Integrating Basic Sciences in the Medical Laboratory Sciences Curriculum: A Case Study of Strategies and Approaches

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Abstract

The Medical Laboratory Sciences profession in Canada is undergoing a transformation in education whereby students can now earn an undergraduate degree alongside a professional technologist's certification. To accomplish both goals, the undergraduate program must focus simultaneously on the performance of clinical diagnostic testing in the laboratory and the underlying basic science principles and mechanisms. This paper is a reflective analysis of the strategies and approaches to enhance student exposure to foundational science in the context of the competency profile for the profession. We also share our guiding principles in course design and delivery, as well as our lessons learned. In conclusion, each course delivered within the program must take a coordinated approach to underscore integration of basic science into clinical concepts to most effectively enhance clinical knowledge and skills.

Keywords: basic sciences; medical lab technologist

Introduction to the Medical Laboratory Science Program at UOIT

The Medical Laboratory Science (MLSc) program at the University of Ontario Institute of Technology (UOIT), as one of only two degree granting programs in Canada, awards a Bachelor of Health Sciences degree that fulfills the Canadian Society for Medical Laboratory Sciences (CSMLS) competencies such that a graduate is eligible to write the national certification examinations. Certification qualifies the graduate for registration with the regulatory college for Medical Laboratory Technologists (MLT), which is a requirement to practice. Other institutions in Canada offer a 2-3 year advanced diploma in MLSc; however, students graduating the UOIT program hold a baccalaureate degree (BHSc) as well as eligibility for the national certification exam. Ours is a four year program that includes both basic science undergraduate courses and clinically focused, laboratory based, discipline specific courses. A degree granting program is transformative in Canada as it promotes a more extensive educational background for MLT graduates, as
well as career advancement opportunities both within and outside the laboratory.

The CSMLS competency profile for the entry to practice medical laboratory technologist contains 8 separate categories with up to 25 subcategories (http://csmls.org/Certification/Certification-Exam/Competency-Profiles.aspx). Embedded within these competencies are areas of reasoning, skill and practice that strongly relate to scientific thinking and foundational knowledge in the sciences. Studying science concepts has long been touted within the medical community as essential to providing a strong lifelong foundation in critical thinking, trouble shooting and the development and expansion of clinical reasoning skills (Finnerty et al., 2010). In our curricular design of the MLSc program at UOIT, we have attempted to both vertically and horizontally integrate basic science courses in Anatomy and Physiology, Biochemistry, Pathophysiology, Chemistry and Molecular Biology within a packed curriculum of clinical courses in the five disciplines of Biochemistry, Hematology, Microbiology, Transfusion and Histology. For the most part, these basic science courses have been developed and delivered from within the Faculty of Health Sciences and have used distinctive strategies to include clinical instructors in curriculum design; however a few courses are delivered as service courses by the Faculty of Science.

As the Bachelor of Health Sciences in Medical Laboratory Science enters its tenth year of existence at UOIT, this article will present a reflective analysis of the integration of basic science courses into the clinically focused four year curriculum. Although much has been written concerning the integration of basic science into clinical education in medical programs (Bandiera, Boucher, Neville, Kuper, & Hodges, 2013; Kulasegaram, Martimianakis, Mylopoulos, Whitehead, & Woods, 2013), there is a paucity of information regarding curriculum integration in allied health programs, where clinical decision making skills are no less an integrated cognitive process requiring the learner to make links between different subject areas for use and application in professional practice. The benefits of integrated learning have been extolled in the medical field and include, but are not limited to, reinforced and deeper learning, improved understanding of biological principles and mechanisms, as well as heightened relevance and improved motivation for student learning (Thistlethwaite et al., 2012). Thus the knowledge of how integration of basic and clinical sciences in undergraduate education improves both student engagement and clinical outcomes strongly applies to our MLSc curriculum of courses that aim to best prepare graduates for mastery of clinical and professional competencies.

Throughout the growth of the program, a range of teaching and assessment methodologies have been introduced within health science courses to promote integrated learning of basic sciences specifically for the MLSc students. Horizontal integration of basic sciences has included case studies, clinical application assignments and technology enhanced learning opportunities that seek to highlight diagnostic testing. Vertical integration has been attempted by including basic science courses in the first 3 years of the program (the final year saved for clinical placement) with a third year, final semester course in molecular diagnostics that both vertically and horizontally integrates both the basic (biochemistry, pathophysiology) and clinical (microbiology, hematology, transfusion, histology) sciences. Our reflection and analysis shows that these methodologies and approaches are necessary for student views concerning the relevance of basic science course content to their program of study, but are not without challenges and obstacles when students and faculty continue to place high value on clinically focused lab techniques.

