinopathy/the ophthalmic exam. Students must integrate material from pre-readings in anatomy, histology, pathology, and physical examination to answer questions posed by facilitators at each station (Table 3).

The PPS classroom session during this week uses the PEARLS cases to more deeply explore best practices of team-based care for patients with chronic disease, using diabetes as a paradigm. The goal of this session is for students to recognize and/or demonstrate the following: principles of

Table 3 Structure small groups—session-level integration

Station scenarios from structure session	Questions posed	Disciplines integrated at the session level
Four histopathology slides shown: acute MI, soft tissue necrosis of the foot, arteriosclerosis in the kidney, glomerulosclerosis	Each of these slides could come from a patient with diabetes. What pathophysiologic process do they have in common? The risk of developing three of these complications can be reduced by decreasing a patient's HbA1c-which one cannot be and why?	Pathophysiology Histopathology Clinical medicine Epidemiology
Normal and abnormal angiograms and foot skeleton are shown	Compare and contrast the clinical presentation of a patient with diabetes who has lower extremity arterial vs. venous insufficiency and relate the underlying pathophysiology to the clinical presentation. Locate on the anatomical specimen and palpate on one another the popliteal, posterior tibial, and dorsalis pedis pulses. Review the anatomy of the angiograms and predict which pulses would be palpable on each of the patients, how you would assess them and what their ankle-brachial index might be.	Pathophysiology Anatomy Radiology Physical examination Clinical medicine

interprofessionalism (the roles of multidisciplinary caretakers in a team-based approach), preventative medicine (the importance of monitoring for diabetes-related complications and how they can be avoided), patient education (the use of teach-back), and clinical skills (the use of a glucometer and an insulin pen). This session begins as a large group facilitated by a certified diabetes educator (CDE), nurse practitioner, and a patient. Subsequently, students divide into multiple small groups co-facilitated by a physician, a pharmacist, and a pharmacy student. In each group, a PEARLS case is extended by providing a fingerstick log for the patient. Students then role-play paired counseling around common issues for patients with diabetes related to prevention, medications, and use of glucometers (Table 4). Students' ICE experience this week is in a medicine practice where they have the opportunity to see patients with diabetes and apply the knowledge, skills, and attitudes to the care of real patients.

By the end of this week, our expectation is that students should be able to evaluate a patient with diabetes and relate aspects of the patient's history, physical examination, laboratory data, diagnostic workup, imaging, clinical course, and pharmacologic therapies to the basic science underlying each. Additionally, students should be able to effectively educate a patient about diabetes care, complications, and management. Perhaps even more importantly, if a student is unable to do some portion of this, that student is capable of finding the information to enable them to do so. These expectations are best evaluated by assessing student performance in exercises that ask learners to explain and apply integrated thinking.

An Integrated Program Requires a New Approach to Assessment

We agree with the tenet "assessment drives the learning process [15]." However, literature regarding integration fails to specifically address assessment in any detail [8] and instead identifies related barriers. Chief among these is that assessment reveals a "hidden curriculum" that rewards the acquisition of facts over the application of concepts [5, 8]. Our integration efforts aim to enhance students' abilities to apply the how and why of basic science to clinical medicine and thus to demonstrate knowledge in action. In order to accomplish this, we offer both formative and summative forms of assessment in the form of essay-based and clinical skills examinations. Importantly, ours is a pass/fail grading system.

Why Is Formative and Summative Assessment and a Pass/Fail Environment Critical?

We contend that synthesizing and applying all aspects of basic, clinical, and social science content related to patients is complex and takes practice and coaching. In our curriculum, this takes the form of ongoing formative assessment. Formative assessment creates opportunities for practice, self-assessment, and coaching and feedback from experts. A pass/fail system encourages students to take risks in applying newly acquired knowledge to clinical scenarios. Additionally, we believe that fostering a collaborative learning environment in a challenging, integrated curriculum is more valuable than identifying the acquisition of incremental amounts of knowledge above a requisite baseline.

At the end of each course, we devote an entire week to summative assessment aimed at answering the question "does this student demonstrate the expected knowledge, skills, and attitudes relative to the basic, clinical and social sciences content of this course?" These weeks of "Reflection, Integration, and Assessment (RIA)" provide opportunities for students to demonstrate the value of integration via short answer final essay exams, Structure laboratory exams, and standardized and simulated clinical encounters.

