Clinical Correlations as a Tool in Basic Science Medical Education

Brenda J. Klement[1], Douglas F. Paulsen[2] and Lawrence E. Wineski[2]

[1]Department of Medical Education, Morehouse School of Medicine, Atlanta, GA, USA. [2]Department of Pathology and Anatomy, Morehouse School of Medicine, Atlanta, GA, USA.

ABSTRACT: Clinical correlations are tools to assist students in associating basic science concepts with a medical application or disease. There are many forms of clinical correlations and many ways to use them in the classroom. Five types of clinical correlations that may be embedded within basic science courses have been identified and described. (1) Correlated examples consist of superficial clinical information or stories accompanying basic science concepts to make the information more interesting and relevant. (2) Interactive learning and demonstrations provide hands-on experiences or the demonstration of a clinical topic. (3) Specialized workshops have an application-based focus, are more specialized than typical laboratory sessions, and range in complexity from basic to advanced. (4) Small-group activities require groups of students, guided by faculty, to solve simple problems that relate basic science information to clinical topics. (5) Course-centered problem solving is a more advanced correlation activity than the others and focuses on recognition and treatment of clinical problems to promote clinical reasoning skills. Diverse teaching activities are used in basic science medical education, and those that include clinical relevance promote interest, communication, and collaboration, enhance knowledge retention, and help develop clinical reasoning skills.

KEYWORDS: clinical correlation, medical curriculum, medical education, medical learning tool, active learning, medical problem solving, gross anatomy education

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CORRESPONDENCE: bklement@msm.edu

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Introduction

Clinical correlations in medical education are tools that assist students in connecting basic science concepts with medical applications. There are many forms of clinical correlations, as well as various methods for their presentation and use. A clinically integrated curriculum includes clinical scenarios and clinically relevant information at its core, and the clinical material is used as the foundation for teaching. In a curriculum that separates the basic sciences from the clinical sciences, students learn the basic science concepts first. Although clinical correlations may be used in both types of curricula, they are particularly useful in the basic science training so that students understand the clinical relevance of the basic science material. Basic science concepts blend with clinical concepts as the student's medical expertise grows, so that the initial requirements to explicitly describe the underlying biomedical mechanisms are no longer needed.[1] Clinical correlations facilitate this process, so that students begin learning in the early stages of their medical training how to associate and translate basic science information into clinical relevance. Teaching basic science topics by including clinical correlations also helps the student develop and practice good clinical reasoning skills.[2]

A clinical correlation in basic science medical education can be regarded as a learning tool that enables learning the association between a basic science concept and its applicability to medical practice or to a disease. The term clinical correlation is a broad concept and can incorporate medical concepts and clinical associations at multiple levels of detail. For example, they can be very superficial, such as the relationship of histology to a disease condition during a didactic lecture.[3] Alternatively, they can involve deeper active-learning experiences such as concept mapping[4] or the use of patient simulator exercises.[5] Clinical correlations can be used to show that the basic science concepts being taught are relevant to medicine and thus of practical use, without requiring a student to learn details about a disease or its clinical treatment. Clinical correlations are incorporated into the learning process as a tool to initially help motivate students to establish a firm foundation in basic science concepts, and then may become more complex as the student learns to diagnose and treat specific diseases and conditions.

There are very few publications that describe or define clinical correlations in medical education. A brief series of articles was published in the early 1990s that outlined several clinical correlation types used at that time. Virella[6] recognized that although lectures are a time-effective way to deliver information, other teaching formats are more efficient in establishing correlations between basic and clinical sciences and learning problem-solving strategies. For example, in a microbiology and immunology course, students used clinical correlation exercises to work through a priority list and justify appropriate diagnostic tests, and the likely diagnosis based on results of those tests.[7] In a biochemistry course, students first interviewed a standardized patient and then learned basic biochemistry concepts, providing motivation and stimulating the student's curiosity and providing the instructor a way to refer to a clinical scenario while teaching the basic science aspects of biochemistry.[8] A pharmacology course used problem-solving techniques to enhance learning,[9] and case studies were used to make the course more interesting and clinically relevant.[10] During this initial acknowledgment of clinical correlation use, course directors recognized that some faculty felt uncomfortable leading small-group discussions, recognized that the material was too clinical for their comfort zone, or felt that using the time for the clinical cases diminished the rigor of a traditional basic science course.[10] Since the time of these publications, it has become standard practice that medical programs include clinical correlations in the medical curriculum. This incorporation can be accomplished in various ways and with varying degrees of intricacy related to the clinical situation.