**Basic Science Courses within the Medical Laboratory Science Program Curriculum: The Pedagogical Context**

In order to strategically integrate the basic sciences as important and useful foundations to the future MLT, it is essential to create "conceptual streams". These streams guarantee a smooth and continuous flow of concepts from
year 1 to year 4, accompanied by a progressive increase in complexity, analysis and expectations. For instance, an MLSc student in first year will be introduced to the fundamentals of carbohydrate chemistry and metabolism, illustrated by a simplified case study of an individual with type II diabetes mellitus. In second year, the same case study will be used to discuss the biochemistry, pathophysiology and microbiology aspects in more detail. Finally, in third and fourth year the same student will be comfortable addressing the clinical aspects of this condition as discussed in the MLSc clinical courses and final-year clinical placements.

The fundamental guiding principle behind this approach is that "basic science" courses must not be isolated from the clinical courses, but rather complement and build toward them. Although, for each course instructor, the clinical relevance of the science concepts is obvious, this may not be so for students. It is thus imperative that the science courses always incorporate clinical case studies and/or real-life scenarios that will challenge students to use science concepts toward strengthening their clinical reasoning.

A corollary from this approach is that basic science courses do not just focus on infusing knowledge of fundamental concepts. It is essential that at the end of each basic science course, students will be expected to integrate these concepts into a clinical context. Strictly, most, if not all, concepts discussed in these courses must be clinically relevant in order to be included into the learning outcomes. Furthermore, at the end of each basic science course, students will also be expected to demonstrate clinical reasoning and integration of basic science concepts appropriate to their level. Using type II diabetes mellitus as an example, at the end of first-year anatomy & physiology they must be able to explain hormonal controls and physiological mechanisms regulating glucose metabolism, which will be brought up again in second-year pathophysiology to explain why there are so many adults with altered glucose metabolism. In third-year clinical and research courses, students are expected to apply these concepts to clinical scenarios and start critically appraising contemporary scientific literature that requires clinical and sciences integration.

As scientific knowledge evolves and advances, our science courses must encourage development of skills that will allow students to pursue a professional life-long learning path that includes using fundamental science concepts as part of their clinical strengths and practice. In this regard, at UOIT, we initially adopted a traditional curricular model in which "basic science" courses were taught by Science professors. Although this still holds true for Biology and Chemistry courses, it quickly became obvious that students needed, starting in first year, to appreciate the clinical implications of science concepts. In response to this need, the MLSc program gradually developed "Health Science" courses to replace and/or augment the "Science" courses, with emphasis on tight integration of concepts within and between courses and disciplines. This shift allowed integration of both basic and clinical concepts into the learning outcomes of individual Health Sciences courses, and, ultimately, into mapping professional MLT competencies.

As with many undergraduate health professional programs, the MLSc curriculum has a significant proportion of mandatory courses, with a limited number of electives. For students that enjoy and are strong in "basic sciences", we allow opportunities for further growth through the creation of elective courses that will support them. One example is an Advanced Pathophysiology course, offered as an online elective for students at the top 20% of the second-year Pathophysiology courses. This course focuses on a problem-based learning analysis of case studies reflecting important Canadian health challenges, including cancer, cardiovascular disease, infectious diseases and allergic conditions, among others. Student-led asynchronous and synchronous discussions coalesce concepts from different courses, invite journal clubs of relevant research literature and encourage science-clinical integration. This is done in an inter-disciplinary online environment in which MLSc students may interact and work with Nursing, Kinesiology, Public Health and/or Human Health Science classmates. The final aim of this course is to develop an online learning community that future MLTs and their allied health professionals may replicate after graduation at their workplaces.
UOIT has had, since its 2003 foundation, a web-centric mobile learning environment that facilitates and encourages the effective use of educational technology. Therefore, we have been strategic as to how to embed technology into the learning process. Specifically, we aim at a curricular continuum in which the initial year emphasizes "face-to-face" activities, with a slow transition into hybrid or blended learning formats in second years. The senior years have a stronger focus on simulations and online courses. This approach maintains the importance of the teacher as an early model in the appraisal and use of basic science concepts into clinical relevance. Students welcome this approach as the Health Sciences in-class interactions primes them into how to study and integrate sciences, without feeling overwhelmed. As they advance into the clinical years, a more blended and online environment is most welcome and makes the learning process mobile and accessible from anywhere at any time.

