The Canadian Journal for the Scholarship of Teaching and Learning

Volume 15 | Issue 2 Article 9

Summer 08-31-2024

The Future is Interdisciplinary: Development of a Medical Sciences Master's Program that Fosters Academic, Professional, and Personal Development

Nicole Campbell
Western University, ncampb47@uwo.ca
Mohammed Estaiteyeh
Brock University, mestaiteyeh@brocku.ca
Isha DeCoito
Western University, idecoito@uwo.ca
Amy Robinson
Western University, arobin45@uwo.ca

https://doi.org/10.5206/cjsotlrcacea.2024.2.16366

Recommended Citation
Campbell, N., Estaiteyeh, M., DeCoito, I., & Robinson, A. (2024). The future is interdisciplinary: Development of a medical sciences master's program that fosters academic, professional, and personal development. *The Canadian Journal for the Scholarship of Teaching and Learning, 15*(2). https://doi.org/10.5206/cjsotlrcacea.2024.2.16366

The Future is Interdisciplinary: Development of a Medical Sciences Master's Program that Fosters Academic, Professional, and Personal Development

Abstract
This paper outlines the design, development, and implementation of a new Master of Science in Interdisciplinary Medical Sciences (MSc IMS) program at Western University in Canada. The course-based program focuses on interdisciplinary education and experiential learning with a goal to foster students' academic, professional, and personal skill development. The authors discuss the rationale for developing the MSc IMS program, describe the curriculum design process, outline the innovative features in the program, and share the findings from the inaugural cohort on their motivation to enroll in the program. The alignment between the data from the inaugural cohort and the rationale for the program is also highlighted. The paper adopts a narrative approach to detail the process used throughout the design of the program and presents findings from a pre- questionnaire—focusing on the overall needs of students and rationale for their enrollment—administered to the inaugural cohort of the program. This scholarly work informs educators, curriculum designers, and administrators about the importance of interdisciplinary programs in higher education. It is also of significant relevance to departments planning to develop new programs or update existing ones to reflect 21st century teaching and learning approaches.

Cet article décrit la conception, le développement et la mise en œuvre d'un nouveau programme de maîtrise en sciences médicales interdisciplinaires (MSc IMS) à l'Université Western, au Canada. Le programme, basé sur des cours, se concentre sur l'enseignement interdisciplinaire et l'apprentissage par l'expérience dans le but de favoriser le développement des compétences académiques, professionnelles et personnelles des étudiants et des étudiantes. Les auteurs expliquent pourquoi le programme MSc IMS a été développé, décrivent le processus de conception du programme, expliquent les caractéristiques innovantes du programme et partagent les conclusions de la cohorte inaugurale sur leur motivation à s'inscrire au programme. L'alignement entre les données de la cohorte inaugurale et la raison d'être du programme est également mis en évidence. L'article adopte une approche narrative pour détailler le processus utilisé tout au long de la conception du programme et présente les résultats d'un questionnaire préalable - axé sur les besoins globaux des étudiants et des étudiantes et les raisons de leur inscription - administré à la cohorte inaugurale du programme. Ce travail scientifique informe les éducateurs et les éducatrices, les concepteurs et les conceptrices de programmes d'études et les administrateurs et les administratrices de l'importance des programmes interdisciplinaires dans l'enseignement supérieur. Il est également très pertinent pour les départements qui prévoient de développer de nouveaux programmes ou de mettre à jour les programmes existants afin de refléter les approches d'enseignement et d'apprentissage du XXIe siècle.

Keywords
interdisciplinary, skill development, experiential learning, medical sciences education, program development, curriculum design; interdisciplinaire, développement des compétences, apprentissage par l'expérience, enseignement des sciences médicales, développement de programmes, conception de programmes d'études

Cover Page Footnote
This research has received ethical approval from Western University Non-Medical Research Ethics Board.

This research paper/Rapport de recherche is available in The Canadian Journal for the Scholarship of Teaching and Learning: https://doi.org/10.5206/cjsotlrcacea.2024.2.16366

Graduate education has expanded significantly over the years, with a wider range of programs and options now available to students. Despite this expansion, critical gaps in graduate education exist, including a lack of focused skill training and insufficient attention to interdisciplinarity (Bishop-Williams et al., 2017; Borg & Scott-Young, 2020; Pearl & Oliver, 2020), resulting in students learning these aspects of their field implicitly, opportunistically, and through trial and error. To ensure that students have equitable access to skill development and interdisciplinary collaborative practices, we need explicit and purposeful core curricula to support development of these domains.

Skills training in academia has slowly evolved over the last few decades. Educators are aware that for graduate students to be successful within their programs and in their future careers, they need to acquire various skills such as communication, problem solving, critical thinking, leadership, and teamwork skills. A report published by the Royal Bank of Canada (RBC, 2018) stated that youth entering the workforce shall require various foundational skills to prepare them for multiple roles and career paths. However, informal feedback from our students in medical sciences graduate programs reveals that they are not adequately exposed to various skills in their academic programs; a finding corroborated in the literature (Dunbar et al., 2006; Gardner et al., 2007). This shortcoming has resulted in students advancing the aforementioned skills on their own. Moreover, students who acquire skills implicitly may be unaware of their development and lack the appropriate language to reflect on their learning to articulate these skills (Ash & Clayton, 2004; Hokanson et al., 2019; Rogers, 2001). Most skill development opportunities that are offered by universities tend to exist in disparate settings, requiring students to actively seek them out across campus, and expending additional fees in some cases. This highlights the need for students to be provided with opportunities to acquire a breadth of skills within their programs and subsequently transfer these skills to career paths outside of academia.

Correspondingly, many fields are rapidly evolving and becoming more interdisciplinary (Ivanitskaya et al., 2002). Medical science research is a great example of a field that has benefited from interdisciplinary collaborations (Liechty et al., 2022; McFadden et al., 2011). For example, researchers in neuroscience often collaborate with computer scientists to develop advanced imaging techniques that allow for better visualization and analysis of the brain's structure and function, leading to improved diagnosis and treatment of neurological disorders. The interdisciplinary effort between biochemists and materials scientists, has led to the development of advanced biomaterials used in regenerative medicine to promote the growth and repair of damaged tissues. Savard (2018) emphasizes the potential of interdisciplinary research to promote public good and help solve complex and wide-ranging problems. Moreover, on an individual level, engaging in interdisciplinary research contributes to the development of skills that are valuable in professional and personal situations (Holley, 2018; Lattuca et al., 2017). These developments highlight the need for students to acquire a breadth of skills and to situate their training in the broader context of various professions (Hessels et al., 2015; Kelly et al., 2019; Wismath & Orr, 2017). In response, universities have developed more collaborative specialties. In fact, some of the learning outcomes associated with integrative approaches are in accordance with employers' expectations based on current market needs. These learning outcomes include improved written and oral communication skills, teamwork skills, ethical decision making, critical thinking, and the ability to apply knowledge in real-world settings (Bear & Skorton, 2019). Yet, despite these efforts, the focus on interdisciplinary programs or interdisciplinarity within graduate programs is still limited. Accordingly, a recent report by members of the College of the Royal Society of

Canada highlights the importance of explicitly integrating interdisciplinary and collaborative approaches in academic programs (Cooke et al., 2020).