Although there are few direct references in the literature about clinical correlations, there are many examples of teaching and learning tools that utilize clinical scenarios to teach basic science concepts. These learning tools can be grouped into different clinical correlation classifications. We have used our experience in medical education and the clinical correlation activities used in our first-year medical curriculum as the basis to categorize and describe different types of clinical correlations.

Morehouse School of Medicine's four-year medical training program uses the first two years for basic science training and the third and fourth years for clinical training. The content of the first year of the basic sciences training focuses on normal human biology taught in sequential courses that closely integrate the basic science concepts of each organ system. The second-year basic science courses teach the mechanisms of disease. The content in both years is taught mostly through a lecture-based format, with clinical correlation activities mixed in.

Our first-year curriculum uses a variety of types of clinical correlations. Several of these were components of previously independent courses that were folded into a revised integrated curriculum. An anatomical sciences course was created in the 1990s from the merging of several courses, so that the cell biology, histology, developmental biology, and gross anatomy topics were included in a single course.[11,12] Part of the success of this course was its rich inclusion of clinical correlations in all topic areas. This course, plus its clinical correlations, formed the backbone/core for reorganization of the entire first-year medical curriculum.[13] Clinical correlations were retained from the previous courses and have been expanded upon and improved in the new courses. They have been used in some form for over 20 years. These clinical correlations enhance student learning, link content from different topic areas within the same course, and form a bridge to the more clinical nature of the second-year curriculum.

In this paper, we describe the activities that we believe to be distinct types of clinical correlations, our interpretation of how each can be used in basic medical science education, as well as their potential benefits for both teachers and learners. The categories were developed and described based upon the authors' experiences and perspectives as educators, and they represent unique contributions to medical education.

Classification of Clinical Correlations

The various types of clinical correlation activities used in our first-year medical program are identified and categorized below according to their complexity, degree of clinical information presented, and time required by the student. Learning tools used in other programs can also be assigned to these categories as additional examples. These clinical correlations are used in the transition between pure basic science education and medical practice to assist in preparing students for more clinically based training in clinical reasoning such as developing diagnoses, evaluating patient histories, and selecting specific diagnostic tests.

Correlated examples. This type of clinical correlation is usually presented as a short factoid or story that relates a basic science concept to a disease (Table 1). They advocate the relevance and importance of the basic science information in understanding the disease. These correlations usually do not require the student to memorize the disease-related information or learn specific facts about the correlation for examinations. They provide superficial clinical information with no advance preparation required by the student. This type of clinical correlation can be used by the instructor to show that the basic science concepts being taught are relevant and interesting and that there is value in learning the information and related details.

In our curriculum, and most likely at other institutions, most basic science didactic lectures have at least one clinical correlation embedded within each presentation. These may comprise a very basic mention of a disease or the result of trauma, or some example that relates to the topic at hand. One example we use is the relationship of defects in connective tissue fibers to diseases such as Marfan and Ehlers–Danlos syndromes. Images of defective collagen organization matched with those of disease features such as hypermobile joints and overly flexible skin help capture students' attention and provide motivation for learning the underlying concepts. The clinical correlation is used as an example of why the student should know and understand the basic science concepts

Table 1. Characteristics of clinical correlations.

TYPE OF CLINICAL CORRELATION	DESCRIPTION	EXAMPLE	RELATIVE COMPLEXITY OF CLINICAL INFORMATION	BENEFIT TO STUDENT LEARNING OR HOW USED IN EDUCATION	ADVANCED PREPARATION REQUIRED BY STUDENT
Correlated examples	Making reference to a disease or—included in a lecture or teaching presentation.	Association of fibrillin defect to Marfan's syndrome. Association of collagen defect to Ehlers-Danlos syndrome.	Superficial	Show that basic science concepts are important. Make material more interesting and that there is a reason for learning it.	None
Demonstrations and interactive learning	Small group demonstrations or short application-based activities.	Review of femur and tibia radiographs during lower limb learning block.	Simple	Consists of application-based information. Students participate in simple, basic activities.	None to minimal
Specialized workshop or laboratory session	Hands-on application of a targeted basic science topic. May include use of specialized equipment or procedures.	ECG lab using electrodes and computer software to examine heart waves.	Basic to advanced	Practice using specialized equipment, targeted application of basic science concepts.	Minimal to small
Small-group activity	Small groups analyze or solve clinical case problems. Led by faculty facilitators.	Discussion of blood disorders during hematology learning block.	Basic to advanced	Students practice team work, communication skills and problem solving strategies.	Small to intermediate
Course-centered problem solving	Use of clinical cases to teach basic science concepts. Advanced problem solving.	Use of computed tomography to promote clinical relevancy of cadaver dissections.	Complex and integrated	Promotes interdisciplinary collaboration and clinical reasoning skills.	Extensive

