MUSCULOSKELETAL MEDICINE IN UNDERGRADUATE MEDICAL EDUCATION

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Lay Abstract

Musculoskeletal conditions are extremely common in the general population and are frequently seen by physicians in their day-to-day practice. Unfortunately, research has suggested that medical students are not receiving the training they need to be prepared to manage musculoskeletal conditions after they graduate. This thesis details the development and evaluation of a novel learning tool to help medical students learn about musculoskeletal medicine. This involved assessing the musculoskeletal curriculum at the DeGroote School of Medicine by engaging students and faculty members. Based on the strengths and weaknesses of the curriculum identified in this evaluation, an online learning tool was developed for students to use during their clinical rotation in orthopedic surgery through a survey and MSK knowledge assessments. The results of the evaluation show that the learning tool holds promise in helping students to learn about musculoskeletal medicine.

Abstract

Musculoskeletal (MSK) instruction has been identified as being inadequate in undergraduate medical education around the world. Just over two decades ago, there began to be recognition by medical education institutions that learners were emerging from their training lacking in both sufficient confidence and knowledge to manage MSK conditions. This was reflected in low passing rates on validated MSK knowledge assessments and in various evaluations that reported that primary care physicians, residents, and medical students generally had low confidence in their ability to accurately diagnose and treat MSK-related complaints. These gaps were linked back to problems at the undergraduate level of training, and barriers to implementing comprehensive MSK instruction were identified as a lack of time and resources dedicated to this subject area.

Despite this recognized issue, little work has been done to reform Canadian medical school's MSK curricula and identify sustainable solutions. Thus, we used the Context, Input, Process, and Product program evaluation framework situated within a sequential exploratory mixed methods approach to develop, implement, and evaluate a novel self-directed learning tool for MSK medicine at the DeGroote School of Medicine. First, a qualitative interpretive description study was used to assess student and faculty perceptions of the strengths and weaknesses of the MSK curriculum and inform the development of the learning tool. Next, a two-groups pre-test post-test design and a cross-sectional survey were used to evaluate the implementation and efficacy of the learning tool in helping medical students learn MSK medicine. Ultimately, this thesis outlines

methods for evaluating MSK curricula and provides a promising learner-informed tool for assisting students in learning about MSK medicine in clinical settings.

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List of Abbreviations

AAMC: Association of American Medical Colleges

AMSEC: Australian Musculoskeletal Education Collaboration

ANCOVA: Analysis of Covariance

BJDUCDG: Bone and Joint Decade Undergraduate Curriculum Development Group

BCE: Before Common Era

CI: Confidence Interval

CIPP: Context, Input, Process, and Product

GALS: Gait, Arms, Legs, Spine

MF: Medical Foundations

MSK: Musculoskeletal

NBME: National Board of Medical Examiners

pGALS: pediatric Gait, Arms, Legs, Spine

REMS: Regional Examination of the MSK System

UGME: Undergraduate Medical Education

Declaration of Academic Achievement

Kestrel McNeill was responsible for all aspects of this thesis, including data collection, analysis, and thesis preparation.

Stella Choe and Natasha Reyes assisted with data collection and analysis in Chapter 2.

Dr. Devin Peterson assisted with data collection in Chapter 3.

The thesis committee advised on all aspects of this thesis.

Chapter 1.0

General Introduction

1.0 General Introduction

1.1 Preface

Musculoskeletal (MSK) diseases are some of the most common causes of long-term pain and disability and are responsible for some of the most prevalent conditions affecting population health in the world (1, 2). Untreated MSK conditions present a substantial risk to an individual's ability to participate in community and occupational activities and can even be life-threatening if untreated (1). Despite their prevalence, previous research has identified deficiencies in the instruction surrounding the diagnosis and treatment of MSK conditions, as well as their management within the broader healthcare system (3, 4). This has been indicated by poor passing scores on basic MSK competency examinations in medical students, residents, and practicing physicians, as well as curriculum evaluations demonstrating insufficient time and resources allocated to MSK training (4-6).

To address the issues in MSK education and knowledge deficiencies that are prevalent across the spectrum of medical practitioners, it is critical to examine how new physicians are trained and the history behind this subject. This chapter will 1) provide a history of MSK medicine and education 2) discuss the progress of MSK medical education over the past decade, 3) identify gaps in the literature and progress needed in this area, 4) and define the objectives and overarching methods of the present thesis.

1.1 History of MSK Medical Education

Understanding the history of MSK medicine is essential to contextualizing present-day issues in medical education around this subject; to look for future curriculum

reform opportunities, the past must be evaluated to build on work that has already been completed and understand the challenges that exist. The following section outlines the progression of using exercise as medicine in ancient civilizations and the shift to curative from preventative medicine. This leads to the eventual attention that MSK medicine and the education of healthcare providers received during the 1900s, after which the Bone and Joint Decade was established. Finally, a review of the progress of MSK education over the last decade is provided.

1.2.1 Exercise as Medicine in Ancient Civilizations

For thousands of years, the relationship between a healthy MSK system and longevity has been recognized. Ancient civilizations and physicians used muscular exercise to prevent and treat disease, the concepts of which can be traced all the way back to 1250 before common era (BCE) (7). While historical contributions to exercise physiology are typically attributed to the ancient Greeks, these concepts existed prior to the emergence of Mycenaean cultures. Susruta (Sushruta), an ancient Indian physician and surgeon who lived during 600 BCE, was the first physician recorded to recommend moderate daily exercise to prevent disease (8). Sushruta supposed that moderate exercise improved the growth of limbs; enhanced muscular strength, endurance, and development; increased digestion and resistance against fatigue; and reduced corpulence (8).

The Ancient Greeks played a large role in promoting the practice of exercise for disease prevention and treatment (7). Although exercise was deeply embedded in ancient Greek culture centuries before his existence, Hippocrates, the father of medicine, is credited as being a defining influence in promoting muscular exercise as a medicinal

practice during the "Golden Age" of Ancient Greece (9, 10). Notably, Hippocrates wrote two books on regimen and stated that "eating alone will not keep a man well; he must also take exercise. For food and exercise….work together to produce health" (11). Similarly, to Susruta, Hippocrates believed that muscular training increased stature, bone and muscle mass, tone, endurance, and tolerance against fatigue amongst other beneficial effects. Hippocrates was the first physician to prescribe exercise to a patient afflicted with consumption, and his ideas informed many of Claudius Galenus' (Galen) beliefs and practice, who was arguably the most important physician of the Roman Empire (7).

Galen (129 – 210 CE) provided a medical theory that was predicated on the concept of "naturals" (being of nature- physiology), "non-naturals" (those not innate- health), and "contra-naturals" (against nature- disease and pathology) (7). Galen believed that in moderation, "non-naturals' – 1) air, 2) food and drink, 3) sleep and wake, 4) motion and rest, 5) excretions and retentions, and 6) passions of the mind- would produce health. Conversely, if performed in excess or pushed into imbalance, pathology and disease would result (7, 12). Thus, Galen posited that exercise, as part of the "motion and rest" non-natural, provided for health and disease prevention when used in moderation. Galen's use of exercise to promote good health in the practice of medicine lasted around 1,400 years into the Middle Ages within Arabic and European countries (13, 14). With the emergence of the Renaissance period and individualism between the 14th and 17th centuries, the ideal of personal responsibility for good health garnered even more traction and maintained its position in medicine for centuries after Galen (7).

Numerous examples of physicians advocating for the use of exercise in promoting health persisted throughout the 18th century (7). Although many of the ideas that had become prevalent amongst Ancient Greek and Roman physicians were eventually replaced by anatomy and physiology and therapeutic interventions, the principle of using exercise as medicine maintained a prominent place in society (15). Ultimately, the historic roots exercise physiology provided a base that contributed to our understanding of the importance muscular fitness in preventing disease and maintaining good health.

1.2.2 The Overshadowing and Rediscovery of MSK Medicine

The 19th and 20th centuries brought about significant technological advancements to society that fundamentally changed the way healthcare was provided. The practice of using exercise as a therapeutic tool was overshadowed by inventions and discoveries such as general anaesthetic, insulin, new surgical techniques, antisepsis, and germ theory, and as a result, the emphasis of medical practice shifted away from prevention to treatment (11, 15, 16). Changes in the workplace also contributed to this shift, and many individuals became inactive within their occupations as industry and farming replaced physically demanding jobs with technology (15, 16).

Around the same time, medical education institutions in America were being challenged by a report produced by the Carnegie Foundation in 1910 that would change medical education forever (17). It had become evident that many physicians were being trained without rigour and that the lack of standards across medical schools was contributing to a general lack of competency amongst medical graduates to provide care to patients (18). Abraham Flexner, the main investigator and author of the report,

identified low admission standards, inadequate exposure to clinical material and poor laboratory facilities amongst the majority of medical schools (18). As a result of his recommendations for improving the state of medical education, several medical schools closed, training became longer and more scientific, and there was a greater emphasis placed on curative rather than preventative medicine in training (11). Moreover, the physicians being trained did not see physical exercise as a potential disease prevention method and exercise lost its place as a prominent treatment modality (11, 17).

Eventually, the sedentary lifestyle that was produced by the technological advancements made in the 19th and 20th centuries was associated with an increase in morbidity and mortality from a number of diseases (19, 20). As the concept of MSK health and exercise as medicine was "rediscovered" in the mid-1900s, physicians and governmental agencies encouraged the general public to engage in physical activity (15). Epidemiological data continued to establish links between MSK health, exercise and disease prevention throughout the late 1990s, and with the resurgence of physical activity that emerged as a result of this attention came the inevitable increase in MSK injuries related to exercise (16, 20, 21). Even prior to this resurgence, studies reported that up to 20% of patients in primary care settings complained of MSK-related problems (22-24).

However, studies conducted throughout the 1970s and 1980s alluded to disparities between the frequency of MSK conditions seen in primary care settings, and the preparedness of medical graduates to practice MSK medicine. Specifically, several studies conducted in the United States revealed possible deficiencies in MSK physical examination skills, and perceptions of inadequate orthopedics training amongst medical

students, residents, and practicing physicians (25-27). For example, in 1997, nine major physician organizations[1] formed a Steering Committee on Collaboration among Physician Providers Involved in Musculoskeletal Care. This committee had the common purpose of ensuring cost-effective and high-quality diagnosis and treatment of MSK conditions through the promotion of MSK knowledge amongst physicians (28). As part of their activities, this group created and distributed a survey to over 5,000 residents in primary care programs across the United States to assess the preparedness of physicians entering post-graduate training to diagnose and treat MSK problems. The results of this survey revealed shocking perceptions of the quality of residents' previous MSK education (28). Up to 60% of residents felt that their training to conduct an MSK examination to assess problems of various areas of the body was poor or very poor (28). Furthermore, when residents were asked to describe their training for treating common fractures and interpreting MSK radiographs, 40% indicated that their preparation was poor or very poor. Following the results of this survey, the steering committee members recommended that greater effort be made by medical institutions to assess the preparedness of physicians entering practice to deal with MSK problems in addition to assessing the quality of their existing curricula.

Similarly, in 1998, Freedman and Bernstein developed a basic MSK competency examination to assess medical trainee's understanding of MSK conditions (29). This examination was validated through a survey distributed to all orthopedic residency

[1] The American Academy of Family Physicians, the American College of Physicians, the American College of Emergency Physicians, the American Academy of Pediatrics, the American Geriatrics Society, the American Academy of Physical Medicine and Rehabilitation, the American Osteopathic Association, the American Academy of Orthopaedic Surgeons, and the American College of Rheumatology.

program chairs in the United States. Through this survey, it was determined that a score of 73.1% on Freedman and Bernstein's assessment represented basic competency in MSK medicine. The examination's criterion validity was assessed by administering the examination to chief residents in orthopaedic surgery who yielded a mean score of 98.5 (± 1.07) percent (29). This assessment was then administered to 85 recent medical school graduates in various specialties to examine their MSK knowledge. Over 80% (70/85) of residents failed to demonstrate basic competency on Freedman and Bernstein's examination based on the criterion set by the orthopedic chairs, with the mean examination score being 59.6 ±12% (range, 35% to 86%). Residents who had graduated from medical school without completing a rotation in orthopedic surgery had the lowest mean scores (55.9%) and the highest failure rate (93%) (29).

1.2.3 The Bone and Joint Decade

Taken with the increasing burden of MSK conditions on society, there was compelling evidence in the late 1990s that supported the need to ensure a strong foundation of knowledge and support in diagnosis and treatment of MSK conditions. The healthcare professionals responsible for treating and managing these conditions realized the need for a high-profile campaign to remedy the lack of attention provided to the seriousness of MSK conditions by policy makers, the media, and the medical profession as a whole (30-32). Moreover, with the state of MSK medical education being questioned, there came a need to thoroughly identify the knowledge gaps present in MSK curricula and provide recommendations for further action.

To bring attention to these issues, over 100 experts from national and international orgnaizations, including healthcare professionals and individuals from patient organizations attended a meeting in Lund, Sweden in April of 1998 to consider the global impact of MSK disorders and strategies to increase public and professional awareness of these conditions (33, 34). At this inaugural meeting, it was agreed that the first decade of the 21st century would be designated "The Bone and Joint Decade" to raise awareness of the impact of MSK conditions on society and improve the quality of life for individuals living with MSK disorders across the globe (35-37). One of the primary goals of this global campaign was to advance the understanding and treatment of these conditions through research, prevention, and education of patients and healthcare providers (32, 38).

The Bone and Joint Decade alongside the aforementioned studies conducted by Clawson and Freedman and Bernstein catalyzed widespread efforts to assess the quality of MSK education medical trainees were receiving and the MSK knowledge base of students and practicing physicians. In the early 2000s, Freedman and Bernstein's original findings were replicated in medical students, residents, as well as practicing physicians in various academic medical institutions around the globe (39-43). For example, Jones (2001) administered the MSK examination to final year medical students at the University of West Indies in Barbados, and over 80% of students failed to achieve basic competency (40). Similarly, Matzkin and colleagues (2005) gave the examination to 334 medical students, residents, and staff physicians, only 21% of whom reached the recommended mean passing score of 73.1% (41). In 2006, Lynch et al. administered the Freedman and Bernstein examination to family medicine, internal medicine, and pediatric faculty along

with a survey to assess self-perceived confidence for managing common MSK problems (44). Only 59 (64%) of the 92 physicians achieved basic competency. Further, when compared to managing medically related problems, these physicians reported significantly lower confidence in dealing with MSK-related issues (44). Similar results were reported after Matheny et al. (2000) evaluated the confidence of family practice residents in their ability to effectively manage MSK conditions compared to a variety of non-MSK conditions (45).