Based on this information, skill development and interdisciplinarity need to be purposefully integrated into graduate programs. To ensure equitable access, students need programs that explicitly address these domains. Therefore, it is important to recognize the changing times in medical science research and education, and the emerging necessity to transform and restructure academic programs to reflect the current and anticipated landscape for students. In response to this changing landscape, the Schulich School of Medicine and Dentistry at Western University in Canada developed a new course-based one-year Master of Science degree in Interdisciplinary Medical Sciences (MSc IMS). This program exposes students to a breadth of research topics and experiences using a highly integrated and innovative approach that allows them to develop personally, professionally, and academically. The program prioritizes skill development directly within its curriculum, fosters equitable education practices by providing students with the knowledge and tools they need to be successful within the program, and prepares them for various career paths. As such, skill development is embedded and explicitly taught throughout the program.

Research Objectives

In this paper we discuss the rationale for developing the MSc IMS program, describe the curriculum design process, outline the innovative features in the program, and share findings from our inaugural cohort on their motivation to enroll in the program. The authors also highlight the alignment between the data from the inaugural cohort and the rationale for developing the program. Accordingly, this paper addresses the following questions: 1) What was the rationale for developing a course-based interdisciplinary master's program in medical sciences? 2) What were some features inherent in the program design? 3) What are some innovative features of this program? and 4) What are students' rationales for enrolling in this new program?

Methodology

This research adopts a qualitative case study design (Creswell & Creswell, 2018) and provides rich descriptions and details using a variety of data collection procedures over a sustained period. Yin (2014) highlights that case studies answer the "how" and "why" questions thus allowing researchers to portray the holistic and meaningful characteristics of real-life events, small group behaviors, and organizational processes. Correspondingly, in this paper the authors provide rich descriptions to explain the rationale for and the design process utilized in the development of the MSc IMS program.

It is important to note that since the principal investigator on this research is the Program Director, a research assistant facilitated all study procedures including participants' recruitment and data collection to avoid any potential conflict of interest as per the research ethics guidelines.

Data Sources

Since the program is newly designed with innovative features, the authors conducted a research study focusing on the systematic collection and analysis of information related to the design, implementation, and outcomes of the program for the purpose of monitoring and improving its

quality and effectiveness (Durning et al., 2007). This paper includes data from three different sources, as described below.

First, the authors adopt a narrative approach (Merriam & Tisdell, 2015) to detail the process used throughout the design of the program. Second, they present findings of an environmental scan in the early stages of the program design (Charlton et al., 2019). Prior to designing the program, an environmental scan was performed to determine the scope and focus of other science graduate programs across Canada. Various groups (students, staff, faculty, and administrators) at Western University were also consulted to obtain needs' assessment data. This information was used to identify curricular gaps and determine areas where the new program could be innovative.

Third, the authors present brief findings from the pre-questionnaire administered to the inaugural cohort of the program, focusing on the overall needs of students and the reasons behind their enrollment. Qualitative data were collected online on the first day of the program, via a Qualtrics questionnaire. The pre-questionnaire was comprised of five open-ended questions, which explored students' initial views about the program and self-reflection (self-assessment) about their personal skills. Responses to the open-ended questions were used to validate graduate students' needs and as baseline data in terms of their personal and professional skills development. Data for this paper emanate from the following two open-ended questionnaire items:

1) *Why did you choose to enroll in this program?*
2) *Do you think that your most recent academic experience (undergraduate degree or other) has prepared your future aspirations (e.g., job market or future schooling)? If yes, please explain how. If not, please elaborate on reasons.*

Participants

Participants in the inaugural cohort of the MSc IMS program included sixteen students (3 males, 13 females) ranging from 21–24 years of age. Students' academic backgrounds included Bachelor Honor Degrees as follows: four in medical sciences, three in biology, three in biology and medical sciences, two in psychology, two in life sciences, one in forensic science, and one in psychology and health studies.

Data Analysis

Qualitative data obtained from open-ended questions were analyzed through an interpretational analysis framework using NVivo 12 data analysis software and executed using thematic coding and the constant comparative method (Stake, 2020). The analysis was performed as an inductive process that builds patterns, categories, and themes by organizing the data into more abstract units of information (Creswell & Creswell, 2018). Participants' responses were entered into NVivo 12 where initial codes were developed using word clouds based on the frequency of words in students' responses. Thereafter, the research team grouped similar codes into themes, finalized, and interpreted the themes to draw conclusions (Gall et al., 2005). Thematic coding (Stake, 2020) was performed to provide an in-depth analysis of the responses of all participants. Afterwards, the research team calculated the frequency of responses in relation to each theme. The findings from the analysis of the pre-questionnaire data were used to evaluate the alignment with the theoretical rationale of the program.

Program Development Process

Using a narrative approach (Merriam & Tisdell, 2015), the section below details the process of program initiation, including the timeline, resources, and findings of the environmental scan.

Timeline and Resources

The program development process occurred over approximately three years. This process entailed initial conceptualization, a comprehensive environmental scan (mentioned below in detail), program planning and development, submission of the program proposal, institutional approval, external review, and provincial approval. The program was initiated by senior leadership who identified a working group of faculty and staff, many of whom are now instructors in the program.

To ensure the successful and timely development of the program, several steps were initiated, including assigning a Program Director to lead the development, accessing innovative institutional funds, and hiring a Curriculum Developer. The Program Director and Curriculum Developer worked closely throughout the process to develop the program. In addition, consultations with various groups (e.g., department chairs, faculty, graduate students, etc.) within and outside the university occurred throughout the process. With respect to human resources, the program has a dedicated team of full-time faculty and staff who facilitate curriculum implementation and student support. The core team comprises faculty from diverse scientific disciplines filling the roles of Program Director, Rotation Coordinator, and Capstone Coordinator positions, alongside staff members serving as Program Coordinator and Experiential Learning Coordinator. Additionally, faculty, staff, and other community members are involved in various program elements such as the courses and rotations. Therefore, students in the program engage with people in various roles and from diverse academic backgrounds.

In addition to resources allocated to develop the program, the institution invested in an innovative classroom space. This space includes moveable tables and chairs to enable instructors and students to reconfigure the setting depending on the various needs of all classes. The space is also equipped with technology that allows educators to provide a flexible and hyflex setup for students. There are multiple screens in the room where instructors and students can connect as needed. The space also includes a tracking camera and whiteboard camera to capture sessions for absentees and/or to record sessions for reviewing certain concepts. The classroom is a dedicated space for students, which means that they can use it outside of class hours to foster meaningful collaborations and professional relationships. It was especially beneficial when classes moved to a hybrid mode, thus allowing students to join virtually due to the COVID-19 pandemic.

Furthermore, to enhance students' affordability of the program, it was structured to accommodate part-time employment such as research or teaching assistants, as well as provincial and federal funding opportunities for students. Additionally, the faculty and the program leadership teams are considering scholarships for international students in the future.