(connective tissue fiber structure and organization) because defects can translate into clinical conditions. At another medical school, a histology course uses clinical correlation within lectures to demonstrate how histology is related to disease and pathological conditions.[3]

Since little class time is spent discussing the details of a disease, in-depth knowledge of the disease is generally not required by the student for examinations. However, they may be used as the basis of an examination question clinical vignette that asks about the key concept being taught, without requiring the student to render a diagnosis. The outcome of this type of clinical correlation for the student is to reinforce that the topic is important, that it must be learned, and that it applies to complex clinical situations they will encounter later.

Interactive learning and demonstrations. This type of clinical correlation requires more designated time than correlated examples, but retains the simplicity of the clinical information presented (Table 1). Students become actively engaged in the correlation activity either by a minimal hands-on approach or by watching a demonstration or review of a clinical procedure. The activity helps the student to better appreciate the topic being covered by providing more detail and more engagement in the correlation. It may or may not be included in a grading assessment, but may be used as the basis of an examination question that queries basic science information directly related to the clinical correlation. The time involved for the student outside of class to prepare for or follow-up on the sessions is variable, but does not require an extensive amount of time.

We use several interactive learning and demonstration correlations during the year, oftentimes occurring a few days before an examination. They are mostly laboratory-based sessions with a focus to integrate the information learned in that examination block and demonstrate its clinical relevance. Small-group laboratory sessions are designed to reinforce concepts by relating those concepts to a clinical aspect. One example is our applied anatomy laboratories, where small groups of students rotate through four to five different stations, each covering a different topic that relates to the material learned in lecture or the laboratory, and relates it to the clinical setting.[14] For example, when students learn about the back and upper limb, some of the interactive learning and demonstration topics include spinal cord prosection review, clinical correlations in lumbar puncture, osteology and radiology, physical examination of the back and upper limb, as well as introductory blood pressure measurement skills. These sessions are valuable for student learning and provide the students with information about medical equipment, basic physical examination procedures, and insights into radiology that is correlated with the back and upper limb anatomy topics covered.

Although the content from these three-hour afternoon sessions is not necessarily included in examinations, it serves as a review and application of the material learned within an examination block. The correlations may provide the instructors a good basis for developing examination question vignettes, but do not require students to know details of the clinical relationships. Students do not have to prepare in advance for these sessions, and there is no follow-up work required.

Another example of interactive learning and demonstration correlations is the use of short student presentations.[15] Following a faculty seminar covering a common disease involved in the organ system being studied, students present a brief overview of one of the learning objectives derived from each subject area covered in that topic. Evaluation of the presentation is included in the student's formative assessment grade. Eisenstein et al[16] described a different type of laboratory activity that can be considered interactive learning and demonstration. Under the supervision of pathology residents, students identified pathologic conditions and collected biopsies from abnormal cadaver tissue. These same biopsies were examined later in the year during the histology course after they had been processed and sectioned. By this time in the curriculum, students were able to understand and recognize the difference between the pathological specimen collected and normal tissue. These clinical correlation activities engage the student in the learning process and promote the importance of basic science in clinical medicine. One aspect of this sort of exercise that often accompanies effective clinical correlations is the inclusion of a discovery element that piques the students' curiosity and adds to the intellectual satisfaction associated with their studies.