These gaps in medical trainee and physician MSK knowledge and confidence were quickly linked back to deficiencies in MSK instruction within the early years of medical training. Various curriculum evaluations conducted at the undergraduate level of medical education found that the amount of time training medical students for MSK medicine as well as the quality of MSK curricula was deficient. In 2001, Pinney and Regan surveyed the directors of the sixteen existing medical schools in Canada to determine the proportion of curricula time dedicated to MSK education as well as the perceived quality of MSK education offered at each institution. It was determined that on average, only 2.26% (range, 0.61% to 4.81%) of curriculum time in Canadian medical schools was devoted to MSK education (5). Furthermore, 11 of the 16 respondents indicated that the time available in their medical school's MSK curriculum was inadequate, and 7 of the 16 program directors rated their curriculum as inadequate overall to prepare students to deal with MSK problems. As part of their analysis, the authors estimated the prevalence of MSK-related complaints in primary care settings in North America through a literature review and survey administered to local family physicians.

This review revealed that up to 27.8% of patients presenting to primary care have an MSK-related complaint (5). When compared with the amount of time dedicated to MSK education in medical school, there was a clear and notable discrepancy that existed between the prevalence of MSK issues and the time spent teaching about them. In 2003, a similar evaluation was conducted in American medical schools by DiCaprio et al., which revealed that only 51 of the 122 medical schools in the United States required a MSK preclinical module or instruction, and only 25 medical schools required students to rotate through an MSK clerkship during their clinical years. Additionally, close to half of the medical schools had no required MSK medicine instruction (46). A survey of medical schools within the United Kingdom conducted in 2001 demonstrated similar time disparities in MSK teaching, and revealed that under 4% of curriculum time was dedicated to MSK medicine within undergraduate medical education (47). Moreover, multiple studies conducted within the United Kingdom displayed that medical students and residents consistently score poorly on Freedman and Bernstein's examination and have low self-rated confidence in their MSK assessment skills (48-51).

As the first decade of the 21st century progressed, more countries verified inadequacies in MSK curricula as well as medical trainee and practitioner MSK knowledge. In particular, Australia identified that the standard of MSK education in their medical schools as insufficient to meet the needs of MSK care in the country; this was determined through a national workshop composed of academic teaching and student representatives who confirmed inadequacies in MSK curricula across the nation (52). A study conducted in Egypt also revealed that over 80% of primary care physicians (n=297)

reported low confidence in their ability to perform MSK physical examinations, and 75% failed to demonstrate the passing score when tested using Freedman and Bernstein's examination (53). In India, 40 final year medical students were given the same examination and only 2 achieved the recommended basic competency score of 73.1% (54). Similarly, Queally et al. administered Freedman and Bernstein's examination to 303 participants in Ireland in 2007, which included medical students, orthopedic residents, general practice trainees, and general practitioners. Over 85% of medical students and approximately 70% of general practitioners and general practice trainees failed the examination (55). In Nigeria, 133 pre-internship graduates from 7 medical schools over a 3 year period (2008-2010) failed to demonstrate basic competency (56). Taken together, these curriculum evaluations and trainee knowledge assessments illustrated the dire state of MSK medical education around the world, and the obligation of academic medical institutions to improve the quality of instruction provided to students.

A number of curriculum reform initiatives were inspired as a result of the increased attention brought to this issue. The largest effort to revamp MSK curricula was coordinated by the Bone and Joint Decade's Education Task Force, who initiated a consultation process with experts from around the world to produce MSK learning outcomes applicable to all physicians. The experts involved in this process all had an interest and experience in education, and came from a variety of fields including orthopedics, rheumatology, and rehabilitation medicine. These individuals formed the Bone and Joint Decade Undergraduate Curriculum Development Group (BJDUCDG) and created global recommendations for a set of core undergraduate curriculum items

regarding MSK conditions (57, 58). These recommendations were determined to be the minimum level of physician competence for MSK-related management regardless of further specialization, and were designed with the intent of being able to be applied to any medical school in the world (58).

Other efforts were initiated at the national level in various countries. These included the American Medical Association's Resolution 310, which encouraged medical institutions in the United States to make changes to their curriculum to ensure students have appropriate education and training in musculoskeletal care, and can demonstrate competence in basic musculoskeletal principles a graduation requirement for medical schools (59). The Association of American Medical Colleges (AAMC) also created a dedicated MSK panel within its medical school objectives project, and the National Board of Medical Examiners (NBME) developed a subject examination in MSK medicine. In Canada, the BJDUCG core curriculum recommendations for MSK education were reviewed by Canadian physicians and surgeons to evaluate their level of agreement with the recommendations, and add items they thought to be important at the postgraduate level of education (57). Statistical evidence of agreement was demonstrated, and topics that were deemed as being important by Canadian physicians to post-graduate medical practice were also added, producing the Canadian Multidisciplinary Core Curriculum for MSK Health (57).

Outside of North America, the Australian Musculoskeletal Education Collaboration (AMSEC) was formed in 2005 with the goal of improving the delivery of MSK care in Australia by establishing a minimum national baseline in MSK education

(52). This AMSEC project established a minimum national benchmark for MSK education in Australian medical schools using a national consensus process involving interdisciplinary and interprofessional working groups. The evidence-informed, principles-based core competencies that were developed through this initiative were implemented in Australian medical schools in 2010 (60). Other recommendations developed during this time period included involving different specialists in the development of MSK curricula to ensure a multidisciplinary and comprehensive approach to teaching this subject. In particular, the Association of Academic Physiatrists formed recommendations on how the specialty could contribute to MSK education within UGME and provided overarching guidance on the development of MSK curricula (61). This included integrating MSK medicine in a longitudinal manner throughout UGME, interdisciplinary partnering with Physical Medicine and Rehabilitation, having a physiatrist MSK education "champion", and the provision of a model curriculum. These widespread and intensive initiatives marked the beginning of a promising era of curriculum reform for MSK medicine and provided a comprehensive framework for medical schools around the world to follow suit.

At the end of the Bone and Joint Decade, Bernstein et al. set out to evaluate whether the aforementioned initiatives resulted in a change in the prevalence of MSK instruction within American medical schools. When compared with the 2003 report, there was a 37% increase in medical schools that required students to complete a preclinical course in MSK medicine, a 4% increase in those that required a clerkship in MSK medicine, and a 30% decrease in schools that had no required MSK instruction at all (62).

Although these results showed MSK medicine's progress in attaining a more prominent place in medical school curricula, the era of MSK curriculum reform in medical education was far from complete. Despite the presence of evidence indicating an increase in the overall instruction and clinical time dedicated to MSK medicine in American Medical Schools over the course of the decade, the methods used to characterise this change failed to capture the exact content taught within the curriculum, and the quality of the instruction provided to students. The first objective of curriculum reform, ensuring MSK medicine had a defined place in medical training, seems well underway, but the broader challenge of evaluating the quality of the content necessitates more work.

1.3 Progress of MSK Medical Education Over the Last Decade

Ten years after the Bone and Joint Decade, various MSK learning and teaching approaches have been examined in isolation and as part of broader curricula renewal in order to address the remaining deficiencies in MSK curricula and ensure quality instruction within undergraduate medical education. Curriculum reform efforts conducted in this area have included increasing the time dedicated to MSK instruction, adding more clinical opportunities, and developing integrated, multidisciplinary courses on MSK conditions. Other popular approaches to enhancing MSK curricula that are cited in the literature include interprofessional education opportunities, experiential and active learning, e-learning, as well as peer- and patient-assisted learning. Evaluation efforts have also continued, both in terms of student knowledge as well as MSK curriculum assessments. The following sections outline the efforts that have been made towards improving MSK curricula over the last decade (2010-2020), and the state of MSK

medicine instruction as we know it today. It should be noted than many of these themes are reflective of general trends in medical education over the last 10 years. However, these themes will be discussed specifically within the context of MSK education and their application within MSK curricula.

1.3.1 Themes that Emerged from the Bone and Joint Decade

In keeping with the trend of curriculum renewal during The Bone and Joint Decade, some medical schools have continued to increase the clinical and classroom-based time dedicated to MSK medicine. For example, Leicester Medical School increased their dedicated clinical MSK coursework by 3 weeks by integrating instruction in rheumatology, trauma and orthopedic surgery, as well as other allied specialties into their curriculum (63). Programming in this curriculum included weekly plenary sessions, traditional firm-based teaching, specialist clinics, and task-based workbooks to stimulate self-directed learning. At the Royal College of Surgeons in Ireland, an interactive MSK module was added as a newly designed 2-week compulsory clinical rotation. Features of this module included lectures, case discussions, clinical examinations, interactive tutorials, and patient interactions (64). After identifying region-specific educational inadequacies, Harvard Medical School produced an integrated MSK curriculum based on the AAMC recommendations and added MSK content across their preclinical curriculum for a longitudinal approach (42, 65, 66). Other medical schools created completely new modules and courses spanning various MSK specialities and topics during preclinical years, including rheumatology, orthopedics, clinical anatomy, and rehabilitation medicine (67-69).

1.3.2 Interprofessional Education

Interprofessional education refers to the collaborative learning process through which students and practicing professionals from different healthcare fields learn from, with, and about each other in an interactive setting (70, 71). Within the context of MSK curricula, the fields of physical therapy, massage therapy, and medicine, have been combined in MSK curricular components including lectures, laboratories and small group learning to improve MSK instruction (70, 72-75). These interprofessional education pairings have yielded largely positive results with students from both fields, particularly physical therapy and medicine, reporting their interprofessional experiences as being beneficial to their learning and demonstrating improved scores on post-program or session testing in specific MSK clinical skills (70, 73, 75, 76). For example, Sander et al. describe a complex, longitudinal competency-based curriculum in which the rheumatic and MSK disease components are taught in an interprofessional manner. Students in various years of their physiotherapy and medical training programs are brought together for anatomy, physical examination, pathology and therapy instruction (73). Regular evaluation of this curricular unit has been implemented, with instructors reporting positive experiences and promoting continuation of the approach. Moreover, the authors report that the majority of students (94%) received a passing grade on their summative assessments and achieved the learning objectives set out at the beginning of the course (73).

1.3.3 Integrated and Interdisciplinary MSK Teaching

Many MSK courses and curricula have also introduced integrated, interdisciplinary approaches to their MSK teaching. This has included vertical integration of basic science content, such as anatomy into MSK clinical education (77-82), and the involvement of various MSK specialists, such as anatomists, physiatrists, and orthopedic surgeons, within curricula development and clinical teaching activities (83-87). Morgan et al. describe the integration of anatomical education into specialty-specific senior electives, including MSK medicine. This institution's MSK course had the aim of presenting MSK anatomical concepts within a clinical framework and is co-taught by anatomy and orthopedic specialists (80). Moreover, faculty from multiple clinical departments, such as rheumatology and PMR, engage in teaching sessions, with the content specific to common orthopedic problems. The course evaluations of these electives have yielded extremely positive results, with students demonstrating significant post-course improvements on applied clinical MSK anatomy assessments and providing positive comments about the usefulness of the course (80). Interdisciplinary approaches coordinated between MSK radiology and anatomy, as well as having physiatry-based teaching of MSK examinations have been documented (83, 88-90).

1.3.4 Experiential and Active Learning

Various experiential and active learning techniques have been incorporated into curricula to enhance MSK education. Active learning involves having students directly engaged in the learning process through strategies such as team-based learning, case-based learning, and problem-based learning. These aforementioned strategies have been

examined within MSK medicine for both pre-clinical and clinical curricula and have played a large role in curriculum renewal activities (91-93). Team-based learning has become increasingly popular and provides students the experience of working in a team to solve real clinical problems. Sydney Medical School has integrated team-based learning within their MSK teaching blocks, and students report that team-based learning sessions are more conducive to learning, participation and engagement when compared to problem-based learning (94). Experiential learning occurs when students are directly involved in a hands-on learning experience and includes clinical and patient interactions within the context of medical training. Ambulatory teaching days and participation in medical student-run clinics in which students receive experience with patients have been implemented within MSK teaching, providing more opportunities for clinical exposure to MSK conditions (95-99). Through these experiences, students are able to contribute meaningfully to patient care in underserved populations while engaging with MSK complaints in a direct manner. Experiential learning opportunities within the field of MSK medicine have also been offered through student interest groups, such as the Orthopedic Surgery and Sports Medicine Interest Group at the University of Washington School of Medicine. This group provides supplemental educational experiences within the field of MSK medicine, including additional instruction, clinical opportunities, networking, and mentorship (100).

1.3.5 MSK Anatomy, Physical Examinations, and Procedural Skills

Cadaveric dissection has long been used as a method for teaching anatomical concepts and continues to be used to instruct medical students in the basics of MSK

anatomy and physiology (101-103). Newer methods of teaching including synthetic models, simulators, and three-dimensional anatomy software have been explored as a way to assist students in learning MSK anatomy and are also being applied to physical examination and procedural skills instruction (104-107). Interestingly, MSK ultrasound has been implemented in curricula during lectures and laboratory sessions as a way to improve student physical examination skills and MSK anatomy knowledge (108-110). This technique has been reported as being highly valued by students, and an effective way to increase their understanding of MSK pathology, anatomy, and physical examination skills (111-113). Companion checklists and standardized approaches to MSK examination have been developed to assist students in learning these concepts (114, 115). For example, the pediatric Gait, Arms, Legs, Spine (pGALS) technique was developed as an evidence-based approach for non-specialists to assess pediatric MSK abnormalities during physical examinations (116). This assessment involves a simple screening approach whereby clinicians perform basic manoeuvres used in clinical practice to diagnose MSK conditions, taking an average of 2 minutes to complete (117). This approach has been shown to be highly sensitive in detecting abnormalities and easy for medical learners to complete. Similarly, the GALS and the Regional Examination of the MSK System (REMS) function as methods to assess adults. These educational resources have been integrated into a number of medical schools' MSK curricula and have been shown to increase student confidence and physical examination performance (114, 118, 119).

1.3.6 Peer and Patient-Assisted Learning

Patient educators have been introduced in many MSK curricular components, including pre-clinical education, physical examination skills, and history-taking instruction. Assessments have indicated that with appropriate training, patients with MSK conditions have the ability to enhance student learning and provide valid assessments of student performance (120). Students report that patient-lead teaching enables them to understand the impact of MSK disease on patients and their families and improve their physical examination skills (121-124).