Findings from the Environmental Scan

Environmental scans have been used in the healthcare sector as an effective approach to information gathering for a range of purposes such as reviewing the current state of services and programs, evaluating community needs, identifying service gaps, assessing professional education

and training needs, supporting quality improvement initiatives, and informing program and policy development (Charlton et al., 2019). Accordingly, the research team completed an environmental scan using internet searches. The purpose of the scan was to determine the scope of similar graduate programs offered within Canada. A total of 20 programs were analyzed, 10 of which were identified as course based. After reviewing other programs, the team evaluated comparable credits, and aimed to provide a similar credit structure to those offered by our own institution and other course-based programs. Results from the environmental scan of similar course-based programs highlighted the following:

1) Most programs are a year in length.
2) A few programs include multidisciplinary or interdisciplinary approaches.
3) Most programs focus on various scientific fields and disciplines such as biomedical sciences, translational sciences, public health, etc.
4) The course topics are focused and specialized based on the field of study of the program, offering more depth than breadth.
5) Many programs include opportunities for students to apply their learning. These opportunities are specifically related to the program field of study, such as major projects, training opportunities, experiential learning components, and placements.
6) There is not an explicit emphasis on personal and professional skill development.

These results helped shape the design and development of the MSc IMS program. As detailed below in the "Program Features" section, the MSc IMS program focuses on a breadth of interdisciplinary approaches to medical science research including basic and clinical sciences, integrates multiple experiential learning rotations to connect theory with practice, and emphasizes personal and professional skill development.

Program Features

Program Objectives, Learning Outcomes, and Core Interdisciplinary Skills

Regardless of career paths, most graduate students will be involved in research to some capacity. Therefore, the main objective of the MSc IMS program is to expose students to a breadth of relevant research topics (e.g., experimental approaches, knowledge translation, ethical implications, diversity, etc.) and experiences that enhance their science literacy. In this context, science literacy is defined as the ability to use scientific knowledge, formulate relevant questions, and draw evidence-based conclusions to benefit humans and society (Vandegrift et al., 2020). To achieve this objective, the program allows students to gain a critical understanding of how research is effectively designed, analyzed, interpreted, and disseminated, particularly in the context of collaborative and interdisciplinary research programs. By doing so, the program aims to make students more confident in the breadth of their knowledge and abilities, which will prepare them to work in various environments. Ultimately, we hope that graduates are more aware of potential career paths that align with their strengths, interests, and passions related to medical sciences and research.

To achieve these goals, the program learning outcomes encompass a breadth of knowledge and experiences, while also recognizing the value of educating the whole student by focusing on

personal and professional development. As stated in the learning outcomes, upon successful completion of the MSc IMS program, students will be able to:

1) Recognize the value of an interdisciplinary approach to medical science research to propose solutions to complex problems.
2) Master research skills by defining a problem and integrating knowledge from multiple medical science disciplines.
3) Develop critical awareness of current problems and/or issues related to medical science research.
4) Critically evaluate scholarly and popular literature to formulate and defend evidence-based scientific arguments in creative and engaging formats to a range of audiences.
5) Engage in ongoing reflective practice to advance personal and professional development skills.
6) Approach and execute research practices with professional and ethical behaviours that consider the impact on the scientific community and society.

It is worth noting that these program objectives and learning outcomes are aligned with Ontario Universities Graduate Degree Level Expectations (Ontario Universities Council on Quality Assurance, 2023). These outcomes were developed in consultation with professionals from various medical science disciplines, and formulated broadly to respond to developments and shifts in the field of medical science. Therefore, the program maintains flexibility in course content to uphold these learning outcomes.

Furthermore, one of the defining features of the MSc IMS program is the explicit emphasis on skill development. Therefore, in addition to program learning outcomes, the team developed a comprehensive, yet broadly applicable list of skills for students to contextualize their learning and training. Upon the completion of a thorough review of the literature, the program development team synthesized a list of seven *core interdisciplinary skills*, including: 1) complex problem solving, 2) leadership, 3) communication, 4) critical reflection, 5) working in diverse teams, 6) project management, and 7) evidence-based decision making.

Students are made aware of the program learning outcomes and these skills throughout their learning and assessments. For instance, students are asked to document their progress and achievement of the seven skills throughout the program (as detailed in the "Assessment Strategies" section). The explicit, reflective, and purposeful inclusion of these skills aims to empower students and allow them to confidently articulate their potential for future endeavours such as employment or advanced education.

Theoretical Foundations of the Program

Several curriculum frameworks informed the program development and specifically its curriculum design. The two main theories include an integrated curriculum approach and experiential learning.

Integrated/ Interdisciplinary Curriculum

One of the true goals of graduate education reform is to allow students to think across disciplinary boundaries. This approach needs to be integrated in specifically designed learning

experiences (Bosch & Casadevall, 2017). Moreover, according to the National Academy of Sciences et al. (2004):

> Interdisciplinary thinking is rapidly becoming an integral feature of research as a result of four powerful "drivers": the inherent complexity of nature and society, the desire to explore problems and questions that are not confined to a single discipline, the need to solve societal problems, and the power of new technologies. (p. 40)

Given one of the main goals of the MSc IMS program is creating a curriculum that is relevant and engaging for learners, the integrated curriculum model (Drake & Burns, 2004) was a central notion in curriculum design. This model includes emphasizing advanced content knowledge, providing opportunities to enrich higher-order thinking and processing skills, and organizing learning experiences around major issues, themes, or ideas (VanTassel-Baska & Wood, 2010). Ivanitskaya et al. (2002) characterize interdisciplinary learning as the integration of multidisciplinary knowledge across a central program theme or focus. Therefore, the MSc IMS program prioritizes interdisciplinary thinking so that students learn how to approach complex research problems with innovative solutions.

Experiential Learning

Another key element of the MSc IMS program is experiential learning (EL), the process by which knowledge is created through the transformation of an individual's experience (Kolb, 2015). More specifically, according to Kolb, learners create knowledge through interactions with their environment and reflect on the process afterwards. The EL theory aims to empower learners to trust their own experiences and to gain mastery over their own learning. Morris (2020) introduces a revised version of Kolb's EL theory, which includes a four-stage cycle of learning: 1) contextually rich concrete experience, 2) critical reflective observation, 3) contextual-specific abstract conceptualization, and 4) pragmatic active experimentation.

Although the MSc IMS program is a course-based program, there are various EL activities embedded throughout the curriculum. Specifically, students are immersed in three EL rotations (clinical laboratory, basic laboratory, and community-engaged), allowing them to disseminate their knowledge within the scientific community and beyond to appreciate the broader context of research. Students also reflect on their experiences and complete a capstone project that connects theory and practice. Students are expected to engage in ongoing reflection and maintain an e-portfolio throughout the program to showcase artifacts of their learning (papers, presentations, digital media, etc.). These program components will be detailed in the next section.

Program Curriculum

The MSc IMS program adopts a cohort model, whereby all students progress through their education at the same time. The program is administered yearly, from May to April and includes medical science research course blocks, skill development courses, experiential learning rotations, a capstone project, and an e-portfolio.