Specialized workshops. Another type of clinical correlation session that can be used in medical education is a specialized or simulation laboratory session (Table 1). Students participate in this type of session for longer time periods than the other types, usually spanning an entire morning or afternoon. These correlations require students to directly participate in activities that are more specialized than routine laboratory sessions. As opposed to standard laboratory sessions that focus on learning the basic science concepts, these specialized sessions contain an application-based focus. The concepts learned can be applied to the activity being undertaken, and there is minimal preparation or follow-up time required by the student. Students may be required to learn terminology or the theory behind a technique or procedure before participating in the activity, but the complexity of the information learned in the activity may vary from basic to advanced.

An example of this type of activity from our institution is an osteology laboratory where students use specialized surgical equipment to practice orthopedic repair techniques on artificial bone models. Another example is a respiratory physiology laboratory where the students use spirometers and specialized laptop software to measure lung volumes and pressures. At another institution, students spent a day investigating domain-specific questions from an integrative case, by meeting with patients, advocates, community leaders, scientists, or other health professionals.[17] They then spent part of the next day discussing the findings in facilitator-led groups with representatives from each domain.

These specialized workshops can also be used for students who are completing their basic sciences education and moving into clerkships. They can assist the student in connecting a variety of basic science concepts and applying them to the clinical setting. Patient simulator laboratories can be used to provide students the opportunity to see course material applied to a patient in a setting where they can perform diagnostic workups and treatments.[18] These tasks can be done as a team exercise that allows the students to experience clinical care before seeing actual patients. At the beginning of a third year Obstetrics and Gynecology clerkship, students attended a gross anatomy laboratory session, rotating through different stations, each with a clinically relevant anatomical topic.[19] Prior to the laboratory participation, students used short interactive online modules to link basic anatomical principles with clinical vignettes and procedures. This specialized activity provided review sessions for commonly encountered clinical topics and significantly improved student performance.

These specialized clinical correlations are fun for the students and provide hands-on experience while learning, or experience applying, the basic science concepts. It also gives them a break from the traditional classroom setting to do applied learning activities. The fundamental basic science concepts of the learning objectives are placed into a clinical context and provide real-time application of these techniques. These sessions may also be used to teach students the fundamental principles of a type of medical equipment or procedures that are used in common clinical situations.

Small-group activity. Some types of clinical correlations are best conducted with small groups of students participating in discussions concerning a particular topic with clinical relevance (Table 1). Students work in groups to solve basic or simple problems that relate the basic science information that has been learned to a clinical topic. The student groups are usually supervised by one or more faculty members who may or may not be clinicians. The groups have a set agenda and require students to work through a list of objectives. The length of the sessions is approximately the same as a standard didactic class session, thus not requiring an extensive time commitment by the student. The student may need to do advance preparation, or follow-up with work after the session concludes. The clinical concepts being addressed can be basic to advanced, depending on the academic level of the student. This type of clinical correlation provides the students with direct guidance by a faculty member, allowing them to receive feedback on their thoughts, ideas, procedures, and communication skills. The activity may be included as a component of a course assessment based on the content supplied or the process itself.

Examples of this type of clinical correlation include small-group clinical case discussions incorporated into basic science courses. The discussions center upon a prominent medical condition (eg, myasthenia gravis, diabetes, or atherosclerosis) that relates to the basic science topics being taught within a particular organ system covered in the course. Each group of students is supervised by a faculty facilitator who leads a discussion pertaining to the clinical situation or disease. The discussion allows students to answer a set of predetermined questions that are designed to enhance the student's understanding of the basic science concepts underlying the disease symptoms. Students receive information about the clinical case in advance so that they can do background reading and prepare for the discussion.

In another example, histology concepts are taught using a small-group approach where students work together on a topic and then present the results to the rest of the class.[3] Similarly, students participated in a one-hour small-group cardiac simulation exercise using a patient simulator with the goal of reinforcing the cardiac physiology didactic lecture learning objectives.[5] Students had the opportunity to interact directly with the simulator and work through a simulation scenario. Another example is the incorporation of small-group learning sessions and concept mapping in a medical biochemistry course.[4] Students were given a clinical case and had to prepare a concept map of the case scenario. The group worked together to lay out the elements of the case and link them to their clinical application revolving around the basic biochemistry concepts outlined in the case's learning objectives. Students felt that the activity made biochemistry fun and meaningful and promoted a deeper understanding of biochemistry. At another medical school, cadaver biopsy information that had been collected and assembled by students during their first year of medical school was revisited when the students were in a third-year radiology clinical clerkship.[16] Student groups worked as a team to discuss the case study and answer a set of designated clinical questions.