Near-peer teaching is a type of peer-assisted learning that refers to the process of a physician trainee teaching a junior colleague. This technique has become more common over the last decade, and evidence suggests that both students and student teachers academically and professionally benefit from participating in these programs (125). Peer-assisted learning has been integrated into undergraduate medical MSK curricula for the purpose of delivering clinical skills and content instruction, including MSK anatomy, as well as MSK examinations and ultrasound skills (126-132). For example, Rosenberg et al. describe near-peer teaching of MSK physical examination skills between physical medicine and rehabilitation residents and undergraduate medical students as a way to overcome the barrier of limited faculty instructor availability. This study further supports the educational benefits of near-peer learning, specifically in terms of increasing student confidence in MSK examination skills and providing hands-on learning opportunities (128). Schiff and colleagues (2014) report a Near-Peer MSK curriculum developed by orthopedic surgery residents for senior medical students participating in an orthopedic

surgery elective. This curriculum consists of a series of lectures covering basic concepts in orthopedics, including assessing MSK injuries, radiograph evaluation, specialized clinical evaluations and orthopedic emergencies. After participating in this elective, over 80% of the students achieved basic competency on Freedman and Bernstein's examination (133).

1.3.7 E-Learning and Flipped Classrooms

E-learning modalities developed within the context of MSK medical education have ranged from virtual patients and hospitals (134), modules and e-learning tools (135-140), blogs (141), mobile applications (142, 143), web-based videos (144-146), as well as evidence-based websites concerning common MSK issues. Paediatric Musculoskeletal Matters (PMM) is one such website which aims to raise the awareness and help medical trainees and practicing clinicians gain the knowledge and skills needed to recognize paediatric MSK conditions and facilitate early diagnosis and referral to specialist care (147-149). Web-based teaching modules have also been constructed to deliver MSK content to medical students, and range in focus from specific-topics such as lower back pain and the examination of the hand (150, 151), to broader areas of MSK medicine like rheumatology (152-154). These modules have frequently incorporated case-based learning through virtual patients or case simulations that present clinical MSK applications to medical students (137, 155-161). Simulated patients have typically been presented in the form of module applications or virtual hospitals in which students are able to access various outpatient clinics and examination rooms (134, 143, 162). Many of these e-learning interventions have been piloted as part of flipped classroom settings and

blended learning approaches in MSK or rheumatology curricula, as well as adjuncts to MSK clinical rotations (154, 163-169).

1.3.8 Curricular Recommendations

Recommendations for MSK medical education produced over the last decade have ranged from pediatric MSK conditions and MSK anatomy, to broad syllabus and course development (170-173). Many of these recommendations were formed using stakeholder focus groups and interviews, surveys, as well as modified Delphi processes (173-175). For example, Jandial and colleagues (2015) developed learning outcomes specifically for pediatric MSK clinical skills and knowledge important at the medical student level through a modified Delphi process. Stakeholders involved included generalists and specialists involved in treating MSK conditions such as pediatrics, primary care, rheumatology and orthopedics, as well as medical students from schools in the United Kingdom (176). The learning outcomes produced by this study related to MSK specific history taking, examination, development, clinical presentation of key conditions, and referral pathways within the scope of child health.

Orthopedic surgeons have also played a large role in both MSK curriculum development and the procurement of recommendations for MSK instruction over the last decade. Specifically, the American Orthopaedic Association symposium report offered guidance for MSK curricula through the description of strategies used by orthopaedic surgeons to expand MSK curricula (172). Modified Delphi processes have also been used to identify orthopedic-related knowledge topics, clinical cases and skills that are relevant to medical students (177), as well as relevant orthopaedic anatomical components to be

taught in UGME (178). Other specialist-involved recommendations incorporated the opinions of practicing physicians to inform the development of an MSK curriculum, with an emphasis on common conditions seen in general practice (175).

1.3.9 Student Knowledge and Curricular Assessments

In addition to the exploration of novel learning interventions and pedagogical approaches for their application to MSK medicine, there has also been continued curriculum evaluation and student assessment efforts. However, when compared to the evaluation work that occurred during the Bone and Joint Decade, many of these initiatives focused on more specialist-driven content and specific areas of MSK medicine rather than examining general MSK knowledge. For example, Milk-Tabassum et al. evaluated 147 final year medical students' undergraduate experience in trauma and orthopedics as well as self-perceived confidence through a national survey in the United Kingdom (179). Overall, 41% of students rated their undergraduate training in trauma and orthopedics as being "poor", and on average, their knowledge and confidence in trauma and orthopedics was rated as 4.9/10 and 5.4/10 respectively (1= no confidence/knowledge, 10= complete confidence/knowledge). Similarly, a nation-wide survey in Germany assessed medical education in orthopedic and trauma surgery, which indicated that the time dedicated to these particular MSK conditions represented less than 6% of undergraduate medical curricula (180). Evaluations of student MSK knowledge, confidence, perceived quality of teaching and preferred instructional techniques have also been gathered within MSK radiology (181, 182), rheumatology (183-186), pediatric MSK clinical skills (187, 188), MSK physical examinations (189-191), orthopedic subspecialties (192, 193), and MSK

anatomy (194-196). These evaluations have largely indicated that the clinical confidence and knowledge of medical students within these various subsections of MSK medicine is severely lacking, and the instructional techniques utilized in these areas are in need of improvement. Freedman and Bernstein's MSK knowledge assessment has also continued to be used around the world, with studies further demonstrating and affirming deficiencies in MSK knowledge amongst medical students in India, the United Kingdom, the United States, and Saudi Arabia (197-203).

In terms of curriculum evaluations, barriers to implementing effective and comprehensive MSK education have been cited as insufficient time and resources dedicated to this subject area (4, 204). Specifically, a lack of exposure to patients in clinical settings, a shortage of faculty instructors able to teach clinical examination skills and effective teaching patients, and time constraints that are imposed on course content delivery (4, 187). For example, DiGiovanni and colleagues evaluated the prevalence of MSK clinical instruction in American medical schools in 2015 and found that a required rotation was found in only 15% of medical schools, making it the least represented subject within specialties (205). Students have also indicated that there is a lack of clarity of what is expected of them in various portions of their MSK curriculum, and clinical instructors have struggled with a perceived lack of consensus on what topics are important to teach in MSK medicine despite the recommendations that have been produced by various experts (181, 189, 206). Thus, despite the advancements in the MSK teaching, there are still areas that are in need of improvement within MSK curricula.

1.4 Gaps in the Literature and Progress Needed

Ten years after the Bone and Joint Decade ended, the literature indicates that meaningful efforts have been made to reform MSK curricula. However, there is evidence that MSK knowledge gaps persist amongst medical students, even in medical schools that have implemented renewed curricula (69, 207). Some have suggested that this is due to a "repackaging issue", meaning that schools may have compiled pre-existing MSK instruction into newly labeled courses or modules while making little to no change to the actual curriculum content (62). Moreover, there continues to be sparse examples of competency-based curricula, as well as a lack of longitudinal integration of MSK content and clinical experience opportunities demonstrated throughout preclinical and clinical years. Most of the interventions implemented and within undergraduate medical curricula have assessed the impact of the learning intervention or curriculum modification immediately after the students have completed it, rather than examining whether these changes yield meaningful improvements over time.

Further, the majority of the initiatives are primarily based in the United States. Outside of the Canadian Multidisciplinary Core Curriculum for MSK Health, there have been limited efforts to initiate broad MSK curriculum overhaul in Canada. There is also a paucity of literature documenting the assessment of MSK curricula and the implementation of MSK instructional techniques in Canadian medical schools. Based on the review of MSK curricula in 2001 conducted by Pinney et al., it is critical that Canadian MSK curricula be examined and assessed for specific limitations given that

many program directors described their MSK instruction as being inadequate at the start of the new millennium.

There is an intense competition for time within medical school curricula, which only continues to grow as expectations of physician's knowledge base increase with society's evolving healthcare needs. Unfortunately, MSK medicine is one of many subjects that continues to grapple with this dilemma. With limited funding available for medical education initiatives, resource intensive solutions to this problem are not viable for many medical schools. Moreover, the MSK learning modalities that have been constructed have largely focused on singular interventions with limited scope, or specialist-specific content. The vast majority of modifications implemented in MSK curricula have also been evaluated based on student perceptions and satisfaction rather than the assessment of student knowledge or skill. Thus, there is a need for efficient, cost-effective, and evidence-based interventions that span a broad range of MSK topics. This brings us to the objectives of the present thesis.

1.5 The Present Thesis

The purpose of this thesis was to develop, implement and evaluate the efficacy of a self-directed learning tool designed to target perceived gaps in medical student MSK knowledge in the DeGroote School of Medicine. We chose the Context, Input, Process and Product (CIPP) program evaluation model situated within a sequential exploratory mixed methods approach to achieve the objectives of this thesis. The CIPP model effectively addresses the planning, implementation, and a final summative assessment of a program. Moreover, the CIPP model was developed with the purpose of evaluating

educational programs, and the usefulness of this approach in educational evaluation settings has been thoroughly documented (208, 209).

The CIPP model consists of a context, input, process, and product evaluation. The context, input and process phases are used for formative evaluation, and provide an improvement-focused framework; in contrast, the product phase is used to conduct a summative evaluation of the program and is used to identify positive and negative outcomes. The context evaluation specifically assesses the problems, needs and opportunities within the defined environment, or "what needs to be done" within the given context (210). The input evaluation assesses the feasibility, potential approaches, and logistics of a program, or "how it should be done" within the given context (210). The process evaluation assesses the implementation of a program and determines "whether it is being done as planned" (209, 210), and the final product evaluation assesses the outcomes of the program and determines whether the program "succeeded" in accomplishing its goals.

We used a sequential, exploratory mixed methods approach to guide the methods used in each phase of the CIPP model. A sequential, exploratory mixed methods approach was chosen as it is particularly effective when the objective of the research is to develop an instrument specific to the context of interest. The exploratory sequential approach typically consists of three phases. The first phase employs qualitative methods, through which results are produced that are used to inform the development of a tool or instrument. Beginning with a qualitative approach ensures that the development of the tool or instrument is informed by the views of the participants. As the goal of this study

was to create a learner-centric tool, having the initial development informed primarily by the voice of the students through qualitative methods aligned with this approach. The second phase of a sequential, exploratory mixed methods approach involves the development of the tool, which is connected to the qualitative results from the first phase of the study. The third phase within this mixed methods design uses quantitative methods to evaluate the success of the tool or instrument, and the fourth and final phase examines the extent to which the quantitative results extend and connect to the initial qualitative development process. Essentially, the qualitative and quantitative portions of this mixed methods approach are separate yet related by the development and evaluation of the instrument produced.

Within this mixed methods design, we completed the context and input evaluations of the CIPP model in the first qualitative phase of the mixed methods approach. Specifically, we conducted the context and input evaluations using the qualitative design of interpretive description to assess required changes within the MSK curriculum at the DeGroote School of Medicine, and how a self-directed learning tool might fill those gaps. We used the qualitative results from the context and input evaluations to inform the development of the self-directed learning tool, which formed the second phase of the sequential, exploratory mixed methods approach, or the "tool development" phase. The process and product evaluations of the CIPP model were located within the quantitative phase of the mixed-methods approach and were used to assess whether the self-directed learning tool had been implemented as planned, and whether it succeeded in helping students to learn MSK medicine respectively. An

overview of these methods can be found in Figure 1, and how the CIPP model was addressed is outlined in Table 1.

The context and input evaluations can be found in Chapter 2 of this thesis. These evaluations were conducted within a single qualitative study which utilized interpretive description as the methodology. The purpose of this study was twofold: (1) to explore faculty and student perceptions of the current MSK curriculum in the DeGroote school of Medicine to identify critical gaps, and (2) to explore the prospect of incorporating a self-directed learning tool into their orthopedic clerkship rotation and how the learning tool should be constructed to fill the identified gaps. The first objective fell within the realm of the context evaluation, while the second objective addressed the input evaluation. We used semi-structured interviews with students and orthopedic faculty members from the DeGroote School of Medicine. The first half of the semi-structured interview focused on the participant's perception of the current MSK curriculum. The latter half of the interviews explored whether a self-directed learning tool could potentially fill any limitations or gaps identified within the first portion of the interview, and how the learning tool could be constructed. Thematic analysis was used to construct themes, which were then sorted into two broad categories: perceptions of the MSK curriculum (context results) and the design and prospect of the self-directed learning tool (input results). This study comprised the first qualitative portion of the sequential exploratory mixed methods design and informed the development of the self-directed learning tool.

The product and process evaluations can be found in Chapter 3 of this thesis. We used a two-groups, pre-test post-test design, in addition to a cross-sectional survey to

conduct these evaluations. The cross-sectional survey addressed the objective of the process phase in evaluating whether the self-directed learning tool was implemented as intended. The product evaluation consisted of two MSK knowledge assessments administered to orthopedic clerks during their 2-week rotation as a pre-test and a post-test. We used the results from these knowledge assessments to examine student progression of MSK knowledge over the course of their orthopedic clerkship rotation, and whether the self-directed learning tool succeeded in accomplishing its goals.

The final chapter of this thesis, Chapter 4, presents the interpretation and explanation of both the qualitative and quantitative results, discusses the implications of the work presented in this thesis, and poses areas for future research.