Table 4 PPS large and small groups—session-level integration

Case scenarios from PPS small group sessions	Questions posed	Disciplines integrated at the session level
The patient asks how he should be checking his fingerstick and why sometimes he gets hypoglycemic.	Counsel him on checking his glucose, including how to use the machine, when to check, how to record sugars, what numbers to look for, why hypoglycemia occurs, how to treat it and define the roles of other team members who may be able to help him.	Communication skills Pathophysiology Clinical medicine Pharmacology Communication skills Interprofessional clinical medicine
The patient says she keeps hearing the A1C number, but is not really sure why everyone is so fixated on this number.	Explain how this number relates to complications in diabetes, if she needs any tests/examinations to see if she has any complications yet and if so, how those tests are performed.	Communication skills Pathophysiology Clinical medicine Epidemiology

Why Avoid Multiple-Choice Questions?

Importantly, we avoid multiple-choice questions (MCQs) in our assessment process in the FOW. We believe that an integrated curriculum is best assessed through examination of knowledge in action, which necessitates explaining and demonstrating one's thinking, neither of which are captured by MCQs. With this in mind, our novel assessment system creates assessments that

- Integrate basic, clinical, and social sciences
- Are case-based so that students can relate scientific principles to clinical problems
- Offer students the opportunity to explain their thinking
- Provide opportunities to assess clinical reasoning

What follows are descriptions of the types of assessments utilized in our curriculum and their application to the sample week.

Within Course Assessments

At the end of each week, students receive two formative essays and are required to complete one of them. The weekly essays are case-based, assess the goals for the week and are reviewed by PEARLS facilitators, who are either PhDs or MDs. Questions from an essay in our example week, which consists of three case scenarios, are shown in Table 5. The suggested answers are posted after the due date and students are responsible for self-assessing their performance versus the suggested answer, and closing the loop on any knowledge gaps identified.

During the course, students complete a write-up on a patient they select from ICE (Table 5). This has multiple goals: documentation of a clinical encounter, discussion of differential diagnosis and clinical reasoning from initial chief complaint to diagnosis, explanation of the relationship of each School of Medicine theme and driver in relation to the patient, and linking a physiologic explanation to the patient's chief complaint. Students complete their write-ups utilizing a template and receive formative feedback prior to submitting a final version that is graded summatively by clinicians.

End of Course Assessments

During each RIA week, students complete four assessments: a final essay examination, Structure lab examination, team-based simulation, and standardized patient encounters. Final essay exams are comprised of 25 case-based short essay questions. These examinations include material from PEARLS, MHDI, and PPS sessions. Similarly, the Structure examination is comprised of approximately 45 case-based short essay questions that include material from PEARLS and Structure sessions. Two separate exams are needed to assess an abundance of material from the preceding 12–15 weeks. Because all the examination questions are patient cases, material from one exam is often found in a new context on the other exams as well. Questions on each examination are collaboratively written by faculty and are carefully vetted to ensure that clinical and basic sciences are linked, patient scenarios are complementary but not redundant, and there is appropriate representation of curricular material between the exams. Questions on completed examinations are assigned to the relevant content expert (i.e., a basic scientist or clinician) for grading.

The sample week from the course FTB (Table 1) is represented in both these exams by case scenarios including patients with diabetes and multiple comorbidities. On the final essay exam, students are asked to compare and contrast pathophysiology, interpret labs and explain these findings to a patient with newly diagnosed diabetes. On the Structure examination, a patient with long-standing diabetes is presented with vascular complications, a CT angiography study is provided and students must interpret and apply this information to the physical examination. Utilizing integrated patient-centered questions and having students explain their thinking in an essay format allows them to demonstrate their ability to apply multiple disciplines to relatively complex scenarios (Table 5).

Throughout courses and during RIA weeks, students spend time at our Center for Learning and Innovation (CLI). CLI is our 45,000-ft^2 assessment facility that houses high-fidelity simulation and standardized patient examination rooms. During simulation, students work in teams of two or three and have about ten minutes to interview, assess, interpret data, and stabilize two simulated patient cases. Following the simulation, the students participate in a debrief co-led by a scientist and a physician, who facilitate a discussion of the basic science behind the clinical presentation and management of these patients. During our sample week, the two simulation scenarios are a patient in diabetic ketoacidosis and a patient in hyperosmolar nonketotic state. Students are asked to compare and contrast various aspects of the two cases (Table 5). While the simulation exercises are formative, students also participate in summative standardized patient encounters while at CLI. During our sample week, students meet a woman with gestational diabetes with whom they communicate and discuss the diagnosis. The patient challenges the student with sample questions (Table 5).