Course-centered problem solving. This more advanced clinical correlation approach is a much broader category of activities that focus much of the basic science learning around clinical problems, or are geared to learning how to recognize and treat clinical problems (Table 1). A clinical scenario is presented, and the student must learn the basic science concepts that result in the clinical symptoms. These clinical correlations may be used in advanced learning years, or as the basis for an entire course, and often comprise some component of the student's grading assessment. Students are required to prepare for the session or to follow-up during or after the session to complete the activity. This type of clinical correlation often uses and provides an opportunity to evaluate teamwork. It is important for students to learn to work together as part of a team to facilitate the interdisciplinary collaboration that will occur later in their careers as a necessary part of health care.[20]

Mechanistic case diagramming is a problem-solving tool that has been used in a medical pathology program.[21] This advanced clinical correlation learning tool is based on a case history developed by faculty. Students sort predesignated factors into a particular order according to a specific flow of etiologic risk factors, mechanisms, and tests that correlate to the current course topics. Torres et al[22] implemented a short, small-group-based, radiological anatomy course using clinical techniques to facilitate integration between anatomy and clinical sciences. Students took the course approximately a year after the traditional anatomy course concluded, but immediately before they entered their clinical training experiences. The course focused on the use of ultrasound and computed tomography (CT) modules for identification of anatomical structures. The goal of the course was to help students improve their three-dimensional and cross-sectional knowledge of anatomy and to develop practical skills in the use of imaging techniques. Similarly, Jacobson et al[23] implemented a transition course that students participated in during the last part of their second year in medical school. The course goal was for students to solve a clinical problem by developing a diagnosis using data provided in the course along with their basic science knowledge. Each week the focus was on a different presenting symptom, requiring the students to associate it with a particular organ system, applying several strategies to develop a diagnosis. The students worked in small groups, building confidence in their clinical reasoning skills prior to entering their clerkships. May et al[24] revised their anatomy curriculum using CT to augment traditional cadaver dissection. This clinical correlation promoted the clinical relevancy of anatomy as the basis for the course. Students had access to CT scans and were responsible for identifying clinical anomalies as a component of the clinical cases associated with the scans. The correlation promoted incorporation of anatomical knowledge with clinical and imaging practice and helped develop critical thinking and clinical reasoning skills.

Discussion

Different types of clinical correlations can be excellent learning tools to support the basic science concepts associated with them. They provide a mechanism for linking biomedical and clinical concepts.[3] This makes learning more fun and meaningful for the student[4] and demonstrates that there is a real purpose for spending the time learning otherwise seemingly monotonous and irrelevant course content. It also gives the instructor leverage in requiring students to know information when clinical correlations they have used demonstrate that the basic science content serves a purpose.

Many clinical correlations have an active learning component that requires the student to be actively engaged and participate in the activity.[3,14,19] Incorporating an active learning approach such as group discussion or hands-on application provides tools that reinforce important concepts and enhances information retention.[25] Active learning can also promote teamwork and a team that functions well together can often work more effectively and safely than can individuals.[20] The use of technology in active learning engages the learner, allows for knowledge acquisition, and can provide a mechanism to assess competency.[26] Further, an interested and lively learner is often more satisfying for faculty to teach. It is rewarding for instructors to see students engaged in the learning process and to see them master individual concepts, and then be able to link them together and work toward associating multiple pieces of information to establish a global understanding of the clinical problem.

The use of clinical correlations in teaching may translate into improved grades and knowledge retention. Upper-level students performed better on questions that they rated as having a high relevance to the clinical situation,[27] while presentation of case scenarios in an anatomy course was associated with improved short-term and long-term knowledge retention.[25] Students establish meaningful connections to clinical information based on the principles learned in basic science courses, allowing them to make diagnostic decisions based on the connections to specific clinical features that they learn.[28]

Improvement in course grades[4,5,29] and clinical reasoning ability[23] has been seen after implementing clinical correlation activities into courses. A team-based, problem-solving process, incorporating clinical correlations to solve problems in basic anatomy, resulted in improved course and National Board of Medical Examiners' subject examination scores, and overall course grades.[30]

It is difficult to separate all the components of clinical correlations to understand which elements(s) are responsible for knowledge improvement and retention. Students use and develop many skills while participating in clinical correlations. These may include group interaction, problem solving, teamwork, independent learning, and facilitated discussions. The success of clinical correlations in teaching is most likely the result of the combination of all of these components.