Ultimately, our MLSc curriculum should lead each of our graduates to be able to, when confronted by a clinical situation: (a) formulate good clinical questions appropriate to her/his expertise, (b) use "basic sciences" to answer some of those questions, (c) be able to effectively evaluate basic science research literature relevant to the clinical situation, and (d) integrate and apply this newly acquired knowledge into the clinical situation. These steps will perpetuate a cycle of an evidence-based clinical approach that will allow the ongoing use of "basic science" concepts to strengthen clinical practice.

Guiding Principles for Basic Science Courses: Integrating into Medical Laboratory Science

When designing a basic science course to be taught to students in a health professional program, such as MLSc or Nursing, there are some fundamental guiding principles that are encouraged.

The first guiding principle is that all concepts discussed in a basic science course must have obvious clinical relevance. This general rule makes it easier to the course professor in selecting course material from the vastness of a comprehensive field and/or textbook. We encourage professors to be very selective, not try to cover everything within the course topic, but rather focus on those fundamental topics that are essential for clinical reasoning, applications and practice. One effective way is for the course professor to define the "Top Ten" questions of the week, for the students to answer through the lectures, laboratories, tutorials, textbooks or reliable web sources. In basic science courses, this works well for students who now have an answer to the persistent "what do I need to know?" and "why do I need to know this?" questions. From the course professor perspective, this is also very useful, as it will help her/him use the best academic and health professional judgement to define the concepts covered weekly in the course and to require them for exams, as all weekly "top ten" questions mark the boundaries of the exam expectations.

A second guiding principle, particularly useful in the MLSc program, is the use of clinical case studies as catalysts for application of basic science concepts. In our program, this approach is valuable as first and second year students have difficulty understanding why it is important to master important topics that will be essential for them in their clinical years. Our case studies have all major components of a clinical situation such as history, physical assessment, diagnostic tests, treatment and outcomes. All students are introduced to the whole clinical scenario, but MLSc students are expected to excel at using basic sciences to understand diagnostic tests, specifically in regard to chemistry, biochemistry, physiology, pathophysiology and microbiology, among others. Given the same case study, clinical reasoning of MLSc students is expected to improve and become more sophisticated as they transition from first- to fourth-year. Thus, the same case study remains as a common denominator for students, but can be shared and used by course professors across different courses for different learning outcomes.

Professors teaching courses within the same "conceptual stream" are encouraged to work together to guarantee that
each course sequentially builds up on the pre-requisite course. For instance, anatomy & physiology obviously leads into pathophysiology, chemistry into biochemistry, biology into microbiology, and so on. A disjointed approach to these streams is not conducive to a continuous "learning curve", frustrates students and professors, can set up some students to fail if they progress prematurely and supports the notion that each basic science course is just a "hurdle to jump over" to get into the "real" clinical content.

Each course must foster students’ skill development in integrating the basic and clinical sciences so that they can become life-long learners, are able to absorb new information, assimilate it as new knowledge and use it in the clinical setting. It is also imperative that, through individual or group "journal clubs", they are able to understand the validity and clinical implications of basic science research studies. As examples, in our basic science courses, students are often challenged to apply concepts into real life scenarios, do clinical reasoning, incorporate knowledge from previous or concurrent courses, and forecast applications into their future clinical courses. Finally, as post-millennial generations of students are immersed daily in the online sea of information, our courses encourage them to be decisively selective of web sources, both peer- and non-peer reviewed. For a basic science assignment we could ask a student or group to select only five resources, thoughtfully extract the relevant information, and ask themselves "is this information going to change my clinical behavior? Why or why not?".

Assessing student performance and success has traditionally been done, in basic science courses, predominantly through midterm and final multiple-choice question (MCQ) exams, as well as lab-based work. Regarding basic science courses in the MLSc program, although our exams continue to have an important MCQ component, we have added some variations, such as incorporating clinical case studies tested with MCQs and/or short-answer questions (SAQs). Written assignments are also used as individual or group tasks. After the assignment is submitted and marked, it may be followed by a SAQ-based test of comprehension of the assignment, to assess if each student understood and is able to explain what was written. We call this variation a "Written Assessment of Comprehension" (WAC), a valuable assessment tool to assure that, as future health professionals, our students are accountable for what they write. In addition, we have used "wiki" online platforms for group assignments, in which students write their assignments in a step-wise manner with specific timelines for each step, monitored online by teaching assistants and/or the course professor. Wiki platforms have, in this modality, proven very useful to assess the process of putting together assignments as well as the individual contributions and group dynamics inherent to this collaborative task.

Overall, we encourage each course professor in a basic science course to apply her/his expertise to select the content, course materials, format and student performance assessment tools. At the same time, we ask her/him to explore links with other courses and identify common educational strategies that will allow our MLSc students to see that although content is compartmentalized as courses, real life clinical situations transcend the limits of courses, chapters and disciplines.