We believe that patient-centered assessments are by nature integrated. In each of our patient-centered assessments, students must explain their thinking aloud or in writing, which allows us to determine if a student understands basic science principles as they relate to clinical medicine. Our assessments closely approximate the physician's role and provide a way to assess the value of integrated curricular efforts on an individual student level.

Table 5 Assessment-level integration

Name and type of assessment	Questions asked
Weekly essay (formative)	Compare and contrast the pathophysiologic mechanisms that explain the glucose, lactic acid and serum ketone findings in each of these three patients.
	Predict the glucose, lactic acid and serum ketone findings for a patient with type 2 diabetes who is poorly controlled and explain the rationale for those findings.
	What is a possible mechanism for how metformin could result in weight loss?
Hofstra write-up (formative and summative)	Where does the patient live and with whom? What do you know about this environment and how it impacts his or her care?
	Does this patient have access to care? If not, what are the barriers?
	Is the healthcare system allowing the patient to meet his/her goals of care? Is it necessary to re-visit the question of: are the patient's goals being met?
Final essay (summative)	Using a pathophysiologic rationale, explain some of the features that differentiate type 1 from type 2 diabetes. Next, write how you would explain this to your patient.
	You send your patient for baseline labs and her HbA1C returns at 9.7 %. Using a physiologic rationale, explain this lab result. How would you explain this to your patient?
	You explain that you will be screening your patient's urine for protein periodically. What is the pathophysiologic rationale for this recommendation?
Structure exam (summative)	A 73-year-old woman with a history of diabetes and coronary artery disease presents with nonhealing ulcerations on the plantar surface of the third and fourth digits of her left foot. CT Angiography is performed, showing occlusion of the left distal posterior tibial artery, just posterior to the medial malleolus. Would assessment of the dorsalis pedis arterial pulse be a useful measure of the occlusion at the site described above? Why or why not?
Team-based simulation encounter with integrated debrief (formative)	What did you think about the patient's respiratory rate? Why was the patient tachypneic and what is the mechanism behind it?
	Based upon your clinical examination and evaluation of the laboratory values, what do you think about the volume status in each of these patients? What is the mechanism for dehydration in each of these patients? Which patient has greater fluid losses? Why and how would you replace them?
	Both patients' fingersticks were too high to read. What is the pathophysiologic basis for hyperglycemia in each of the patients? Based on the pharmacokinetics of various insulins, how would you treat the hyperglycemia in these patients? Would you use oral antidiabetic medications? Why or why not?
Standardized patient encounter (formative and summative)	Can you explain how my diabetes is different from the kind my aunt developed when she was 55 years old?
	Does this mean that I will be on medications for life?
	How much do the medications cost?

Implications and External Validation of Our Assessment Approach

We designed our unique assessment approach to remain true to our guiding principles. We also realize that at the completion of the FOW, students must pass the USMLE step 1 examination and we must ensure that they are prepared to do so. To that end, students are required to take formative, custom NBME exams at the completion of every course with the expressed purpose of demonstrating to the students that the way they are learning and are assessed in our curriculum translates to success when assessed via MCQs. Three years' worth of USMLE step 1 performance data reveal performance above the national mean with a pass rate of >99.4 %.

The next question becomes how does this type of assessment translate to performance in clinical rotations? Although only two classes have moved beyond the FOW in our new school, experienced medical educators who have trained students from other institutions find that our students distinguish themselves in their abilities to examine content from multiple perspectives, generate and explain ideas and concepts, create and challenge one another with application exercises, facilitate discussions through the use of higher order questions, and naturally approach and communicate with patients. We believe this to be a natural extension of our integrated curriculum and assessment process.

Lessons Learned

After 3 years of planning and 4 years of execution, we believe strongly that focusing on philosophy, organizational structure, content, and assessment have enabled us to achieve integration at the program and course levels. We find that the dynamic nature of sessions and assessment makes achieving integration at these levels an iterative process. Here, we share several important lessons.

An organization's philosophy must support integration efforts because integration is costly, faculty intensive, and frequently challenged [12]. For this reason, class size must be taken into consideration. For instance, with a class size of 100 learners, one of our courses requires at least a dozen small group rooms, many support staff, faculty (including ICE preceptors) and patients, use of a simulation facility, standardized patients, thousands of person-hours of facilitating and grading, and coordination amongst these disparate entities. Without the commitment of our school's leadership, this effort would not succeed. Similarly, we have found that although all stakeholders support the notion of an integrated curriculum, the temptation to revert to a more traditional approach is ever present; guiding principles that foster integration support decision-making at all levels and maintain focus on a common goal.