Figure 1: Overview of Sequential Exploratory Mixed Methods Design

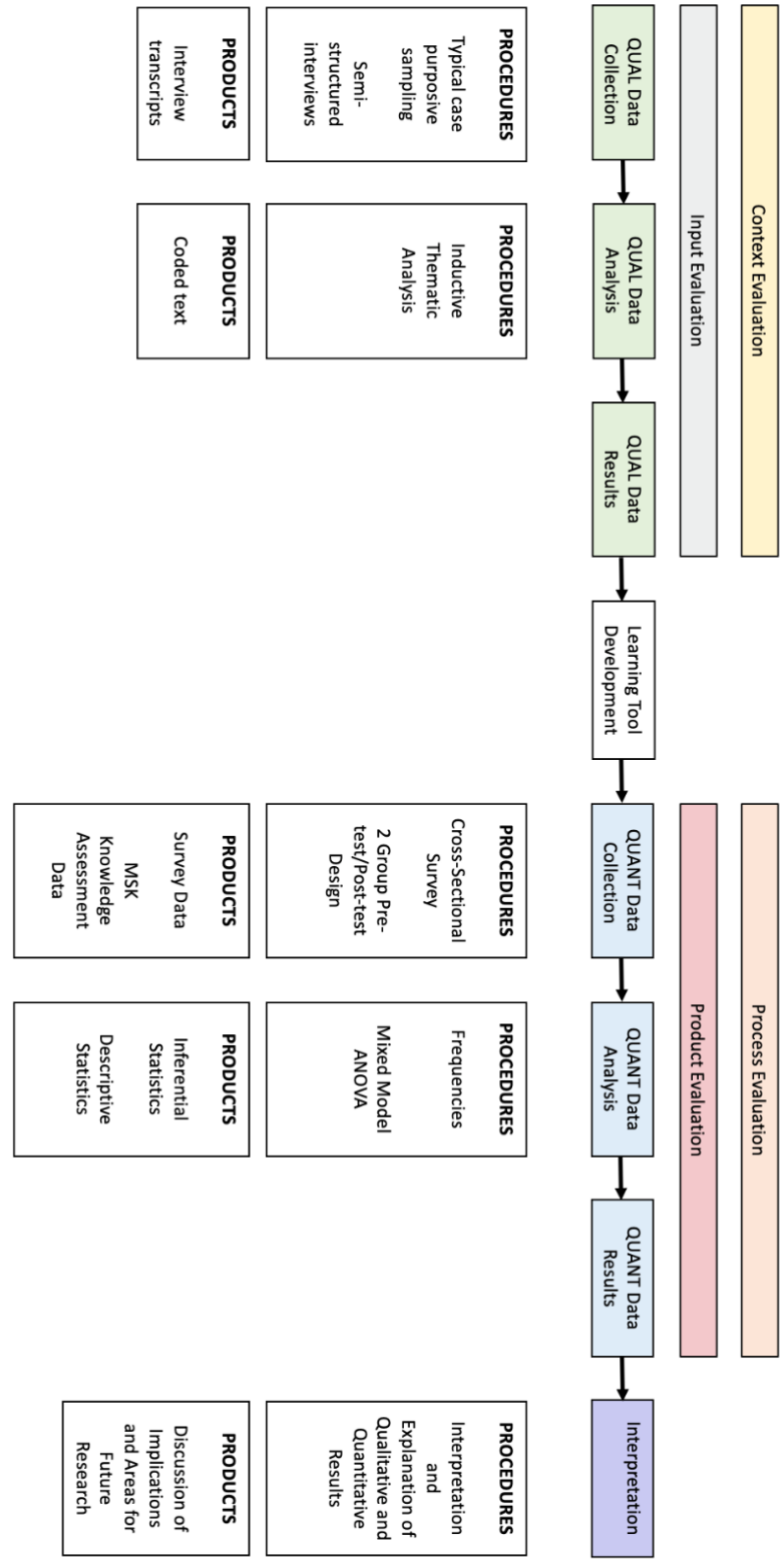

Table 1: Overview of Context, Input, Process, Product Model and Associated Methods

	Context "What needs to be done?"	**Input "How should it be done?"**	**Process "Was it implemented as planned?"**	**Product "Did it succeed?"**
Evaluation Objective	To evaluate educational problems, practices and needs of the MSK curriculum at McMaster University	To determine how a self-directed learning tool could fill the identified curriculum gaps	To assess the implementation of the learning tool	To assess whether the self-directed learning tool was successful
Methodology	Interpretive Description		Cross-Sectional	Two-group pre-test post-test design
Research Question	How do medical students and orthopedic faculty describe their perspectives of the MSK curriculum at the DeGroote school of Medicine?	How might a self-directed learning tool fill the identified gaps in the MSK curriculum at the DeGroote School of Medicine?	What improvements need to be made to the design and implementation of the self-directed learning tool?	Did the self-directed learning tool help orthopedic clerks improve their MSK knowledge?
Participants	Medical students and orthopedic faculty members		Orthopedic clerks	
Data Collection	Semi-structured interviews (Part 1 of the Interview Guide)	Semi-structured interviews (Part 2 of the Interview Guide)	Survey	MSK Knowledge Tests

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Chapter 2

Perceptions and Practices of One Canadian Medical School's MSK Curriculum

2.0 Perceptions and Practices of One Canadian Medical School's MSK Curriculum

2.1 Introduction

Musculoskeletal (MSK) conditions are estimated to account for up to 30% of primary care visits, with approximately one in three people being affected by a chronic, painful MSK condition (1-4). According to the Global Burden of Disease Study, MSK disorders are amongst the ten most important drivers of disease burden and contributed to some of largest absolute increases in the number of disability-adjusted life-years between 1990 and 2019 (5).

Despite the widespread prevalence of MSK disorders, many physicians and medical trainees are not comfortable treating MSK conditions and lack the knowledge to diagnose and manage these disorders effectively (6-11). In the United States, Nigeria, the United Kingdom, Ireland, Barbados, and India, medical schools have consistently reported poor performance by their students on a validated MSK assessment developed by Freedman and Bernstein (12). In fact, the majority of medical students tested in these countries failed to achieve a passing score (7, 13-18). Similar results have also been reported amongst residents and practicing physicians who also demonstrate low passing rates on MSK knowledge assessments and confidence levels with respect to diagnosing patients with MSK symptoms (18-20).

Ultimately, there exists an issue with medical learners emerging from their training with an inadequate knowledge base for managing MSK conditions. This problem has been linked to deficiencies in undergraduate medical education (UGME) MSK curricula, which are related to insufficient time and resources for learners to understand

the material (4, 9, 21-24). Specifically, evaluations of MSK curricula have consistently identified that the amount of time dedicated to MSK medicine instruction in medical school is disproportionately low compared with the prevalence of MSK disorders seen in primary care settings (4, 25). Moreover, resources such as faculty to teach MSK clinical skills and teaching patients are in high demand and are not readily available for this portion of UGME curricula (4, 26).

With increasing time constraints and demands being imposed on students and faculty members in medical education (27), it is critical that effective and efficient learning strategies be explored for improving the quality of MSK education. We propose that self-directed learning may be a potential solution to this problem. First, self-directed learning presents as a model for increasing the amount of exposure to MSK content that medical students are provided without impacting time spent on other important aspects of the curriculum. Moreover, self-directed learning has been promoted in medical training due to its value in developing students into lifelong learners and has become a vital component in higher education (28, 29). The competencies of self-directed learning include proficiency in the self-assessment of learning gaps, evaluation of knowledge, critical thinking, critical appraisal and information management. Although self-directed learning has not been thoroughly examined as a potential modality for assisting medical students in learning MSK medicine, it has been shown to be an effective and efficient method of training healthcare professionals in other domains (30, 31). Specifically, self-directed learning is associated with improved knowledge acquisition and similar effectiveness in terms of skill development and receptive attitudes when compared with

traditional methods (30). Self-directed learning has also been determined to be effective particularly for more advanced learners, such as those in the latter years of medical school (30). Thus, self-directed learning may provide greater educational opportunities for students in MSK medicine while being a resource and time efficient option for UGME programs to enhance MSK instruction.

Given the identified inadequacies in MSK instruction, it is critical that we explore novel approaches within the context of UGME to target gaps in medical student MSK knowledge. We suggest that self-directed learning could be an effective and resource-efficient method for increasing student exposure to clinically relevant MSK content without impacting other important aspects of the curriculum. Thus, the purpose of this study was to explore the strengths and weaknesses of the current MSK curriculum at a single Canadian institution to inform the development of a novel self-directed learning tool for MSK medicine.

2.2 Methods

2.2.1 Setting

This study took place at McMaster University, an academic institution located in Hamilton, Ontario, Canada. McMaster's UGME Program within the DeGroote School of Medicine is a 3-year program divided into a 15-month pre-clinical phase and a 63-week clinical phase. The pre-clinical phase focuses on core medical science and professional competencies through five sequential Medical Foundations (MF) units, and the clinical phase consists of rotations in general surgery, orthopedic surgery, family medicine, anesthesia, psychiatry, pediatrics, obstetrics and gynecology, emergency medicine, and

various electives. The current MF pedagogical methods include small group tutorials, large group sessions, anatomy lab sessions, and clinical skills sessions, with small group problem-based learning and self-directed learning being the primary focus. During each MF unit, students are divided into groups of 6-8 students and attend biweekly tutorials, weekly clinical skills sessions, weekly anatomy sessions, and some large group sessions as a class. In the problem-based learning tutorials lead by a physician tutor, students are presented with a clinical case and accompanying learning objectives during the first tutorial of the week and are expected to research the case and present their findings during the week's second tutorial. Clinical skills sessions occur in most of the MF units and are led by a preceptor to cover the appropriate skills being taught in the corresponding MF unit. Anatomy sessions occur in a self-guided, station-based learning environment during which faculty preceptors are available to provide students with clinical context and guidance. Within MF, students in the DeGroote School of Medicine receive MSK related training during an MF4 subunit which is 4 weeks in length. During clerkship, the orthopaedic rotation serves as the primary clinical setting in which students are exposed to MSK conditions.

2.2.2 Interpretive Description

This study used the qualitative research design of interpretive description to meet its objectives. Interpretive description seeks to create a rich and detailed description of the phenomenon of interest and allows the researcher to discover patterns and associations that lead to a better understanding of a phenomenon of interest (32). Interpretive description has also been described as a goal-oriented methodology (33), and as such is

appropriate to use to identify ways to improve the current MSK curriculum by providing insight and understanding into the patterns and relationships that exist in the learning experiences of students. By focusing this work on the perspectives of medical students, a learner-centric solution will be developed to address the perceived gaps in their MSK curriculum. The qualitative research questions explored in this study fell also within the realm of interpretive description as the analysis of the data involved delving into an interpretation that was "beyond the self-evident" and exceeded qualitative description in its required level of interpretive depth (33). The results from this study will be used to make interpretative conclusions about the current MSK curriculum's strengths and weaknesses and will inform the development of a novel, self-directed learning tool.

2.2.3 Sampling Strategy and Data Collection

In interpretive description, a variety of sampling techniques are utilized, including convenience sampling, purposeful or purposive sampling, and theoretical sampling (33). Qualitative researchers often employ a mix of these sampling strategies in interpretive description to recruit participants who are able produce meaningful results (33). This study employed typical case purposive sampling and snowball sampling at the inception of the study, then proceeded to use a theoretical sampling strategy in-situ.

Purposeful sampling is comprised of non-probability strategies that rely on the judgement of the researcher to select the most appropriate participants for providing rich and relevant information in relation to the research question (34). Participants in this study were students and faculty in the DeGroote School of Medicine. Students recruited for this study were those who had completed their Medical Foundations MSK subunit and

were in the process of completing clerkship at the time of recruitment. Faculty recruited for the study were preceptors for the orthopaedic clerkship rotation. We specifically chose preceptors for the orthopaedic clerkship rotation to examine what specific orthopaedic MSK conditions faculty identified as being areas of weakness for students. Moreover, the orthopaedic clerkship was identified as being the most "MSK intensive" clinical rotation, and thus the most appropriate clinical context to examine how student's foundational MSK training translated to practice. The particular type of purposeful sampling strategy utilized was typical case sampling. Within the scope of purposive sampling, typical case sampling selects participants with the intent of illustrating or highlighting what is "normal", "average", or "typical" in the phenomenon of interest (35). This sampling strategy was the most appropriate technique to utilize, as the purpose of this research was to identify the commonly perceived curriculum strengths and weaknesses and to develop a self-directed learning tool for the typical medical student.

We first identified participants using a snowball sampling recruitment technique. After a preliminary round of data analysis, theoretical sampling was employed to purposefully recruit students from outside of the Hamilton campus, and to include those interested in "MSK heavy" specialties to reach data saturation. We also recruited faculty from different orthopaedic subspecialties located at different clerkship sites. These decisions were made in situ and were based on themes identified in initial interviews conducted with students and faculty. Theoretical sampling is a hallmark of interpretive description and is a technique in which participants are recruited based on novel constructs identified in the data during analysis (33). In qualitative research, data

collection and analysis occur concurrently to determine the point of data saturation and inform further sampling decisions. The term "data saturation" refers to the point at which researchers have obtained sufficient richness of information and can conclude that no additional or novel themes will arise from further data collection. The concept of theoretical sampling is therefore inextricably linked to data saturation as it guides the parameters through which participants are identified to fully understand the phenomenon of interest. This concept also illustrates why no formal sample size calculation is completed prior to the inception of qualitative research, as the number of participants recruited for interpretive description studies is dependent upon concurrent analysis of the data and the determination of data saturation.

Semi-structured interviews were used as the primary data collection strategy and were conducted in person, over the phone, or through video conferencing. The questions listed in Appendix A served as a guide to the interview; however, the researcher conducting the interviews allowed the participants answers to guide further questioning. Students and faculty who participated in these interviews were asked questions about their perceptions of the current MSK curriculum content and teaching techniques, as well as about their experiences with self-directed learning. They were also asked questions about how a self-directed learning tool might fit into their orthopedic clerkship rotation. All interviews were audio recorded and transcribed verbatim.

2.2.4 Analysis and Trustworthiness

Data from the semi-structured interviews were analyzed using thematic analysis. In particular, the Braun and Clark approach to reflexive thematic analysis was utilised

(36). This process goes through the six phases of data familiarization, coding, initial theme generation, theme reviewal, defining and naming themes, and writing up the themes. The inductive variation of reflexive thematic analysis was employed, in which the coding and theme development were informed by the content of the data rather than existing concepts, categories, or ideas. To ensure dependability of the data, stepwise replication was used to identify themes from the coded data. This involved having two members of the research team independently code a sample of transcripts for the purpose of identifying key codes. The researchers established and built consensus on code labels and definitions. Data were analyzed and codes were organized into themes in Excel. This process was iterative and occurred concurrently with data collection.

Various strategies to promote rigour were implemented throughout this qualitative research process. To enhance the credibility of this study, data source triangulation was implemented to confirm themes across the dataset. A reflexive journal was maintained by the lead researcher to track and challenge the assumptions, biases and interpretations they had during the course of the study and was used to document the potential influence of their experiences on the qualitative research process. Credibility was also promoted during the interview process by seeking validation of answers from participants as a form of member checking and by developing internally consistent interview guides. Reflexivity practices and triangulation further promoted confirmability, and a detailed audit trail was kept throughout the sampling, data collection and data analysis to document decisions made by the research team. Dependability of the interview data were ensured through

stepwise replication and involved having two members of the research team independently code a sample of transcripts for the purpose of identifying key codes.