Medical Science Research Course Blocks

Instead of traditional courses that often span a semester and occur concurrently, content in the MSc IMS program is delivered in sequential intensive interdisciplinary learning blocks. Each block is four weeks in length and includes two longer class sessions a week with pre- and post-session tasks in between. Course content is administered via lectures, case studies, discussions, and real-world applications that are relevant to topics in medical science research. Each block is strategically placed in the curriculum to build on one another and prepare students for their experiential learning rotations. A list of all courses and a brief description can be found in Table 1. These courses were identified by the curriculum team as necessary and relevant topics for students to have a breadth of understanding of medical science research.

As shown in Table 1, the block courses highlight the interdisciplinary nature of the curriculum. The range of courses offered not only encompasses a wide breadth of medical science content (e.g., MEDSCIEN 9502 and MEDSCIEN 9506) but also integrates theories and perspectives from a multitude of disciplines including insights from humanities and social sciences (e.g., MEDSCIEN 9503, MEDSCIEN 9504, and MEDSCIEN 9505).

Skill Development Courses

Students enrolled in the program also complete two skill development courses—Interdisciplinary Skill Development and Career Development and Communication Skills. The first course is offered in the summer semester and includes a series of workshops that focus on personal and professional skills needed to work in collaborative and interdisciplinary environments. This course lays the foundation for experiential rotations and capstone project, which are team based. The second course occurs throughout the fall and winter semesters, and students are expected to attend class sessions and seek out additional seminar opportunities offered at the university that align with their professional goals and interests. Students reflect regularly on their skill development and receive feedback from the course instructor on their progress. Collectively, these courses are expected to set students up for success within the program and prepare them for their future professional endeavours.

Table 1

List of All Courses, Their Brief Description, and Time of Offering in the IMS Program

Course	Brief Description	Offering Time
MEDSCIEN 9501 Communicating Science in the 21st-Century	This course discusses different types of oral and written scientific communication and how to effectively communicate to different audiences.	Summer (June)
MEDSCIEN 9502 Designing, Analyzing, and Interpreting Medical Science Research	This course teaches the theoretical framework of experimental design and important aspects of the scientific method.	Summer (July)
MEDSCIEN 9503 Science Policy	This course simulates a policy-focused work environment where students learn the foundational principles of Canadian science policy and government regulation.	Summer (August)
MEDSCIEN 9504 Ethical Research Practices	This course applies ethical principles to discussions and analyses of basic science and clinical research.	Fall (September)
MEDSCIEN 9505 Academic Integrity and Professionalism	This course openly discusses what constitutes ethical behaviour and the implications of academic misconduct in research.	Fall (October)
MEDSCIEN 9506 Data Science	This course provides students with a foundational understanding of the role data science plays in research design, data collection, analysis, interpretation, and visualization of findings to a wide variety of audiences.	Fall (November)
MEDSCIEN 9507 Research Excellence Through Diversity	This course addresses foundational knowledge on what diversity means when applied to medical science research and why it is essential to strive towards equitable diverse and inclusive medical science.	Winter (January)
MEDSCIEN 9508 Intellectual Property, Implementation, and Commercialization	This course examines the intellectual property and business challenges that need to be overcome for successful clinical translation.	Winter (February)

Experiential Learning Rotations

In addition to their coursework, students complete several experiential rotations, where they connect theory and practice with various elements within the program. Students complete three rotations throughout the program: 1) a basic science rotation (eight weeks in the fall term), 2) a clinical science rotation (eight weeks in the winter term), and 3) a community-engaged learning rotation (24 weeks throughout the fall and winter terms). The breadth of these rotations allows students to learn about medical science research in various contexts from bench to bedside, to the local community.

All rotations are completed in the same teams of three to four students. This is done to ensure consistency among team members as they apply learning from their rotations to the capstone project (detailed in the next paragraph). As such, team members develop rapport with one another and enhance their project management and conflict resolution skills. The rotations are framed within fields of study in the medical sciences so that students can apply the breadth of their knowledge and skills to a specific area. Each year, members of the MSc IMS program determine the fields of study based on existing interdisciplinary research areas at the institution. The curriculum team identifies basic science, clinical science, and community partners for the rotations and allocates students to a field of study based on their prior knowledge, experiences, and skillsets. The goal is to create a team of students with common interests and a broad skillset who will effectively work together to complete their deliverables. Examples of fields of study include cancer, fetal maternal health, and neurodegenerative disorders.

The basic and clinical sciences rotations are designed using non-traditional graduate supervision model. Rather than having students complete a research project led by principal investigators (PIs), the PIs and their lab members serve as mentors who provide opportunities for students to better understand their research environment. Each year there is a call for research partners and project proposals, which are evaluated by the core team who identifies fields of study and matches up potential basic and clinical science rotations before forming the student teams. Students are expected to contribute 15–20 hours per week to the selected lab in different capacities, including observing lab processes, conducting techniques and practices, and engaging in lab activities such as journal clubs and clinical rounds. However, most of the rotation is dedicated to teams of students working on a deliverable with their PI. This mutually agreed-upon deliverable is determined based on the needs of the PI and the skills of the students. This model aims at increasing students' motivation, engagement, and agency in the rotation work.

The community-engaged learning rotation operates on a similar model to the previously described research experiences; however, the observation component is minimal. Because this rotation spans a longer period, students are expected to contribute eight hours per week where they work with a community partner on a deliverable.

For all rotations, the deliverables support the research interests, operations, or mission of the community partner. Examples include a literature or scoping review, data analysis, database creation and management, online material creation, research ethics proposal, and development of instructional materials.

To ensure that students are appropriately on-boarded and supported throughout their rotations, the MSc IMS program has Rotation and Experiential Learning Coordinators. These members meet regularly with students during their rotations to help them navigate the professional relationships and ensure they meet the needs of their partners and complete their deliverables on time. As such, students have opportunities to discuss progress and challenges of their rotations with the program

team while also receiving specific feedback on their deliverable(s) from their partners. Students complete the Clifton Strengths external assessment (Clifton & Harter, 2003) to contextualize their experiential learning in the program and engage in ongoing critical reflection.

Capstone Project

Although the course-based program does not require a thesis, the curriculum design team intended to provide students with the opportunity to complete a collaborative interdisciplinary project, independent of their course instructors and rotation partners. Therefore, a capstone project was introduced as one of the program milestones. Capstone projects are defined as culminating experiences that allow students to integrate, extend, and apply multiple aspects of their academic experience (Minshew et al., 2020), and have the potential to empower students through personally meaningful and motivating activities (Lee & Loton, 2019).