The organizational structure of a medical school can facilitate or impede integration. Establishing a single department of Science Education with full time physician and science faculty educators who are charged, supported, and held accountable for integration allows such a group to break through traditional barriers. In our case, we also find that the FOW and Curriculum Integration and Innovation subcommittees are critical to meeting our curricular goals. The FOW group looks at the week as a whole, digests student evaluations and faculty impressions of the week, knows the fine details of the curricular content in all courses, exchanges content and adjusts sequencing so the curriculum is meaningful for learners. It is also the place to discuss "special topics" that arise such as suggestions on how to better integrate specific topics (e.g., pharmacology), the relative balance of topics represented given the curricular goals (e.g., immunology vs infectious disease), and the need for more detailed feedback to students. The Curriculum Integration and Innovation subcommittee provides a forum for vetting the relevance of content as related to overall curricular goals and generates ideas and opportunities within the curriculum to continuously improve integration of material. Aligning our educational Deans' roles with case-based learning, and integration and assessment ensures leadership support for integration endeavors.

Our decisions to utilize case-based learning, simultaneously teach normal, abnormal and therapeutics, provide early clinical experiences and create a student-centered curriculum have been critical. These decisions provide students opportunities to learn to think and behave as physicians from the onset of medical school, enabling us to develop and assess them in this capacity much earlier than is done traditionally. The work of physicians is challenging and we believe formative assessments promote success in summative assessments that are patient-centered and multidimensional. Nonetheless, this assessment schema provides new challenges. For instance, we have encountered students who achieve high scores on essay exams, but (a) struggle in communicating empathy during a clinical skills exam, (b) rarely contribute to group discussions, or (c) rarely complete administrative responsibilities (e.g., program evaluations). Such students require individual feedback from faculty who coach them on strategies for success. Indeed, success in an integrated curriculum implies success in all its components, including those that have not traditionally been assessed in the preclinical years.

The true success of integration in our new curriculum will be graduating physicians who are critical thinkers, apply basic science principals to clinical medicine, are skilled educators, and providers of expert, compassionate care. Our current and future research will test the impact of our philosophy, organizational structure, content, and assessment on student achievement thereby measuring the value of integration. We hope that some of our experiences and specific examples can provide guidance and insight to others seeking to advance medical education in a similar fashion.

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References

1. Irby DM et al. Calls for reform of medical education by the Carnegie Foundation for the Advancement of Teaching: 1910 and 2010. Acad Med. 2010;85:220–7.

2. Kaufman DM, Mann KV. Teaching and learning in medical education: how theory can inform practice. In: Swansick T, editor. Understanding medical education: evidence, theory and practice. West Sussex, UK: Wiley-Blackwell; 2010. p. 7–30.
3. Ambrose SA, Bridges M, DiPietro M et al. How learning works: seven research-based principles for smart teaching. San Francisco, CA: Josey-Bass; 2010.
4. Woods NN et al. It all makes sense: biomedical knowledge, causal connections and memory in the novice diagnostician. Adv Health Sci Educ. 2007;12:405–15.
5. Kulasegaram KM et al. Cognition before curriculum: rethinking the integration of basic science and clinical learning. Acad Med. 2013;88:1–8.
6. Goldman E, Schroth WS. Deconstructing integration: a framework for the rational application of integration as a guiding curricular strategy. Acad Med. 2012;87:729–34.
7. Martimianakis MA et al. Understanding the challenges of integrating scientists and clinical teachers in psychiatry education: Findings from an innovative faculty development program. Acad Psych. 2009;33:241–7.
8. Brauer DG, Ferguson KJ. The integrated curriculum in medical education. Med Teach. 2015;37:312–22.
9. Kwiatkowski T et al. Medical students as EMTs: skill building, confidence and professional formation. Med Educ Online. 2014;19:24829.
10. Harden RM. Curriculum mapping: a tool for transparent and authentic teaching and learning. Med Teach. 2001;23:123–37.
11. Bandiera G et al. Integration and timing of basic and clinical sciences education. Med Teach. 2013;35:381–7.
12. Jones R et al. Changing face of medical curricula. Lancet. 2001;357:699–703.
13. Muller JH et al. Lessons learned about integrating a medical school curriculum: perceptions of students, faculty and curriculum leaders. Med Educ. 2008;42:778–85.
14. Stevenson F et al. Paired basic science and clinical problem-based learning faculty teaching side by side: do students evaluate them differently? Med Educ. 2005;39:194–201.
15. Epstein RM. Assessment in Medical Education. New Eng J Med. 2007;356:387–96.