2.3 Results

A total of 17 participants were interviewed before data saturation was reached. The sample was composed of 8 students and 9 faculty members. All 8 students were completing clerkship at the time of their interviews and varied in terms of their specialty of interest and completed clerkship rotations. The students recruited also varied in terms of their primary campus and year of study, with the majority being from the Hamilton campus and in their 2nd year of study. Most students had completed an undergraduate degree in science, and one student held a master's degree. The faculty members recruited for this study were all preceptors in the orthopaedic clerkship rotation. Faculty members varied in terms of their clerkship location and their orthopaedic subspecialty and had anywhere from 1 to 20 years of experience teaching in the clerkship rotation.

Eight major themes were identified regarding student and faculty perceptions of the current MSK curriculum within the DeGroote School of Medicine. A further six themes regarding the prospect of incorporating a self-directed learning tool into their orthopedic clerkship rotation were identified. These themes are described in detail below and are supplemented with supporting quotes from participants.

2.3.1 Perceptions of the Current Curriculum's Strengths and Weaknesses

2.3.1.1 Large Group Sessions

Students identified the current large group sessions as being generally ineffective and inefficient as a modality for learning about MSK conditions during their MF MSK subunit. They described the delivery of the content as being too fast-paced and specialist-focused, with not enough information provided about common MSK conditions. One student stated:

"I think that a key issue with large group lectures is that often specialists are delivering these lectures, and they work with this material in minute detail every day, so they aren't focused on the big picture- like what are the big important things… When lectures are done really well and are very engaging, they can be really good, but I really don't think it's the ideal way to deliver MSK concepts certainly" 004-S

These perceptions were reflected in the low attendance of these lectures, as students often found that their time was better allocated to learning the content through other means of delivery. One student described budgeting their time as a "triaging" process, with lectures being low on their list of priorities:

"They're [large group session] often not great use of our time, and I think that's all of like med school—like, triaging where we're going to put our time. So, I think as a general rule, unless someone said it was a really good lecture, the amount of people that would watch it were low." 006-S

While faculty members iterated the importance of having a component of structured instruction, they also recognized that the current lectures within the MSK subunit were ineffective for engaging and retaining students' attention. One faculty member who had been involved in delivering these sessions commented:

"I think they [large group sessions] are very ineffective. I did them for years, and honestly, I just don't even think students pay attention. I don't think the retention was there, and they need more of a dynamic discussion" 001-F

2.3.1.2 Clinical Skills Sessions and Problem-Based Learning

Students identified the clinical skills sessions within their MSK medical foundations subunit as being particularly good for learning useful content that they thought would be applicable to day-to-day practice. The structured guidance provided by the faculty and residents who run these sessions was perceived as being extremely helpful and was identified as a key component of why students found them to be so effective. Students also identified the problem-based learning tutorials as being a constructive and applicable way to learn many of the clinical presentations of MSK conditions. One student commented:

"I found those [clinical skills sessions] really helpful, because it helps you learn the high-yield stuff. For instance, when you're kind of just researching on your own, or learning about how muscles work on their own, it's hard to know which facts, or information you learn is going to be relevant for you in the medical field. The self-directed learning tutorials based around cases are nice, because it also kind of helps to guide you in terms of what kind of clinically relevant, or high-yield information you should be looking for. " – 001-S

2.3.1.3 So Much Content, Such Little Time

Both students and faculty identified the vast amount of content students are required to know as well as the short timeframe in which it's taught as a significant barrier to learning MSK medicine. The MSK subunit, being only a month in length, is one of the shortest units in their medical foundations training and the short timeframe presents a challenge to students in terms of learning all of the content that they are expected to cover. One student stated:

"I mean a key issue certainly is that there isn't enough time. It's [MSK subunit] just it's one month, it's quite crammed, there's a lot of content to learn and it's really like a fire hose for just a month" 004-S

Students who had exposure to the topic prior to entering medical school also found the short timeframe in which MSK content is taught challenging, despite having developed a previous knowledge base in the subject. One student commented:

"Oh gosh, I think we need more time. It was kind of like shoved into four weeks to learn the entire body, and it was just too much. At least I had the anatomy primer out of undergrad, so this was like manageable, but for other people who never looked at bones before, I don't know how they got through it." 002-S

Students also noted that the pace at which the MSK subunit moves results in a surface-level understanding of MSK medicine. This surface level understanding becomes an issue particularly during their orthopedic clerkship rotations when students encounter a high proportion of MSK-related cases.

2.3.1.4 Lack of Longitudinal Integration and Repetition

Students and faculty also identified that the way in which MSK content is integrated into their medical foundation's curriculum is not effective for promoting long-term retention. Specifically, they indicated that the lack of repetition of the subject throughout their training leads to students learning the content for their medical foundations training and forgetting the material by the time they reached their orthopedic clerkship. One student commented:

"I think that probably my biggest problem with the way that MSK was taught is I didn't feel like there was a lot of repetition, and so even if I learned it in that moment, for the medical foundations, it didn't feel like I really retained it by the time I got to my electives" 007-S

Students also indicated that since the MSK subunit is located at the end of their medical foundations training, that many find it difficult to focus on the content due to feeling "burned-out" at that point in the curriculum. Students suggested that the topic

needs to be more longitudinal and introduced early in their foundational training to encourage repetition and long-term retention of the content. For example, one student suggested:

"I think a couple of things should be helpful—I think making it more longitudinal, instead of shoving into a month. It's so common that I think that having it early is helpful, but also not dropping it after that." 006-S

2.3.1.5 Underrepresented and Variable Clinical Experience

In terms of MSK clinical experiences, participants described student exposure to MSK conditions as being underrepresented and extremely variable. The orthopedic rotation during clerkship is the primary clinical setting in which students receive exposure to MSK conditions. Since this rotation is only 2 weeks in length, they often do not get to see a wide variety of cases. Moreover, their experience is highly dependent on the site and preceptor they are assigned to during clerkship. One faculty member stated:

"The entire MSK clinical experience is compressed into three- or four-days experience, and then, if you're going to, say, a non-orthopedic specialty, or a non-MSK specialty, those 3-4 days are the basis for your career, because it's not mandatory in, say, family medicine. So, I think it's the exposure time that's limiting." 006-F

Some faculty members suggested that blocking MSK-heavy clinical rotations together would give students the opportunity for long-term exposure to MSK content during clerkship. Moreover, students indicated that there is a paucity of MSK-related learning opportunities in clinical settings within the curriculum outside of their orthopedic clerkship. Many specifically indicated that MSK is particularly underrepresented when compared to the prevalence of MSK conditions across specialties. One student commented:

"It's [MSK in clinical settings] very, very underrepresented, because you think about like, you know the majority of the class is going to go into something like family medicine, and then even if they're not, there are very few specialties that don't benefit from knowing MSK." 008-S

2.3.1.6 Underemphasized Yet Essential: MSK Anatomy

Both students and faculty identified MSK anatomy knowledge as a particularly weak content area for students. While students recognised the importance of knowing the relevant anatomy for diagnosing and treating MSK conditions, they described the medical foundations anatomy curriculum as being insufficient to gain an understanding of the "minutia" required for the depth of understanding they are expected to have during their orthopaedic clerkship rotation. Faculty members specified that the self-directed learning environment of the curriculum necessitates that students must learn anatomy of their own accord, and that not many students engage in the material at the depth required for their orthopedic rotation. One faculty member commented:

"I would say they are weak in anatomy, which is not atypical for McMaster medical students. I mean, it has been like that every year. You know, they have to sort of take it upon themselves to do electives and learn it, and they don't. So, anatomy would be one issue." 001-F

Students described anatomy as being underemphasized in the curriculum, perceived as an elective component, and lacking long-term access to anatomy resources at the regional campuses. This underemphasis led to a lack of motivation for many students to learn MSK anatomy. One student stated:

"And I think that [motivation] can be the initial obstacle, especially in a program like Mac where MSK anatomy is, dare I say, a bit underemphasized." 003-S

2.3.1.7 Specialty Blinders and Intrinsic Motivation

Students indicated that there is also a lack of intrinsic motivation for many to learn MSK content primarily due to student perceptions that MSK is not a priority unless they are interested in pursuing an "MSK-heavy" speciality such as orthopedics. One student commented:

"I think motivation will be a barrier, only because those people who feel like they are maybe going into a specialty where MSK anatomy is really low yield, they will have a number of other things on their plate that they might prioritize before learning the anatomy" 007-S

Faculty members also identified this lack of intrinsic motivation as an issue in the self-directed learning environment of medical foundations. While they identified that "MSK-interested" students in the program were generally better prepared for their orthopedic clerkship rotation, they felt that the majority of students did not have the knowledge base to thrive during the rotation. One faculty member speculated:

"If the student doesn't have the initiative or the interest- they don't think that MSK is that important for them —then I find that they lag behind, you know, we get students that are surgically interested or MSK interested, if they're MSK interested, then they're knowledge from McMaster is very good, whereas there are other students who are focused on different areas, and they haven't brushed up on MSK—despite the fact that, MSK is really essential for every single medical specialty." 004- F

2.3.1.8 Implicit Signalling and Triaging Time

Students noted that if they did not have intrinsic motivation to learn the subject (i.e., the desire to pursue an MSK-related specialty), the structure of the MSK portion of their medical foundations curriculum did not provide external motivation for students to learn the subject. They noted that the MSK portion of the curriculum is seen as being

"elective" in nature due to a lack of formative testing and attendance in anatomy sessions being voluntary. One student commented:

"I think in the Mac curriculum there is a lack of extrinsic motivation to learn MSK. It's integrated, into our problem-based learning cases, but it is by no means necessary, we're by no means assessed on it in any formative sense. And I think that lack of extrinsic motivation is part of the reason why the weekly anatomy sessions, had historically, and this year, quite a low turnout." 003-S

Moreover, the voluntary nature of the anatomy sessions and lack of formative testing implicitly signals to students that MSK is not an important part of the curriculum, and thus, many students choose to allocate their time elsewhere. One student commented:

"So I think that making it [MSK anatomy] voluntary makes it not important, and I think that the program implicitly signals that anything not mandatory is not important, and we spend our time on other things." 006-S

2.3.2 Perceptions of the Potential Efficacy, Feasibility, and Viability of a Self-Directed Learning Tool

2.3.2.1 An Accepted Adjunct Method to Clinical Experience

When asked about the prospect of a self-directed learning tool, faculty and students speculated that it would be widely accepted and useful for students specifically during their orthopedic clerkship. Participants thought that an accessible learning tool would provide for more standardization across the different clerkship sites and preceptors and would ensure that students be exposed to a variety of MSK topics. Many students commented that they felt unprepared for their orthopedic clerkship and that the tool might be able to cover gaps in their MSK knowledge. Faculty members also echoed this sentiment. One faculty member commented:

"I think it [a learning tool] would be useful, because I don't think they're getting the exposure to all the different topics we want them to, and it's too is hit or miss. Having

tool that they can use, I think would make it more comprehensive and thorough. Right now, it's very spotty – their orthopaedic trainings – site based, and student motivation based, and everything." 001-F

Students spoke about how self-directed learning is a method that they are already quite familiar and comfortable using since their medical foundations training had a self-directed focus. Students indicated that the existing material provided to them during their orthopaedic clerkship was superficial and insufficient to assist in learning MSK content. Students also felt as through their medical foundations did not prepare them for the cases and pathology that preceptors expected them to know, and that a self-directed learning tool could supplement their perceived gaps. One student commented:

"I would want to see a little bit of everything. I would want to see the clinical perspective, MSK presentations, I want to see indications or contraindications for like surgery for orthopaedics, I want to see like different rheumatological conditions, some of the physiology behind that. And then also, MSK anatomy. I think that would be really helpful, especially for your orthopaedic rotation." 005-S

2.3.2.2 Faculty Outlined and Supported Objectives

Students thought that the tool should be built around faculty developed and supported objectives to inform what students are expected to know during their orthopedic clerkship. Students identified that there seemed to be discord around what their preceptors expected during their orthopedic rotation, compared to what their medical foundations curriculum emphasized. One student commented:

"I think it's difficult because my preceptor had very high expectations for what he thought we should know in terms of our anatomy, whereas we did not know that anatomy at all. So there was a lot of that discord between what we were expected to know by the curriculum and what our preceptors wanted us to know." 005-S

Faculty members also indicated that detailed objectives are vital to self-directed learning to guide students to relevant content. Specifically, they thought that self-directed learning has to be partially directed to be effective. One faculty member commented:

"I think self-directed learning is vital, I mean they're [students] going to have to go back and read about 'x' 'y' and 'z' and find where to get it and I think it's totally vital. But I think self-directed learning needs to be marginally directed in terms of what they need to self-directed learn." 008-F

2.3.2.3 Integration of MSK Anatomy and Examination Skills

MSK anatomy was identified as being a critical component to the content development of the learning tool, given that it was recognized as a persistent weakness in student MSK knowledge. Specifically, students emphasized that the anatomy included in the tool should be clinically relevant and integrated into case-based applications. One student commented:

"Knowing the clinical applications would be really great. Because having an anatomy app that stand alone just lists muscles and bones doesn't really mean much to me, but as soon as you sort it by issue, it kind of makes more sense." 002-S

MSK examination skills were also identified as being a vital component to the learning tool's content development. Students relayed that having diagnostic content, such as MSK examinations, presented in a "functional" manner helps them conceptualize the different joint-specific examinations and the relevant pathological indicators when performing the maneuvers themselves. Specifically, students and faculty suggested presenting information in blocks according to extremity and the corresponding major joints. One faculty member suggested:

"The tool should have some structured outline of the target goals, expectations, and go through most of the major big joints in the body, and focusing on this is what you need to do to examine, and then testing at the end to make sure they've [students] captured the pivotal examination steps." 006-F

2.3.2.4 Multi-Modal and Interactive Delivery

In terms of structure, students and faculty advocated for the use of an interactive, online, module-based tool. They also indicated that the delivery of the tool should be multi-modal and include a variety of material for students to utilize, such as journal articles, videos and simulated anatomy components. One faculty member suggested:

"I think the most effective way to do this [create a learning tool] would be some sort of module where students could be asked questions and would have to click on the appropriate structure in some sort of interactive way, so they can actually get the experience of being asked questions, and apply their answers, and being directed in that manner to understand MSK" – 004-F

Students also recommended that the learning tool be interactive, since a key issue with the delivery of their medical foundations MSK training was its passive nature. One student stated:

"I think, resources would have to be a bit interactive, because one of the problems with lectures is that they are a bit too passive…so if such a module was to exist, and I would say that there is a need and a desire for it, then it would have to be interactive" 003-S