In their work on knowledge networks and collaborative capacity builders, Weber and Khademian (2008) discuss the dynamic complexity of wicked problems faced by public and private organizations. They also identify three dimensions of wicked problems—they are unstructured, cross-cutting, and relentless. Many of the problems encountered in medical science research fit Weber and Khademian's (2008) description and require the expertise of multiple disciplines working collaboratively to come up with innovative solutions. Therefore, in their capstone project, students work with their small team (same members as the experiential rotations) to identify and address a wicked problem while integrating multiple disciplinary lenses across the medical sciences. The capstone project is divided into three milestones, which are spread throughout the program. Similar to the experiential rotations, students are mentored by a faculty member (Capstone Coordinator) throughout the process of completing their capstone project milestones. The first milestone includes identifying a wicked problem within the student team's field of study and completing a related environmental scan to understand it. The second milestone is conducting an extensive literature review to acquire a comprehensive understanding of the wicked problem. The third milestone is a final written paper which proposes recommendations to address the wicked problem. Finally, at the end of the program students present their capstone project to peers and program faculty members. The following is an example of a capstone project that was conceptualized by students in the first cohort to address a wicked problem in medical sciences: Educational Intervention Programs for Osteoporosis Prevention in Adolescent Females.

e-Portfolio

An e-portfolio is an electronic repository where students can showcase artifacts of their learning (papers, presentations, digital media, etc.), as well as reflect on learning to highlight growth (Babaee et al., 2021; Chang et al., 2018). e-Portfolios are essential for portraying students' improvement over time in an educational program; thus, instructors should stress the importance of these digital collections for personal and professional development (Greviana et al., 2020). Das (2021) maintains that generating an e-portfolio is a powerful learning experience as it allows students to focus on the process of learning as opposed to just the product. In this process, students revisit previous work, make modifications, and self-assess their training in a goal-oriented approach. Moreover, an e-portfolio can function as digital curriculum vitae that supports lifelong learning after graduation (Babaee et al., 2021). The literature suggests that e-portfolios are an opportunity for students to think critically about their skill development and their ability to

confidently articulate the skills they have developed (Ciesielkiewicz, 2019; Ray et al., 2020). This ability is significant because students find it challenging to translate research skills into something relevant for audiences or individuals outside academia.

In the MSc IMS program, every student is expected to create and maintain an e-portfolio throughout the program using a website building platform of their choice. This requirement runs parallel to the block courses and experiential rotations. Students are provided with a framework and timeline of what to include in their e-portfolios at different stages of the program, including evidence of their learning and reflections on their progress throughout the program. Students are required to formally update their e-portfolio at the end of every term and meet with the Program Director to showcase their website and discuss their achievements. Based on the Director's ongoing feedback, students edit their e-portfolios to ensure that they are representative of their personal growth and professional development. The e-portfolios can be shared later with future employers or utilized in preparation for a job interview.

Assessment Strategies

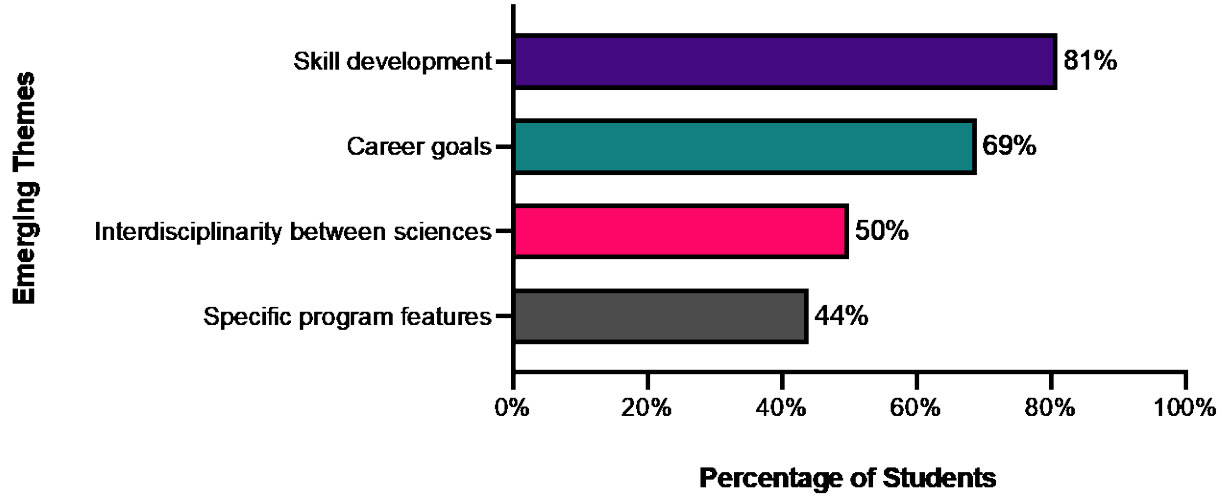
Based on the aforementioned features, it was imperative that student assessment matched the innovative program design. Therefore, various strategies were planned to ensure authentic assessment, including both formative and summative tools (Bloxham & Boyd, 2007; Bryan & Clegg, 2019). All program requirements emphasize process and progress through the incorporation of ongoing critical reflection, which attempts to remove the emphasis on product and grades. The positive impacts of these reflective strategies in higher education have been documented and supported over the years (Boud & Falchikov, 2007; Veine et al., 2020). With the exception of the medical science block courses, all other program requirements (e.g., skill courses, rotations, and capstone project) are evaluated as pass/fail. Students receive feedback and mentorship from their instructors, supervisors, and coordinators throughout the program and have opportunities to improve their assignments and tasks. Moreover, students are asked to write and submit progress reports by the end of each course and each rotation. In this report, students reflect on their progress and skill development and recommend a grade (numeric or pass/fail) they feel they have achieved based on completion of their tasks and their participation. Finally, students document their overall progress in the program on their e-portfolios and discuss it with the Program Director in the individual end-of-term meetings. Overall, the emphasis on ongoing reflections, as well as authentic and formative assessments is unequivocal in this program.

Student Motivation for Enrolling in the Program

To validate the theoretical rationale of the MSc IMS program, students in the inaugural cohort were asked on the pre- questionnaire about their reasons for enrolling in the program. Four themes emerged from students' open-ended responses, which include the need for skill development (81%), future career-related reasons (69%), interdisciplinary nature of the program (50%), and specific program features (44%) (Figure 1).

Figure 1

Analysis of Students' Responses to an Open-Ended Question on Reasons Behind Their Enrollment in the IMS Program



Most students (81%) acknowledged the need for developing their skills specifically with respect to academic, personal, and research skills. Two students said:

> I look forward to building my academic knowledge and disseminate them within the scientific community while keeping tracking my personal development.
>
> I am excited to expand my knowledge in research literacy and the importance behind science communication and ethical principles when conducting research.

Additionally, 69% of the students mentioned how the program aligns with their future career goals, such as applying to medical school or other professional programs in the year after the program, or that this program would help them choose a future career by exposing them to a variety of pathways. Students noted:

> I thought it would be a great way to figure out if medicine is something I want to pursue.
>
> I believe the skills I would develop in this master's program would prepare me for many potential careers that align with my interests and goals.
>
> I chose to enroll in this program as I felt it was the perfect fit for me upon completing my undergraduate degree. I am interested in applying to medical school, and I think that this program will help to build upon my undergraduate science education and expand my interests (in my decision of applying to medical school, or possibly another professional program).

In relation to the area of focus of the program, 50% of the students indicated that interdisciplinarity between sciences is a feature that encouraged them to enrol. Students

appreciated that the program integrates basic sciences, clinical sciences, and community-engaged experiences where they can transfer the acquired skills and knowledge. Students said:

> I wanted to learn the important, translatable skills that are required to bridge research with clinical settings.