Lessons Learned and Challenges

Although both faculty and student interest in an integrated curriculum is high, the implementation process and maintenance of both vertical and horizontal integration have particular challenges (Bandiera et al, 2013). Perhaps, as reported by Brueckner & Gould, there is too little incentive for faculty to outlay the resources of time and effort into building cohesion between basic and clinical science courses. Additionally, however, there can also exist a strong territorial response by experts in any field to any outside opinions surrounding the relevancy of chosen course topics or to any change in the way ‘their’ course is delivered. Digging deeper, this may be due to discomfort on the part of either the professoriate or clinical faculty to venture into the other domain, even as instructors agree about
the benefits of integrating the sciences in order to facilitate students’ cognitive connections. If clinical instructors leave the basic science content out of their teaching due to lack of comfort with that content, then there is risk of the perception that the content is dismissed due to lack of relevancy to the clinical world. Conversely, basic science instruction that does not have clinical relevance is not meaningful to the students in a focused clinical program. To combat either of these scenarios, there must be constant dialogue concerning the intention and process of integration (who is teaching what and where) and these discussions must be open and inclusive to all those teaching and administering the curriculum. This is especially important as students are acutely aware when there is lack of program cohesion towards integration or if they perceive the learning objectives as outside the competency profile of the profession. The only option is complete buy-in for each course, its content and its placement within the curriculum by all those in the program. As an example, one of us (HJT) learned this the hard way when a small group of students in a third year Molecular Diagnostics course wrote a letter to the program director concerned with the credibility of a basic scientist teaching not only fundamental concepts, but also methodology and clinical applications, in a course pivotal to student advancement to 4th year clinical placement. On my part, consultation with the clinical instructors was lacking until it was too late. On the part of the program, there was a political response to protect and defend the expertise and value of the clinical lab instructors, who were perceived as absent from the course. As remedy, further course deliveries have involved more frequent and in depth discussions amongst instructors for the course, much more solicitation of feedback on concerns and suggestions as the course progresses, and, perhaps most importantly, physical presence of both clinical instructors and myself at all course related activities. Every effort to build a large interdisciplinary team that models an integrated approach to clinical practice, requires considerable resourcing and support to be successful.

A further challenge in integrating basic with clinical sciences within the curriculum is to contradict the viewpoint that this may be a dilution of the fundamental sciences (lack of depth) in order to make it ‘easier’ for health sciences students. This again may be a territorial response due to the gradual abandonment of departmentalization of the courses, characterized in the past by a traditional 2+2 model of curricular delivery (2 years of basic science followed by 2 years of clinical courses) in favor of an integrated curriculum. As discussed elsewhere (Kulasegaram et al, 2013; Thistlewaite et al, 2012; Heiman et al, 2015), an integrated curriculum has been shown to reduce redundancy and repetition of content and increase learner motivation, engagement and clinical reasoning over the traditional model. Still it can be a challenge to fight for integrated health science courses in biochemistry, molecular biology, chemistry and physics when faculty delivering these courses are not on board. We have had tremendous success in partnering with other Faculties in the University to deliver courses for the health professions, but there have also been tensions around who designs content (who is the expert, anyway?). Again, putting energy and resourcing into communication is important to establish a cohesive group of "Sciences in Health" faculty.

We have also felt that new models of assessment are needed with more diverse opportunities for students to demonstrate successful integration of these two different knowledge domains. If the aim of integrating the sciences in the curriculum is to achieve more occasions for students to make a cognitive connection that fosters understanding and performance (Kulasegaram et al. 2013; Heiman et al, 2015), then learner assessments should reflect this by evaluating how students use basic science knowledge in their clinical thinking. Since multiple choice testing is the mode of assessment for the MLSc national certification exam, course assessments tend to follow that same model (and most students prefer this); however, it is more likely that retention of facts instead of the application of basic science knowledge is being assessed with this type of examination. This paper has sought to include examples of how case studies, clinical application tutorial sessions and assessments that focus on integration of basic science into clinical concepts can be used to more effectively evaluate the integration of basic science and clinical knowledge.
Take Home Messages

Notes On Contributors

Dr. Holly Jones Taggart is an Associate Professor and Dr. Otto Sanchez is a Professor in the Faculty of Health Sciences at the University of Ontario Institute of Technology. Both have been involved in the curricular design of health sciences programs and the creation, delivery and assessment of basic science courses across four different programs at the University since it opened its doors in 2002.

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Appendices

Declarations

The author has declared that there are no conflicts of interest.

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