2.3.2.5 Critical Content Areas and High Yield Content

Students emphasized that the tool should focus on common MSK conditions and "high yield content", since they felt as though much of their previous MSK training revolved around the specialist-focused or uncommon pathology. One student commented:

"I think that sometimes, in an effort to make such a broad exposure to everything, they spend too much time on the weird and wonderful things, and not enough on common things. If we knew all the common things, we would understand 95% of what we're going to see." - 006-S

Specific content areas that faculty identified as being pertinent for the learning tool to cover included orthopedic related emergencies, common fractures and soft-tissue injuries, and pediatric specific conditions. One faculty member advised:

"I always say, you have to know the orthopaedic emergencies- compartment syndrome, open fractures, cauda equina, and necrotizing fasciitis. Those are things you have to get down, because there's no time to waste if you see one of those… Then, of course, common fractures and injuries- back pain, right? And things people always break—wrists, ankles, shoulders- when they fall on ice and slip. Those things should be the front runners, and then the pink elephants can come after." – 007-F

2.3.2.6 Self-Assessment and Case-Based Applications

Faculty and students promoted the use of self-assessments, or check points within each module to help students consolidate key information and evaluate their knowledge on the different MSK conditions presented in each module. One student suggested:

"Having a self-directed tool, that does practice questions, I think that would be the most useful. I mean, you learn the most when you get a question wrong, or like you're reading the question and you don't know how to answer it, or you don't know what the next step in management is. And then being told, thoroughly, what the proper answer is." 001-S

Many students also recommended the use of case-based scenarios to enhance their understanding of how the content would apply to real patient encounters. They stated that this would be extremely helpful in preparing for cases encountered during their orthopedic rotation. One student suggested:

"So if we could have a more interactive tool that helps you not only memorize the different MSK components, but also teaches you a way to conceptualize MSK cases and how to think about them in that sort of clinical and problem-based way- if it can help facilitate that, then it would be very useful." 003-S

2.4 Discussion

Medical school curricula should reflect the health needs of the populations they serve (1). Given the high prevalence of MSK conditions (1, 2), a strong foundation of knowledge in MSK medicine should be central to modern medical education. Thus, it is critical that specific gaps in MSK medicine training be addressed in a comprehensive manner that overcomes the barriers to implementing robust MSK education identified in previous work (1, 2). These barriers include a lack of time and resources dedicated to the subject; given that self-directed learning has been identified as an effective and efficient learning modality in other areas of health professions education, a novel self-directed learning tool may be viable a way to improve instruction in MSK medicine.

2.4.1 Identifying Strengths and Weaknesses in the MSK Curriculum

Research examining MSK curricula have identified that MSK is underrepresented as a whole in UGME, both in terms of foundational and clinical teaching (4, 21). In this particular setting, students and faculty recognized that a vast content area such as MSK medicine requires a significant portion of time allotted to its instruction. However, only one and a half months of structured time is allocated to MSK medicine- this includes one month of medical foundations teaching, and 2-weeks within an orthopedics rotation during clerkship.

Students described the delivery of the content during their month-long medical foundation's subunit as a "firehose" of content and emphasized that the curriculum needed to be more longitudinal to promote long-term retention. The 2-week orthopedic clerkship is the primary setting in which students gain exposure to MSK conditions in a

clinical setting, which is highly variable and dependent on site and preceptor. Both faculty and students also spoke of a scarcity of clinical learning opportunities in this area outside of their orthopedic clerkship rotation. Our findings align with previous research on the prevalence of MSK instruction in Canadian medical schools that on average, only 2.26% (range, 0.61% to 4.81%) of Canadian medical school curricula is dedicated to MSK instruction (21). Furthermore, only five of the sixteen schools surveyed in this study by Pinney et al. provided mandatory musculoskeletal education within a clinical setting, such as in orthopedics, rheumatology, or rehabilitation medicine (21). In contrast, a literature review conducted by these authors indicated that up to 27.8% of problems amongst patients presenting in primary care settings are MSK-related. Thus, the scarcity of MSK instruction and clinical exposure provided to medical students poses alarming implications for the quality of care provided to patients with MSK complaints in primary care settings.

Concerns about MSK medical education specifically regarding the insufficient time dedicated to MSK anatomy teaching has also been identified in the literature (20, 37-39). While an understanding of anatomy has been highlighted as a critical component of MSK medicine, there is evidence to suggest that medical students and practicing physicians have substantiative knowledge gaps in this area (40-42). This is especially concerning since many academic medical institutions have reduced the time allotted to basic anatomy teachings (20, 39, 43). Our study supports these observations, with MSK anatomy consistently being identified as the most common area of weakness amongst medical students during their orthopedic clerkship rotation.

Interestingly, the themes identified in this study also reflect the way in which students interpret the implicit priorities their medical school sets through the structure and organization of the curriculum and corresponding assessments. In McMaster's UGME curriculum, anatomy session attendance is voluntary, which many students took as a signal that the sessions were not an important component of their MSK subunit. Moreover, the lack of formative testing throughout the subunit further reinforced this perspective, resulting in low extrinsic motivation for students to learn the content. It is generally accepted that assessment drives medical student learning; what medical students learn is often influenced by how they think they will be assessed (44, 45). This phenomenon has specifically been examined in relation to anatomy instruction (44). Wormald et al. constructed a survey to assess the effect of assessment structure on students' motivation to learn anatomy. The results of this investigation revealed that increasing the weighting of anatomy within the curriculum's assessment significantly increased students' drive to learn the subject (44). While many students and faculty members in this study iterated the importance of MSK and MSK anatomy knowledge regardless of specialty, this perception was not ubiquitous. Learning MSK content was often identified as being a low priority for students who were not interested in what they perceived to be as "MSK-heavy" specialties, thus resulting in further amotivation to learn the content. This theme further reiterates the importance of considering how assessment might drive students to learn content they might not otherwise be motivated to learn. Moreover, work must be done to iterate the importance of understanding anatomy and

MSK medicine to medical students as these subjects pertain to family medicine and other specialties.

2.4.2 The Potential Efficacy, Feasibility, and Viability of a Self-Directed Learning Tool

A self-directed learning tool was identified by students and faculty as a potentially useful learning modality to enhance students' clinical experiences during their orthopedic clerkship. In terms of how participants conceptualized a self-directed learning tool, faculty and students promoted the use of an interactive, virtual tool covering orthopedic emergencies, common soft-tissue injuries and fractures, and pediatric specific conditions. The aforementioned content areas have been identified as core curriculum items that should be included within UGME, and are outlined in the Canadian Multidisciplinary Core Curriculum for MSK Health (46). This set of objectives was originally developed by the Bone and Joint Decade Undergraduate Curriculum Group and was subsequently validated by a set of Canadian educators representing medical disciplines that manage MSK conditions (46). The motivation behind these actions was so that medical schools would adopt these curricula. Additional support for the use of these topics are found within the self-directed learning tool (46). Similar topics were also identified by a Delphi consensus study on topics, skills, and cases that should be included in MSK curricula (47). Our study involved international MSK experts who identified common fractures and dislocations, red flags and emergencies, and a limping child as being amongst the most important MSK knowledge topics for medical students to learn. Participants in our study also advocated for case-based applications and self-assessment questions to help with

content retention, and structured guidance provided by their preceptors to direct their learning to relevant content areas.

Based on our results, a self-directed learning tool spanning the previously identified critical content areas will be developed. A general approach to orthopaedic MSK problems will be outlined, with each content area structured by extremity and further divided into the corresponding major joints. The purpose of this structure will be to provide students with a coherent and compartmentalized approach to identifying and managing MSK conditions. Within each extremity and major joint component, the relevant MSK examinations and corresponding orthopaedic anatomical concepts will be integrated to promote a functional and structured approach to the diagnosis of common MSK pathologies. The self-directed learning tool will target identified gaps in student orthopaedic anatomical knowledge and MSK physical examination concepts while exposing students to common soft tissue injuries, fractures, pediatric conditions, and emergencies. All the modules will contain self-assessment activities in the form of multiple-choice and case-based short answer questions to reinforce key concepts and provide students with opportunities to apply the concepts from the module to clinical scenarios.

2.4.3 Strengths and Limitations

This study has both strengths and limitations. First, this study captured stakeholder perceptions at a single Canadian institution and is therefore limited in its generalizability to other settings. Moreover, the faculty members sampled for this study were preceptors from the orthopedic clerkship rotation and had limited experience in

teaching in the medical foundations portion of the curriculum. The MSK experiences and perceptions of faculty captured in this study are orthopedic-specific, and thus, the self-directed learning tool developed from these findings may have limited applications beyond this scope.

In terms of its strengths, this research was approached primarily from the perspective of the learner and will provide an MSK learning intervention that has been informed by the voice of students. Rigour was also promoted throughout the research process, and strategies to achieve credibility, dependability and confirmability were considered. Overall, this project adds to the limited literature that exists on Canadian medical school MSK training and will inform the development of effective learning modalities in MSK medicine.

2.5 Conclusion

With the burden of MSK conditions expected to rise with the aging population, it is crucial that medical students receive adequate training to properly diagnose and treat patients with these conditions. While the results of this study indicate that MSK teaching is insufficient, self-directed learning is welcomed by students and faculty as a potential solution to this issue and is supported as an effective learning style. The themes identified in this study outline strengths and weaknesses of an MSK curriculum that will be used to develop a leaner-informed tool that will deliver clinically relevant MSK content to medical students on an engaging and interactive platform. This leaning tool will comprise of interactive modules covering critical content areas in MSK medicine, and will include case-based learning and self-assessment activities.

Appendix A: Interview Guide

- What do think is the most effective way for students to learn MSK topics?
- What settings do you normally teach students in and what methods do you use to teach students? Do you think these methods are effective or ineffective? How so?
- What are the other types of methods used to teach MSK to medical students?
    - Do you think students find this method of learning to be helpful and effective? What do you like or dislike about the methods and how do you think they could they be improved?
- How effective do you think large-group lectures are in teaching students MSK medicine?
    - What is the attendance like at large group lectures?
    - Do you think students enjoy the large group lecture style?
- Have you noticed any specific areas of MSK medicine that students are weak in?
- Are there any specific areas of the MSK curriculum that need improvement?
- Outside of normal lectures and assigned work, are there any outside resources that you provide to your students on MSK medicine or would like to provide if you had more time or the resources?
- Do you feel as though the way in which students are taught MSK topics adequately prepare them for their ortho rotation in clerkship?
- Do you think that there are any barriers that exist to teaching MSK medicine effectively?
- What is your overall perception of using self-directed learning to teach medical students?
- What do you believe that effective self-directed learning involves?
- What do you think an effective self-directed learning tool for MSK medicine would look like?

- What content would you like to see specifically in a learning tool which is meant to improve student knowledge of orthopaedic related MSK issues?

- Can you think of any high yield MSK topics that should be included in the development of the learning tool?

    - Do you think there are certain parts of MSK that are best learned by self-directed learning?

    - Are there any specific learning techniques such as case-based learning that you would like to see integrated into a self-directed learning tool?

    - Do you think this self-directed learning tool would be useful for students during their ortho clerkship?

- Have you ever incorporated self-directed learning into your teaching? If so, please describe this experience and what you found to be effective or ineffective.

- Do you think that students would be interested in using a self-directed learning tool like this?

- Do you think that students would benefit from an MSK self-directed learning tool?

- Would you be interested in using more self-directed learning opportunities for students to learn about MSK medicine?

- Would you be interested in incorporating any other learning techniques for teaching MSK medicine into the current curriculum?

- Are there any barriers to implementing a self-study tool within the orthopaedic clerkship rotation?

- Is there anything else you would like to comment on?

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Chapter 3

Evaluating the Implementation and Efficacy of a Self-Directed Learning Tool for Musculoskeletal Medicine

3.0 Evaluating the Implementation and Efficacy of a Self-Directed Learning Tool for Musculoskeletal Medicine

3.1 Introduction

Across the globe, medical trainees consistently fail to demonstrate basic competency on validated MSK examinations and report a lack of confidence in their ability to appropriately manage MSK conditions (1, 2). These deficits in MSK knowledge amongst medical learners and physicians alike have been linked to inadequate instruction in undergraduate medical education (3). There have been various shortcomings identified within existing MSK curricula, including insufficient classroom and clinical time dedicated to the subject, a lack of resources, and inadequate knowledge of basic anatomical concepts amongst medical students (2, 4-6).

Various initiatives have been implemented around the world to address this recognized issue, some of which have spurred widespread curriculum reform in medical schools within certain countries (7-9). Specifically, a global effort to improve the quality of MSK curricula was created in the early 2000s as part of the Bone and Joint Decade (2000-2010), and the International Education Task Force and Undergraduate Curriculum Development Group were established (10). As part of their agenda these groups created a set of global core curriculum recommendations for MSK undergraduate medical education to be adapted to local institutional needs (10, 11). Medical schools and education bodies around the world quickly adopted these guidelines, and various countries based their own MSK medical education standards around the Bone and Joint Decade's recommendations (7-9).

Despite these global efforts, there have been few examples of MSK curricula evaluation endeavors documented in Canada specifically. The most recent and thorough review of Canadian MSK curricula was conducted in 2001 by Pinney et al., who administered a survey to the sixteen medical schools existing in Canada at that time. This survey assessed program directors' perceptions of the quality of MSK education delivered in their curriculum, and the percentage of the curriculum dedicated to MSK-related education in both preclinical and clinical contexts (4). A rating scale ranging from 1 (inadequate) to 5 (excellent) was used to rank the quality of teaching, time and resources available, quality of preclinical and clinical education, and overall quality of the MSK curriculum. In total, 11 program directors indicated that the time dedicated to MSK teaching was inadequate, and 7 rated their institution's MSK curriculum as being inadequate overall. The questions that assessed the resources, quality of preclinical education, and the quality of clinical experiences with respect to MSK education obtained an average rating of 2.81, 3.0, and 2.93 respectively. It was also determined that on average, only 2.26% (range, 0.61% to 4.81%) of curriculum time was devoted to MSK education (4). Although this study revealed stark inadequacies within Canadian medical schools' MSK curricula, there have been limited attempts to initiate concentrated reform. The most prominent effort to realize change in Canadian MSK curricula was conducted by Wadey et al. in 2007, whereby the Bone and Joint Decade's Undergraduate Curriculum Development group's core recommendations were validated for use in Canadian settings. This group also added items thought to be important at the

postgraduate level, and produced the Canadian Multidisciplinary Core Curriculum for MSK Health (11).