> I hope to work in an interdisciplinary setting because I believe that healthcare cannot be practised without focusing on the whole of the patient. I thought that this program would provide me with exposure to different disciplines in the medical sciences, teach me about the importance of an interdisciplinary setting.

Finally, with respect to specific program features that led to their enrollment, students identified networking opportunities, the breadth of course topics offered, the one-year duration, and the program's overall innovation of combining courses, research, and practice. Students said:

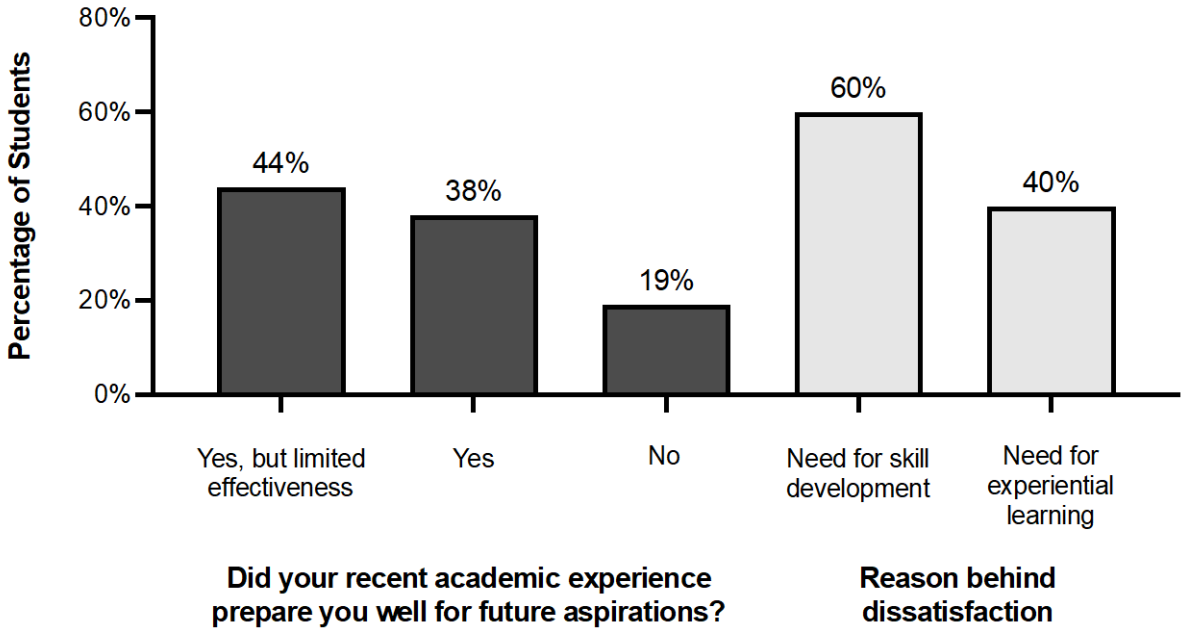
> [There is a] unique mix of course based and research experience. The authentic learning experience of courses into block sections is innovative. I appreciate the opportunity to focus on a particular problem or subject in the medical sciences to allow for a thorough investigation of relevant topics.

> [There is an] opportunity to connect with renowned academics and innovative scholars.

To further explore the need for programs similar to the MSc IMS program, students were prompted with a question on whether they think that their most recent academic experience (undergraduate degree or other) has prepared them for their future aspirations (e.g., job market or future education). As shown in Figure 2, 44% of students believe that their most recent experiences prepared them to a limited extent, 38% of the students believe that it prepared them well, and 19% believe it did not prepare them well. With respect to the reasons behind their partial or complete dissatisfaction, two themes emerged from students' responses: the need for better skill development and the lack of experiential learning opportunities.

Figure 2

Analysis of Students' Responses on Their Readiness for Future Endeavors



On skill development, students mentioned that their previous programs prioritized content knowledge and that more emphasis on personal and professional skills is needed. They said:

> I think my undergraduate degree has prepared me for this master's program, but I am less confident that I would be able to jump straight into professional school. I believe there are more academic skills I can learn and hone before that challenge.

> I have learned to problem solve, present information, and critically think. However, I feel that I have scratched the surface of these skills and want to further develop these skills through the MSc IMS program.

> I graduated with a BSc in Biology and I think my degree was really focused on teaching me content. Other than some basic laboratory skills, I feel that I have had to grasp most real-world skills on my own.

With respect to experiential learning, students mentioned that they needed opportunities to practice and transfer the skills they acquire. They noted:

> There are also so many things I would have liked to learn about but couldn't … I also would have liked to do some sort of CO-OP/work placement so I gained real work experience and could have a job after my degree related to what I studied.

> A BMSc in IMS has prepared me for an MD due to the diverse exposure to many different medical science fields and also research. However, getting engaged with the community was not emphasized.

Conclusion

University graduates with various transferable skills are sought by many employers and are an asset to society. However, skill development and interdisciplinary learning are often not embedded within the curriculum of graduate programs in Canada. This research showcases a graduate program that was designed to address students' academic, professional, and personal development in an interdisciplinary medical sciences context. The program includes several innovative features such as medical science research course blocks, skill development courses, experiential learning rotations, a capstone project, and an e-portfolio. These requirements are designed to emphasize integrated and experiential learning approaches to ensure high quality teaching and learning. In harmony, the assessment strategies adopted in the program emphasize ongoing student reflection, indicating a preference for authentic and formative assessments that capture students' learning and allow them to articulate their achievements and areas for improvement.

Moreover, the development of the program highlights several factors influencing its success, including the involvement of faculty members in the program design, administrative support, availability of resources, the creation of an interdisciplinary team including curriculum experts, the importance of programmatic research throughout the program, and the alignment of curriculum and assessment strategies.

Finally, research findings from students from the inaugural cohort align with the rationale for the design and development of the MSc IMS program. Students emphasized that the major reasons behind their enrollment in the program were the need for skill development, the importance of future career-related preparation, experiential learning opportunities, the interdisciplinary nature of the program, and specific innovative program features.

Looking Ahead

Feedback from the first cohort noted that the MSc IMS program positively impacted students, particularly in terms of enhancing their competence in the seven core skills, with notable improvements in complex problem solving, oral and written communication skills, and critical reflection. Results also show that students specifically appreciated the contribution of experiential learning components of the program in advancing their skills (Estaiteyeh et al., 2023).

Upon their graduation, students pursue a variety of paths and endeavours, highlighting the broad nature and extensive training offered by the program. For some students, the MSc IMS serves as a terminal degree, demonstrated by their successful attainment of positions in various fields following graduation such as clinical coordinators and research assistants. Alternatively, other students have opted to further their education, gaining admission to various programs including medicine, dentistry, law, and respiratory therapy.