Anatomy courses provide a rich opportunity for utilization of clinical correlations within the classroom. Curriculum integration folds anatomy topics in among the other basic science topics.[12,13] There has been an increase in the number of gross anatomy courses that are part of an integrated curriculum,[31] creating additional opportunities for clinical correlation activities that span multiple subject areas. Clinical correlations become more valuable as the number of course contact hours decreases within a curriculum.

There may be drawbacks and disadvantages to any type of clinical correlation. Many require the availability of skilled faculty members to conduct the sessions. As institutions deal with increasing class sizes, reduced availability of adequate teaching space, as well as other demands on faculty (research, service, and teaching in other educational programs), it becomes more difficult to ensure that the ideal clinical correlation learning environment is preserved. When the number of available faculty members to teach the sessions cannot meet the demands of increasing class size or the availability of teaching space, the result may be larger groups, reduced interactions between individual students, or more hands-on correlations that become demonstration activities. There is much value in all types of clinical correlations, owing to their direct relationship between basic science material and its clinical application.

Conclusion

The types of clinical correlation activities used in medical education are diverse, serve multiple functions, and play varying roles in institutional curricula. The overall goal of a clinical correlation is to connect basic science education with medical practice. The clinical correlation activity may or may not contribute to the assessment of the student, depending on how the activity is incorporated into the classroom. Its overall benefit to the student is to promote interest, show relevance, develop clinical reasoning skills, and enhance long-term retention of the basic science concepts underlying clinical practice.

Author Contributions

Conceived and designed the experiments: BJK, DFP, LEW. Analyzed the data: BJK, DFP, LEW. Wrote the first draft of the manuscript: BJK. Contributed to the writing of the manuscript: BJK, DFP, LEW. Agree with manuscript results and conclusions: BJK, DFP, LEW. Jointly developed the structure and arguments for the paper: BJK, DFP, LEW. Made critical revisions and approved final version: BJK, DFP, LEW. All authors reviewed and approved of the final manuscript.

REFERENCES

1. Woods NN. Science is fundamental: the role of biomedical knowledge in clinical reasoning. *Med Educ*. 2007;41:1173–1177.
2. Elizondo-Omana RE, Lopez SG. The development of clinical reasoning skills: a major objective of the anatomy course. *Anat Sci Educ*. 2008;1:267–268.
3. Ettarh R. A practical hybrid model of application, integration, and competencies at interactive table conferences in histology (ITCH). *Anat Sci Educ*. 2016;9: 286–294.
4. Surapaneni KM, Tekian A. Concept mapping enhances learning of biochemistry. *Med Educ Online*. 2013;18:1–4.
5. Sheakley ML, Gilbert GE, Leighton K, Hall M, Callender D, Pederson D. A brief simulation intervention increasing basic science and clinical knowledge. *Med Educ Online*. 2016;21:30744.
6. Virella G. Clinical correlations in the basic sciences. *Med Sci Educ*. 1992;2(2). Available at: http://www.iamse.org. Accessed July 13, 2016.
7. Virella G. Clinical correlations in microbiology and immunology. *Med Sci Educ*. 1992;2(2). Available at: http://www.iamse.org. Accessed July 13, 2016.
8. Saffran M. Clinical correlations in medical biochemistry: when should clinical correlations be introduced? *Med Sci Educ*. 1992;2(2). Available at: http://www.iamse.org. Accessed July 13, 2016.
9. Ingenito AJ. The use of clinically-oriented problem solving modalities to enhance learning in a basic pharmacology course. *Med Sci Educ*. 1993;3(2). Available at: http://www.iamse.org. Accessed July 13, 2016.
10. Nierenberg DW. Integrating basic and clinical sciences: one approach involving basic and clinical pharmacology. *Med Sci Educ*. 1993;3(1). Available at: http://www.iamse.org. Accessed July 13, 2016.
11. Wineski LE, Paulsen DF. Course syllabus for human morphology: gross anatomy, embryology, histology, cytology. *Med Educ Online*. 2005;71. Available at: http://www.med-ed-online.org/resources/The_Human_Morphology_Course_Syllabus.pdf. Accessed September 30, 2010.
12. Paulsen DF, Klement BK, Wineski LE. Role of anatomists in building an integrated medical curriculum. In: Chan LK, Pawlina W, eds. *Teaching Anatomy: A Practical Guide*. Cham, Switzerland: Springer International Publishing; 2015: 331–337.
13. Klement BJ, Paulsen DF, Wineski LE. Anatomy as the backbone of an integrated first year medical curriculum: design and implementation. *Anat Sci Educ*. 2011;4:157–169.
14. Lovejoy Mork A, Klement BJ, Paulsen DF, Wineski LE. Applied anatomy labs: interactive small group learning. *FASEB J*. 2016;30(suppl):785.7.
15. Shankar PR. Conducting correlation seminars in basic sciences at KIST Medical College, Nepal. *J Educ Eval Health Prof*. 2011;8:10.