Given the established need for robust MSK education (6), we set out to evaluate the strengths and weaknesses of the MSK curriculum at the DeGroote School of Medicine and the potential use of self-directed learning to overcome gaps in instruction. This was accomplished through a qualitative interpretive description study engaging both medical students and orthopedic faculty members. Students and faculty members reported inadequate MSK anatomy knowledge and instruction, sparse opportunity for immersion in MSK-focused clinical settings, and a scarcity of intrinsic and extrinsic motivation for students to learn MSK content due to a lack of formative testing and interest in "MSK-heavy" specialties. Moreover, the MSK curriculum was described as being extremely short for the amount of material expected to be learned, and that the lack of longitudinal integration of the subject throughout their education led to a general feeling of unpreparedness amongst students prior to entering their orthopedic clerkship rotation.

Self-directed learning was identified as a potentially viable solution to these issues since its effectiveness in health professions education settings has been well documented (12, 13). Moreover, it presents as a resource and time efficient way for increasing student exposure to MSK clinical concepts. This is key to overcoming the barriers to implementing comprehensive MSK curricula, which have been cited as a lack of human resources and insufficient time dedicated to this subject area in both foundational and clinical instruction (3, 14). Students and faculty members who participated in our qualitative study conceptualized an online, module-based self-directed learning tool for

student use during their orthopedic clerkship rotation. This self-directed learning tool was constructed with the intent of filling the identified gaps in student MSK knowledge and its design was informed by the voice of learners and instructors. The learning tool spans 4 key areas: Common Soft Tissue Injuries, Common Fractures, Orthopedic Red Flags and Emergencies, and Pediatric Orthopedics. These overarching areas were identified as being relevant during our qualitative assessment of the MSK curriculum, and the subtopics covered within each of these areas were informed by the Bone and Joint Decade's Undergraduate Curriculum Group core curriculum recommendations (11). The tool is comprised of a collection of online modules and learning resources which were guided by the objectives outlined by the Bone and Joint Decade.

The purpose of this study was to explore the efficacy of the self-directed learning tool in helping students learn MSK content during their orthopedic clerkship rotation. Specifically, the primary objective of this study was to assess the impact of the self-directed learning tool on student knowledge of orthopedic MSK conditions, and the secondary objective was to assess the implementation of the self-directed learning tool and identify necessary modifications to the structure and the content to improve its delivery.

3.2 Methods

To assess the efficacy and implementation of the learning tool, this study employed a two-group pre-test post-test design. Data were collected from orthopedic clerks from January 2021 to May of 2021 using two MSK knowledge assessments. Students completed the pre-test before starting their rotation and completed the post-test

at the end of their 2-weeks in orthopedics. Pre-test scores were obtained to establish students' baseline MSK knowledge and enable the measurement of improvements over the course of their orthopedic clerkship rotation. These test scores were also used to determine the impact of the self-directed learning tool on students' MSK knowledge.

Students who completed their orthopedic clerkship rotation without the self-directed learning tool from January to March of 2021 served as the comparator group. The self-directed learning tool was implemented in the DeGroote School of Medicine's 2-week orthopedic clerkship rotation in March of 2021 as a voluntary learning resource. There was no opportunity for contamination between groups as the learning tool was released to students in March after the last students in the control group completed their rotation in orthopedics. At the end of their orthopedic clerkship rotation, students were asked to complete a survey to assess the implementation of the self-directed learning tool.

3.2.1 MSK Knowledge Assessments

The most widely validated and implemented assessment for measuring medical student MSK knowledge is the Freedman and Bernstein examination (15). This examination consists of 25 short-answer questions that covers topics from orthopedics and primary-care settings including fractures and dislocations, emergencies requiring immediate orthopedic referral, and basic anatomical knowledge necessary for the diagnosis of MSK conditions (15). A score of 73.1% was deemed as being representative of "basic competency" in MSK medicine. Outside of the Freedman and Bernstein evaluation, there exists a paucity of testing methods to assess medical students' MSK knowledge. No other examinations have become prevalent in the literature since the

introduction of the Freedman and Bernstein examination in 1998. Recently, Cummings et al. (2019) developed a 30-question multiple choice examination dubbed the MSK30. This MSK knowledge assessment includes topics such as trauma, infection, pediatrics, and sports injuries. A modified Delphi method was used to obtain consensus on the importance of each item included in the assessment (16).

Using the MSK30 for the pre-test and the Freedman and Bernstein examination for the post-test, or vice versa, would have posed issues to accurately measuring the progress of students throughout their orthopedic clerkship rotation due to differences in examination structure and topics covered within each assessment. Instead, individual questions were extracted from these two assessments to construct the pre-test and the post-test. Each examination's questions were reviewed for their relevance to the self-directed learning tool's objectives and separated into the categories corresponding to the topic covered. An equal number of multiple-choice questions and short-answer questions were included in each assessment, and similar topics were covered within the pre-test and post-test. It was critical to capture student knowledge before and after their orthopedic clerkship rotation to gauge MSK knowledge obtained and retained from their pre-clinical education, as well as the potential impact of clinical experience on MSK knowledge. An overview of each test is available in Appendix A and B.

3.2.2 Cross-Sectional Survey

This survey was developed by the primary graduate student researcher and investigated the implementation of the learning tool. This survey was emailed to students on the last day of their orthopedic clerkship rotations to evaluate the learning tool's

implementation and usefulness throughout the rotation. Section A of the survey assessed the effectiveness of the learning tool's implementation through 12 items measured on a Likert-type scale, whereas Section B and C evaluated areas for improvement and overall successes of the learning tool. A copy of this survey is available in Appendix C.

3.2.3 Statistical Analysis and Sample Size

An analysis of covariance (ANCOVA) was used as the primary statistical analysis in this study. Pre-test scores were incorporated as a covariate to adjust for potential differences in students' MSK knowledge scores coming into their orthopedic clerkship rotation. The assumptions of normality, homogeneity of variance, and homoscedasticity were examined using Shapiro-Wilk's test, Levene's test, and inspection of residual scatterplots. An *a priori* sample size of 128 was determined using a moderate effect size (f=0.25), an alpha of 0.05, and a power of 0.8 in G Power (Version 3.1).

As a secondary analysis, a paired samples t-test was utilized to examine the mean change in MSK knowledge scores across each group. Also, the proportion of students meeting Freedman and Bernstein's basic competency benchmark of 73.1% post-rotation was compared between the learning tool group and the control group using the Chi-Square test. Survey data were analyzed using descriptive statistics. Averages and standard deviations are presented for each item included in the survey, and frequencies with percentages are displayed where appropriate.

3.2.4 Supplementary Data Collection

After completing a preliminary analysis of the survey data, it was determined that supplementary data collection was necessary to explain some of the results obtained from

student responses. Thus, open-ended response options were added to the survey to give students the opportunity to elaborate on their selections for the learning tool's improvement and successes (Section D). These open-ended responses were analyzed using qualitative content analysis by two independent coders. This process involved the coders familiarizing themselves with the data, deriving codes from the data, and collating the codes into emergent themes and categories (17). The themes and categories formed from the open-ended response data were then triangulated with the quantitative data obtained from the survey, making this cross-sectional survey's methodology a convergent mixed methods design (questionnaire variant). This approach is commonly used when the researcher requires extra data to validate and enhance quantitative survey findings (18).

3.3 Results

One hundred and forty medical students in their 2nd and 3rd year of training completed the MSK pre and post-tests from January to May of 2021. Of these students, 53 completed their orthopedic clerkship without the learning tool (January – March), and 87 completed the rotation with the learning tool (March – May). The data met the assumptions for the ANCOVA based on visual inspection of the scatter plots and the insignificant values of the Shapiro-Wilk's test and Levene's test at the $p > 0.05$ level. Out of those with access to the learning tool, 11 completed the implementation survey.

3.3.1 MSK Knowledge Assessments

The average pre-test score in the control group consisting of students without access to the learning tool was 57.6% (95% Confidence Interval [CI], 54.8% to 60.5%), and 57.7% (95% CI, 54.9% to 60.5%) amongst the students with access to the learning

tool. The average adjusted post-test score was 80.5% (95% CI, 78.1% to 83.0%) in the control group and 82.1% (95% CI 80.2% to 84.0%) in the learning tool group. The mean difference between the learning tool group and the control group was 1.6% (95% CI, -1.6% to 4.7%), and statistically insignificant ($p = 0.33$).

When examining the difference in MSK knowledge scores after students completed their orthopedic clerkship rotation, both the learning tool and the control group demonstrated significant change. The mean difference between the pre-test and post-test scores was 24.4% (95% CI, 21.2% to 27.6%, $p<0.001$) within the learning tool group, and 22.9% (95% CI, 19.6.2% to 26.2%, $p<0.001$) in the control group. Moreover, of the 87 students in the learning tool group, 73 (83.9%) passed the basic competency benchmark of 73.1% post-rotation; of the 53 students in the control group, 43 (81.1%) passed. The difference in proportions of students who passed between groups did not represent a significant difference ($p=0.67$). Figure 1 and Tables 1-4 demonstrate these scores.

3.3.2 Survey Results

Overall, 21 students with access to the self-directed learning tool completed the survey. The mean and standard deviations for each item presented in section A of the survey are displayed in Table 5. Notably, all agreed or strongly agreed that the content covered in the learning tool was relevant to the orthopedics rotation, and 19 (90.4%) agreed or strongly agreed that their understanding of orthopedic MSK conditions increased as a result of using the learning tool. Moreover, 20 (95%) of students agreed or strongly agreed that the amount of content in the learning tool was appropriate and that

the self-directed learning tool was an effective way of learning about orthopedic MSK conditions.

In terms of improvements, the most common area identified as being in need of modification was the delivery of the learning tool (n=11, 52.4%). It was also suggested that the selection of the learning resources could be improved (n=5, 23.8%), as well as the structure of the modules (n=4, 19%). When evaluating the successes of the learning tool, the most commonly identified aspect was the self-assessment questions (n=11, 52.4%). Students also indicated that the content included in the modules was a success of the tool (n=6, 28.6%), in addition to the explanations provided with the self-assessment questions (n=5, 23.8%) and the objectives outlines within the tool (n=3, 14%).

Within the open-ended responses, three overarching themes were constructed. First, students emphasized the broad utility of the learning tool. Specifically, students indicated that they would be using the tool to learn about MSK medicine beyond their orthopedic clerkship rotation, such as during their pediatric and family medicine rotations, and described the learning tool as being extremely helpful in preparing for their end of rotation assessment. However, students also stated that the delivery of the learning tool needed improvement: they indicated that the usefulness of the learning tool needed to be emphasized more at the beginning of their rotation so that they would be able to schedule their time more effectively. Moreover, they stated that the vast number of resources provided to medical students during the course of the rotation tends to oversaturate and dilute the use of those that are most important and helpful; thus, highlighting the importance of the tool at the beginning of the rotation is critical.

3.4 Discussion

3.4.1 Efficacy and Implementation of the Self-Directed Learning Tool

This study explored the implementation of a novel self-directed learning tool and its efficacy in improving medical students' understanding and knowledge of MSK medicine during their orthopedics rotation through a 2 groups pre-test post-test design and a cross-sectional survey. The cross-sectional survey revealed positive perceptions of the learning tool and identified areas for improvement in its structure and delivery.

In 1998, Freedman and Bernstein developed the most widely validated and used MSK knowledge examination. During their validation process, they concluded that a score of 73.1% represented basic competency in MSK medicine (19). Although the MSK knowledge assessment used as a pre-test in this study is not identical to the Freedman and Bernstein examination, there are parallels that can be drawn between the two in terms of subject matter, length, and structure. When compared with Freedman and Bernstein's competency benchmark, 48 (90.6%) and 74 (89.7%) of students in the control group and learning tool group, respectively, failed to meet this score before entering their orthopedics rotation. This finding aligns with the results of our qualitative needs assessment, during which students largely reported that they felt unprepared to enter their orthopedic clerkship rotation due to inadequate foundational MSK knowledge.

Interestingly, students in both the learning tool group and the control group displayed significant change (over a 20% difference) between the pre- and post-test assessment scores. The average adjusted post-test scores for both the control group and learning tool group were above the basic competency benchmark at 80.6% (95% CI,

78.1% to 83.1%) and 80.9% (95% CI 78.3% to 83.5%), respectively. Moreover, 43 (81.1%) students in the control group and 73 (83.9%) of students in the learning tool group passed the basic competency benchmark. This improvement in scores is almost certainly due to the impact of the clinical experience students gained throughout their time in orthopedics. A broad array of studies have identified clinical exposure to MSK conditions and prior completion of an MSK elective as being two of the only variables that positively impact medical trainee and physician knowledge of MSK conditions (15, 20-22). The results from this study further iterate the importance of ensuring that medical students are exposed to MSK conditions in clinical settings, and the necessity of providing additional opportunities for students to engage with this subject matter. In fact, recommendations that have been produced within the realm of MSK education have suggested that "MSK-heavy" clinical rotations should be stacked in succession to provide students with a prolonged exposure to this subject area in a clinical setting.

While it appears that the effect of the self-directed learning tool was insignificant on students' MSK knowledge scores, the results from the cross-sectional survey demonstrate positive student perceptions of the learning tool. All students who completed the survey indicated that the tool as a whole helped increase their understanding of MSK conditions. Based on the results of the survey, we suspect that many students were not fully using the learning tool during their rotation. The most common area that students indicated for improvement was the delivery of the learning tool. Moreover, within the open-ended comments, students stated that the usefulness of the tool needed to be emphasized at the beginning of the rotation, and that they felt as though medportal (the

online curriculum management platform used at this medical school) has become oversaturated with resources, resulting in the dilution of those that are the most useful for students to use. Thus, further research will need to be conducted to evaluate the use and uptake of the tool following modifications to the learning tool's delivery to ensure that all students entering the orthopedic rotation are aware of its usefulness. This work is beyond the scope of the present thesis.

After validating the Bone and Joint Decade Undergraduate Curriculum Group's core curriculum recommendations for MSK education at the undergraduate level, Wadey et al. (2007) suggested changing the educational paradigm for MSK medicine by developing novel technologies to support this core curriculum. One of the initiatives they proposed involved a collection of online interactive modules based on the items in the MSK core curriculum as an educational tool to augment (and not replace) clinical encounters (11). More recently, a review published by Lynch et al. (2020) on MSK education also emphasized the use of technology in facilitating affordable, succinct, and evidence-informed MSK curricula reform (1). This self-directed learning tool provides a proof-of-concept creation that aligns with these ideals and has the potential to fill gaps in MSK curricula based on the results from the implementation survey. Future work will involve improving the uptake of the tool and expanding the module creation to include more topics in MSK medicine.