Since the first offering of MSc IMS program, enrolment has doubled, a growth likely attributed to the comprehensive curriculum and success of recent graduates. Following this expansion, some adjustments were made to accommodate the increased number of students and to implement updates based on early feedback. Currently, the program has adequate resources to offer a high-quality offering to enrolled students. Should the program continue to expand, the institution has the capacity and access to appropriate resources. In addition, the program plans to have ongoing conversations with the university administration to consider how aspects of the program can be offered broadly to students from other faculties in the university.

Implications

This paper is part of a larger ongoing study that aims to evaluate the impact of the MSc IMS program. Results from this research will inform future offerings of the program and will have a positive impact on other science graduate programs across various universities, especially in Canada. The 21st century, student-centered, and holistic approach inherent to the MSc IMS program can be adopted or adapted by various disciplines and graduate programs. This research also provides a framework to inform the development of new science graduate programs or the modification of existing programs. Findings from this project reiterate the importance of interdisciplinary programs and the need to support graduate students' skill development to better prepare them for their futures.

This work also reflects important aspects related to the Scholarship of Teaching and Learning (SoTL). First, describing the process of developing a new program that embeds interdisciplinarity and skill development is significant to share with the academic community, so that others can adopt or adapt relevant elements. Moreover, this research highlights the importance of embedding evaluation at the inception of a program to ensure scholarly informed decisions are made and to maintain sustainable advancement of academic programs. As the program continues to evolve, we hope to inform current and future graduate programs about our best practices, the accompanying affordances, and encountered challenges. Finally, it is important to note that the MSc IMS program development, evaluation, and dissemination were all the result of interdisciplinary collaborations between scholars and researchers in the fields of education and medical sciences. Such collaboration models of interdisciplinarity are instrumental in advancing SoTL in higher education.

References

Ash, S. L., & Clayton, P. H. (2004). The articulated learning: An approach to guided reflection and assessment. *Innovative Higher Education*, *29*(2), 137–154. https://doi.org/10.1023/B:IHIE.0000048795.84634.4a

Babaee, M., Swabey, K., & Prosser, M. (2021). The role of e-portfolios in higher education: The experience of pre-service teachers. *Journal of Digital Learning in Teacher Education*, *37*(4), 247–261. https://doi.org/10.1080/21532974.2021.1965508

Bear, A., & Skorton, D. (2019). The world needs students with interdisciplinary education. *Issues in Science and Technology*, *35*(2), 60–62.

Bishop-Williams, K. E., Roke, K., Aspenlieder, E., & Troop, M. (2017). Graduate student perspectives of interdisciplinary and disciplinary programming for teaching development. *The Canadian Journal for the Scholarship of Teaching and Learning*, *8*(3). https://doi.org/10.5206/cjsotl-rcacea.2017.3.11

Bloxham, S., & Boyd, P. (2007). *Developing effective assessment in higher education: A practical guide*. McGraw-Hill Education.

Borg, J., & Scott-Young, C. M. (2020). Employers' perspectives on work readiness in construction: Are project management graduates hitting the ground running? *International Journal of Managing Projects in Business*, *13*(6), 1363–1379. https://doi.org/10.1108/IJMPB-10-2019-0238

Bosch, G., & Casadevall, A. (2017). Graduate biomedical science education needs a new philosophy. *MBio*, *8*(6), e01539-17. https://doi.org/10.1128/mBio.01539-17

Boud, D., & Falchikov, N. (2007). *Rethinking assessment in higher education*. Routledge. https://doi.org/10.4324/9780203964309

Bryan, C., & Clegg, K. (2019). *Innovative assessment in higher education: A handbook for academic practitioners*. Routledge. https://doi.org/10.4324/9780429506857

Chang, C.-C., Liang, C., Chou, P.-N., & Liao, Y.-M. (2018). Using e-portfolio for learning goal setting to facilitate self-regulated learning of high school students. *Behaviour & Information Technology*, *37*(12), 1237–1251. https://doi.org/10.1080/0144929X.2018.1496275

Charlton, P., Doucet, S., Azar, R., Nagel, D. A., Boulos, L., Luke, A., Mears, K., Kelly, K. J., & Montelpare, W. J. (2019). The use of the environmental scan in health services delivery research: A scoping review protocol. *BMJ Open*, *9*(9), e029805. https://doi.org/10.1136/bmjopen-2019-029805

Chen, R.-J. (2010). Investigating models for preservice teachers' use of technology to support student-centered learning. *Computers & Education*, *55*(1), 32–42. https://doi.org/10.1016/j.compedu.2009.11.015

Ciesielkiewicz, M. (2019). The use of e-portfolios in higher education: From the students' perspective. *Issues in Educational Research*, *29*(3), 649–667.

Clifton, D. O., & Harter, J. K. (2003). Investing in strengths. In A. K. S. Cameron, B. J. E. Dutton, & C. R. E. Quinn (Eds.), *Positive organizational scholarship: Foundations of a new discipline* (pp. 111–121). Berrett-Koehler Publishers, Inc.

Cooke, S. J., Nguyen, V. M., Anastakis, D., Scott, S. D., Turetsky, M. R., Amirfazli, A., Hearn, A., Milton, C. E., Loewen, L., Smith, E. E., Norris, D. R., Lavoie, K. L., Aiken, A., Ansari, D., Antle, A. N., Babel, M., Bailey, J., Bernstein, D. M., Birnbaum, R., … Woolford, A. (2020). Diverse perspectives on interdisciplinarity from Members of the College of the Royal Society of Canada. *FACETS*, *5*(1), 138–165. https://doi.org/10.1139/facets-2019-0044

Creswell, J. W., & Creswell, J. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). Sage.

Das, S. (2021). Preparing e-portfolio as an element of online training by clinical chemistry residents in the COVID-19 era. *Biochemistry and Molecular Biology Education*, *49*(3), 316–317. https://doi.org/10.1002/bmb.21505

Drake, S. M., & Burns, R. C. (2004). *Meeting standards through integrated curriculum*. ASCD.

Dunbar, N. E., Brooks, C. F., & Kubicka-Miller, T. (2006). Oral communication skills in higher education: Using a performance-based evaluation rubric to assess communication skills. *Innovative Higher Education*, *31*(2), 115–128. https://doi.org/10.1007/s10755-006-9012-x

Durning, S. J., Hemmer, P., & Pangaro, L. N. (2007). The structure of program evaluation: An approach for evaluating a course, clerkship, or components of a residency or fellowship training program. *Teaching and Learning in Medicine*, *19*(3), 308–318. https://doi.org/10.1080/10401330701366796

Estaiteyeh, M., Campbell, N., DeCoito, I., & Takkouch, M. (2023). Setting students up for success: Developing interdisciplinary skills in a medical sciences graduate program. *GILE Journal of Skills Development*, *3*(2), 66–84. https://doi.org/10.52398/gjsd.2023.v3.i2.pp66-84

Gall, J. P., Gall, M. D., & Borg, W. R. (2005). *Applying educational research: A practical guide* (5th ed.). Pearson/Allyn & Bacon.