16. Eisenstein A, Vaisman L, Johnston-Cox H, et al. Integration of basic science and clinical medicine: the innovative approach of the cadaver biopsy project at the Boston University School of Medicine. *Acad Med*. 2014;89:50–53.
17. Schapiro R, Stickford-Becker AE, Foertsch JA, Remington PL, Seibert CS. Integrative cases for preclinical medical students: connecting clinical, basic science, and public health approaches. *Am J Prev Med*. 2011;41:S187–S192.
18. Gordon JA, Oriol NE, Cooper JB. Bringing good teaching cases "to life": a simulator-based medical education service. *Acad Med*. 2004;79:23–27.
19. Jurjus RA, Brown K, Goldman E, Galoosian A, Butera G, Krapf JM. Curricular response to increase recall and transfer of anatomical knowledge into the obstetrics/gynecology clerkship. *Anat Sci Educ*. 2016;9:337–343.
20. Lerner S, Magrane D, Friedman E. Teaching teamwork in medical education. *Mt Sinai J Med*. 2009;76:318–329.
21. Dee FR, Haugen TH, Kreiter CD. New web-based applications for mechanistic case diagramming. *Med Educ Online*. 2014;19:24708.
22. Torres A, Staskiewicz GJ, Lisiecka J, et al. Bridging the gap between basic and clinical sciences: a description of a radiological anatomy course. *Anat Sci Educ*. 2016;9:295–303.
23. Jacobson K, Fisher DL, Hoffman K, Tsoulas KD. Integrated cases section: a course designed to promote clinical reasoning in year 2 medical students. *Teach Learn Med*. 2010;22:312–316.
24. May H, Cohen H, Medlej B, Kornreich L, Peled N, Hershkovitz I. Computed tomography-enhanced anatomy course using enterprise visualization. *Anat Sci Educ*. 2013;6:332–341.
25. Azer SA, Hasanato R, Al-Nassar S, Somily A, AlSaadi MM. Introducing integrated laboratory classes in a PBL curriculum: impact on student's learning and satisfaction. *BMC Med Educ*. 2013;13:71.
26. Guze PA. Using technology to meet the challenges of medical education. *Trans Am Clin Climatol Assoc*. 2015;126:260–270.
27. Malau-Aduli BS, Lee AY, Cooling N, Catchpole M, Jose M, Turner R. Retention of knowledge and perceived relevance of basic sciences in an integrated case-based learning (CBL) curriculum. *BMC Med Educ*. 2013;13:139.
28. Woods NN, Brooks LR, Norman GR. It all make sense: biomedical knowledge, causal connections and memory in the novice diagnostician. *Adv Health Sci Educ Theory Pract*. 2007;12:405–415.
29. Diaz-Perez JA, Raju S, Echeverri JH. Evaluation of a teaching strategy based on integration of clinical subjects, virtual autopsy, pathology museum, and digital microscopy for medical students. *J Pathol Inform*. 2014;5:25.
30. Vasan NS, DeFouw DO, Holland BK. Modified use of team-based learning for effective delivery of medical gross anatomy and embryology. *Anat Sci Educ*. 2008;1:3–9.
31. Drake RL, McBride JM, Pawlina W. An update on the status of anatomical sciences education in United States medical schools. *Anat Sci Educ*. 2014;7:321–325.