Gardner, S. K., Hayes, M. T., & Neider, X. N. (2007). The dispositions and skills of a Ph.D. in education: Perspectives of faculty and graduate students in one college of education. *Innovative Higher Education*, *31*(5), 287–299. https://doi.org/10.1007/s10755-006-9029-1

Greviana, N., Mustika, R., & Soemantri, D. (2020). Development of e-portfolio in undergraduate clinical dentistry: How trainees select and reflect on evidence. *European Journal of Dental Education*, *24*(2), 320–327. https://doi.org/10.1111/eje.12502

Hessels, A. J., Robinson, B., O'Rourke, M., Begg, M. D., & Larson, E. L. (2015). Building interdisciplinary research models through interactive education. *Clinical and Translational Science*, *8*(6), 793–799. https://doi.org/10.1111/cts.12354

Hokanson, S. C., Grannan, S., Greenler, R., Gillian-Daniel, D. L., Campa, H., & Goldberg, B. B. (2019). A study of synchronous, online professional development workshops for graduate students and postdocs reveals the value of reflection and community building. *Innovative Higher Education*, *44*(5), 385–398. https://doi.org/10.1007/s10755-019-9470-6

Holley, K. A. (2018). The role of threshold concepts in an interdisciplinary curriculum: A case study in neuroscience. *Innovative Higher Education*, *43*(1), 17–30. https://doi.org/10.1007/s10755-017-9408-9

Ivanitskaya, L., Clark, D., Montgomery, G., & Primeau, R. (2002). Interdisciplinary learning: Process and outcomes. *Innovative Higher Education*, *27*(2), 95–111. https://doi.org/10.1023/A:1021105309984

Kelly, R., Mackay, M., Nash, K. L., Cvitanovic, C., Allison, E. H., Armitage, D., Bonn, A., Cooke, S. J., Frusher, S., Fulton, E. A., Halpern, B. S., Lopes, P. F. M., Milner-Gulland, E. J., Peck, M. A., Pecl, G. T., Stephenson, R. L., & Werner, F. (2019). Ten tips for developing interdisciplinary socio-ecological researchers. *Socio-Ecological Practice Research*, *1*(2), 149–161. https://doi.org/10.1007/s42532-019-00018-2

Kolb, D. A. (2015). *Experiential learning: Experience as the source of learning and development* (2nd ed.). Pearson Education, Inc.

Lattuca, L. R., Knight, D., Seifert, T. A., Reason, R. D., & Liu, Q. (2017). Examining the impact of interdisciplinary programs on student learning. *Innovative Higher Education*, *42*(4), 337–353. https://doi.org/10.1007/s10755-017-9393-z

Lee, N., & Loton, D. (2019). Capstone purposes across disciplines. *Studies in Higher Education*, *44*(1), 134–150. https://doi.org/10.1080/03075079.2017.1347155

Liechty, J. M., Keck, A.-S., Sloane, S., Donovan, S. M., & Fiese, B. H. (2022). Assessing transdisciplinary scholarly development: A longitudinal mixed method graduate program evaluation. *Innovative Higher Education*, *47*(4), 661–681. https://doi.org/10.1007/s10755-022-09593-x

McFadden, K. L., Chen, S.-J. (G), Munroe, D. J., Naftzger, J. R., & Selinger, E. M. (2011). Creating an innovative interdisciplinary graduate certificate program. *Innovative Higher Education*, *36*(3), 161–176. https://doi.org/10.1007/s10755-010-9164-6

Merriam, S., & Tisdell, E. (2015). *Qualitative research: A guide to design and implementation* (4th ed.). John Wiley & Sons.

Minshew, L. M., Yi, J., Morbitzer, K. A., & McLaughlin, J. E. (2020). Use of capstone experiences in pharmacy education to synthesize and apply students' knowledge and skills. *American Journal of Pharmaceutical Education*, *84*(11), 8060. https://doi.org/10.5688/ajpe8060

Morris, T. H. (2020). Experiential learning – a systematic review and revision of Kolb's model. *Interactive Learning Environments*, *28*(8), 1064–1077. https://doi.org/10.1080/10494820.2019.1570279

National Academy of Sciences, National Academy of Engineering, & Institute of Medicine. (2005). *Facilitating Interdisciplinary Research*. The National Academies Press. https://doi.org/10.17226/11153

Ontario Universities Council on Quality Assurance. (2023). *Appendix 1: Ontario universities council on quality assurance*. OUCQA. https://oucqa.ca/framework/appendix-1-ontario-universities-council-on-quality-assurance/

Pearl, C. M., & Oliver, B. (2020). World's greatest challenges: Building interdisciplinary understanding and collaboration among business and social work students. *The Canadian Journal for the Scholarship of Teaching and Learning*, *11*(1). https://doi.org/10.5206/cjsotl-rcacea.2020.1.10804

Ray, M. E., DuBrava, L., & Jacks, M. (2020). Leveraging a required e-portfolio course to meet multiple needs: Student assessment, curriculum improvement, and accreditation. *Currents in Pharmacy Teaching and Learning*, *12*(12), 1437–1446. https://doi.org/10.1016/j.cptl.2020.07.004

RBC. (2018). *Humans wanted: How Canadian youth can thrive in the age of disruption*. RBC Future Launch. https://www.rbc.com/dms/enterprise/futurelaunch/humans-wanted-how-canadian-youth-can-thrive-in-the-age-of-disruption.html

Rogers, R. R. (2001). Reflection in higher education: A concept analysis. *Innovative Higher Education*, *26*(1), 37–57. https://doi.org/10.1023/A:1010986404527

Savard, D. (2018). Seeing through the network: A focus on interdisciplinary student research and information discovery. *Reference Services Review*, *46*(1), 4–15. https://doi.org/10.1108/RSR-05-2017-0016

Stake, R. (2020). Case studies. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., pp. 435–454). Sage.

Vandegrift, E. V. H., Beghetto, R. A., Eisen, J. S., O'Day, P. M., Raymer, M. G., & Barber, N. C. (2020). Defining science literacy in general education courses for undergraduate non-science majors. *Journal of the Scholarship of Teaching and Learning*, *20*(2), 15–30. https://doi.org/10.14434/josotl.v20i2.25640

VanTassel-Baska, J., & Wood, S. (2010). The integrated curriculum model (ICM). *Learning and Individual Differences*, *20*(4), 345–357. https://doi.org/10.1016/j.lindif.2009.12.006

Veine, S., Anderson, M. K., Andersen, N. H., Espenes, T. C., Søyland, T. B., Wallin, P., & Reams, J. (2020). Reflection as a core student learning activity in higher education—Insights from nearly two decades of academic development. *International Journal for Academic Development*, *25*(2), 147–161. https://doi.org/10.1080/1360144X.2019.1659797

Weber, E. P., & Khademian, A. M. (2008). Wicked problems, knowledge challenges, and collaborative capacity builders in network settings. *Public Administration Review*, *68*(2), 334–349. https://doi.org/10.1111/j.1540-6210.2007.00866.x

Wismath, S. L., & Orr, D. (2015). Collaborative learning in problem solving: A case study in metacognitive learning. *The Canadian Journal for the Scholarship of Teaching and Learning*, *6*(3). https://doi.org/10.5206/cjsotl-rcacea.2015.3.10

Yin, R. K. (2014). *Case study research: Design and methods* (5th ed.). Sage.