3.4.2 Strengths and Limitations

This study adds to the limited body of literature on MSK curriculum evaluation work performed in Canadian undergraduate medical education. The novel self-directed

learning tool evaluated in this study shows promise in furthering student exposure to MSK-related clinical concepts and augmenting clinical experiences. Modifications will be implemented to improve the tool's delivery and ensure students are aware of its potential uses prior to the start of their orthopedic clerkship rotation. This work also provides two new evaluations that medical educators are able to use to assess their students' MSK knowledge. These two assessments allowed us to examine the progression of student knowledge from the beginning to the end of their clerkship rotation, and the impact of clinical experience on medical student MSK knowledge.

However, there are also limitations in this study. First, the scope of knowledge tested by the assessments implemented in this study is limited in breadth and depth given that they were only composed of 20 MCQ and short answer questions. When compared to the scope of the learning tool, these tests only assess a portion of the material covered by the learning objectives, resources and modules in the tool. Student performance on multiple choice questions and short answers also does not necessarily extend to clinical performance, and the number of topics covered within these assessments was limited by the time available to test students. Ideally, to holistically assess students' understanding of MSK medicine, a combination of assessments would have been used, including objective structured clinical examinations (OSCEs), and faculty member evaluations from students' time during their orthopedics rotation.

3.5 Conclusion

In summary, although the learning tool failed to demonstrate greater learning in MSK content then experiential learning during clerkship, students indicated positive

perceptions of the learning tool and provided areas for further improving the delivery and design of the tool. Future work will involve modifying the self-directed learning tool and expanding its use to other settings.

Figure 1: Boxplot of MSK Knowledge Assessment Scores Before and After the Orthopedics Rotation

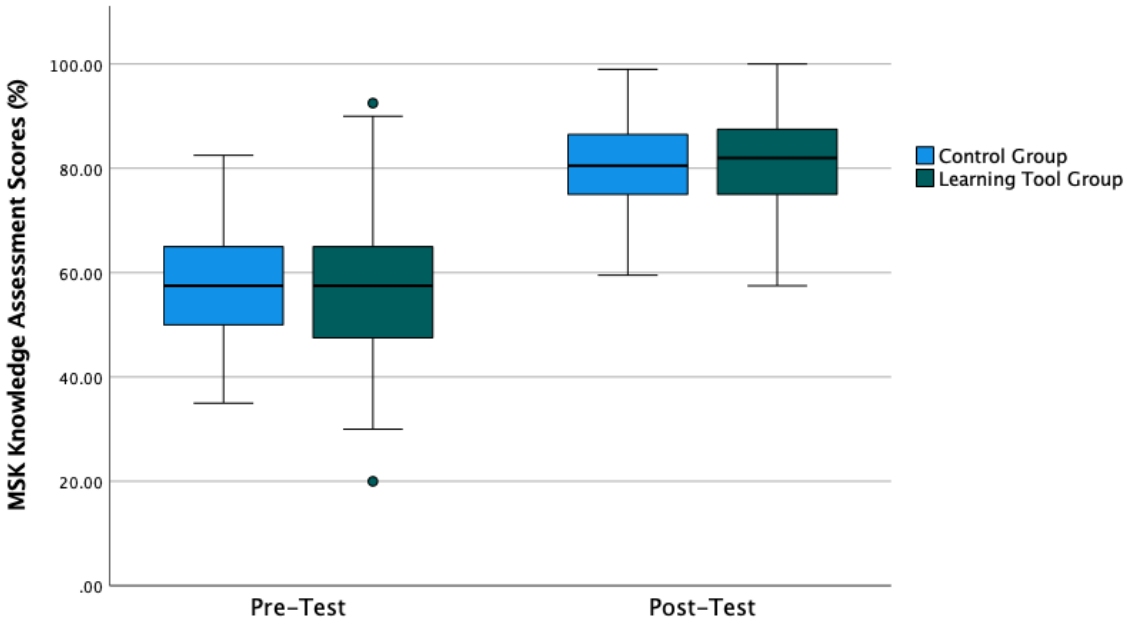

Table 1: Between-Group Differences of MSK Post-Test Scores[a]

Assessment	Control Group	Learning Tool Group	Difference (95% CI)	P Value
Post-Test Assessment	80.5% ± 1.3%	82.1% ± 1.0%	1.6% (-4.7% to 1.6%)	0.33
[a]Adjusted means ± standard errors, mean differences (95% confidence intervals [CI]) and p-values are presented for the post-test MSK knowledge assessment				

Table 2: Within Group Differences of MSK Pre- and Post-Test Scores[b]

	Pre-Test	Post-Test	Mean Difference	95% CI of the Difference	P-Value
Control Group	57.6% ± 1.4%	80.5% ± 1.2%	22.9%	19.6% to 26.2%	<0.001
Learning Tool group	57.7% ± 1.4%	82.1% ± 1.0%	24.4%	21.2% to 27.6%	<0.001
[b]Unadjusted means ± standard errors, mean differences (95% confidence intervals [CI]) and p-values are presented for the pre- and post-test MSK knowledge assessments					

Table 3: Proportion of Students Meeting Basic MSK Competency Pre-Rotation[c]

Pre-Test			
	Control Group (n=53)	Learning Tool Group (n=87)	P-Value
Pass	5 (9.4%)	9 (10.3%)	0.86
Fail	48 (90.6%)	74 (89.7%)	
[c] Proportion (%) of students meeting Freedman and Bernstein's basic competency score for MSK medicine pre-orthopedics rotation			

Table 4: Proportion of Students Meeting Basic MSK Competency Post-Rotation[c]

Post-Test			
	Control Group (n=53)	Learning Tool Group (n=87)	P-Value
Pass	43 (81.1%)	73 (83.9%)	0.67
Fail	10 (18.9%)	10 (16.1%)	
[c] Proportion (%) of students meeting Freedman and Bernstein's basic competency score for MSK medicine post-orthopedics rotation			

Table 5: Learning Tool Experience Questionnaire Item Scores

Learning Tool Experience Questionnaire Items	**Mean (SD)**
At the start of the orthopedic rotation, I received clear information and guidance on what the self-directed learning tool covered and on how assessments will be conducted	3.7 (1.5)
My understanding of orthopedic MSK conditions has increased as a result of using the learning tool	4.8 (0.7)
The learning tool content was relevant to the orthopedics rotation	4.5 (0.6)
The assessment at the end of the orthopedic rotation seemed more interested in testing what I had memorized than what I had understood	3.0 (1.1)
The learning tool made orthopedics interesting	3.6 (0.6)
The structure used in the modules helped me to learn	4.0 (0.8)
The self-assessment questions provided within the learning tool were helpful to my learning	3.9 (0.8)
The learning resources provided within the modules (videos/simulations) were helpful to my learning	4.0 (0.8)
The objectives provided within the learning tool were sufficiently detailed and helped guide my learning	4.0 (0.6)
The learning tool prepared me well for the assessment at the end of the orthopedics rotation	4.2 (0.7)
The amount of content in the self-directed learning tool was appropriate	4.4 (0.7)
Overall, I found the self-directed learning tool to be an effective way of learning orthopedic MSK conditions	4.4 (0.6)

Table 6: Successes, Improvements, and Supplemental Data Collection[c]

	Success	Improvement	Quotes
The delivery of the learning tool	3 (14.3%)	11 (52.4%)	"There's so many resources... I wish I used the self-directed learning tool from the beginning. Maybe take away the mandatory modules or somehow emphasize the learning tool more. There's other learning materials too (external resources, lectures on medportal, etc). When there's so much learning material out there it can dilute the most useful learning material. We only have 2 weeks after all." "The self-directed learning tool was the most helpful resource during my rotation. I loved the way the content was organized (very important for how I learn). I think this was more helpful than the module PowerPoints on med portal. I would say to please make this tool more obvious that it is available as a learning aid. If I knew earlier about it I would have scheduled my study plan differently and more effectively." "Excellent learning tool. Just emphasize its usefulness MORE at the start of the rotation, by de-emphasizing other resources - this is necessary because we have limited time in a short rotation. Medportal is too oversaturated with resources."
The structure of the modules	8 (38.1%)	4 (19.0%)	
The content of the modules	6 (28.6%)	1 (4.8%)	
The selection of learning resources provided within the modules	7 (33.3%)	5 (23.8%)	
The self-assessment questions	11(52.4%)	3(14.3%)	
The explanations for the self-assessment questions	5 (23.8%)	4 (19.0%)	
The objectives outlined in the learning tool	3 (14.3%)	0 (0%)	
Other	0 (0%)	7 (33.3%)	

[c] Success and improvement columns represent the frequency (%) of students selecting each option as either a success or something to improve for the learning tool within the survey. The quotes column contains feedback provided by students as part of the supplemental data collection and illustrates the themes of improving the learning tool delivery, oversaturation of reseources, and the usefulness of the tool.

Appendix A: MSK Pre-Test

1. A patient lands on his hand and is tender to palpation in the "snuff box" (the space between the thumb extensor and abductor tendons). Initial radiographs do not show a fracture. What diagnosis must be considered?

   Scaphoid fracture or carpal bone fracture

2. An 18-month-old toddler is brought to the emergency department for irritability, fever of 101.5°F, and refusal to walk or bear weight. The infant refuses to move the right hip and cries with passive motion. Ultrasound of the hip shows fluid in the joint. Of the choices listed, what is the most likely diagnosis?

   ✓A. Septic hip
   B. Transient synovitis
   C. Legg-Calve-Perthes disease
   D. Developmental dysplasia of the hip

3. What is compartment syndrome?

   Increased pressure in a closed fascial space

4. What muscle(s) control(s) external rotation of the humerus with the arm at the side?

   Infraspinatus OR teres minor OR rotator cuff

5. An 18-year-old football player injured his foot and ankle after it was stepped on during a game. He is able to bear weight on the foot but has significant pain in the midfoot region. Which of the following findings on history and physical exam would be an indication for x-rays?

   A. Pain with weight-bearing on injured foot/ankle
   ✓B. Tenderness on palpation of the first/second metatarsal bases
   C. Tenderness over the lateral foot distal to the fibula
   D. Tenderness at the anterior aspect of the medial malleolus

6. A patient has a displaced fracture near the fibular neck. What structure is at risk for injury?

   Common peroneal nerve

7. A 17-year-old rugby player catches his ring finger on an opponent’s shorts and feels immediate pain. On sideline examination, there is swelling of the distal ring finger.

When the DIP joint is isolated, the patient is unable to flex. Most appropriate management after the match is:

A. Buddy tape the ring finger to the long finger until symptoms resolve
B. Place in extension splint for six weeks
✓C. Referral to orthopedics
D. Relative rest for two weeks and re-evaluate

8. A patient punches his companion in the face and sustains a fracture of the 5th metacarpal and a 3-mm break in the skin over the fracture. What is the correct treatment? Why?

1. Irrigation and debridement
2. Risk of infection

9. A 64-year-old male with past medical history of hypertension, hyperlipidemia, and prostate cancer comes to the clinic complaining of new onset back pain that has woken him up from sleep on multiple occasions. Physical exam is unremarkable. The best next step in management is:

A. Physical therapy
B. NSAIDs
✓C. Imaging of spine
D. Rest and follow up in two weeks

10. A 25-year-old male is involved in a motor vehicle accident. His left limb is in a position of flexion at the knee and hip, with internal rotation and adduction of the hip. What is the most likely diagnosis?

Hip dislocation

11. A 10-year-old basketball player comes into clinic with gradual onset of left heel pain that is worse with running and jumping. On examination, he has tightness of the gastroc-soleus complex and pain with the calcaneal squeeze test. What is the most likely diagnosis?

✓A. Sever's disease
B. Calcaneal stress fracture
C. Achilles tendinopathy
D. Plantar fasciopathy

12. A patient has a disc herniation pressing on the fifth lumbar nerve root. How is motor function of the fifth lumbar nerve root tested?

Dorsiflexion of the great toe OR toe extensors

13. A 12-year-old boy severely twists his ankle. Radiographs show only soft-tissue swelling. He is tender at the distal aspect of the fibula. What are two possible diagnoses?)

    1. Ligament sprain
    2. Salter Harris I fracture

14. What common problem must all newborns be examined for?

    Congenital dislocation of the hip

15. A 45-year-old female who recently started playing tennis regularly comes into clinic with pain in her Achilles tendons bilaterally. Ultrasound confirms mid-substance Achilles tendinopathy bilaterally. The most appropriate initial management of this condition is:

    A. Referral to orthopedics for surgical management
    B. Corticosteroid injection
    ✓C. Rehabilitation focused on eccentric exercises
    D. Platelet-rich plasma injection

16. What muscle(s) is/are involved in lateral epicondylitis (tennis elbow)?

Wrist extensors OR extensor carpi radialis brevis OR extensor carpi radialis longus OR extensor digitorum communis

17. A 62-year-old female with hypertension, diabetes, and obesity comes into clinic with chronic left knee pain. Anterior-Posterior weight bearing radiograph of the knee shows medial joint space narrowing and osteophyte formation. Which of the following is the most appropriate initial management?

    A. Referral to orthopedics for joint replacement
    B. Obtain MRI of the knee
    C. Limit weight bearing until pain resolves
    ✓D. Recommend weight loss and exercise program

18. A high school football player comes into clinic after injuring his knee when he was tackled during practice. On inspection of the knee, he has a moderate effusion. Examination of the knee is limited by guarding and he has pain with motion of the knee. Which of the following should be included high on the differential diagnosis?

A. ACL tear
B. Osteochondral lesion
C. Medial meniscus tear
✓D. All of the above

19. A 31-year-old male comes into clinic with two weeks of lower back pain after helping a friend move into a new house. He describes the pain as dull and says it is diffuse but does not radiate down his leg. Physical exam reveals tenderness to the paraspinal muscles in the lumbar region but is otherwise unremarkable. What is the most appropriate next step in management?

A. X-rays of lumbar spine
B. Oxycodone
C. Referral for epidural steroid
✓D. None of the above

20. A 17-year-old high school football player is tackled and lands directly on the point of his left shoulder, causing him immediate pain. He points to the superior aspect of his shoulder when asked to locate the pain. On exam, his pain is reproduced when he attempts to reach across his body with the affected arm. What is the most likely diagnosis?

A. Deltoid muscle tear
✓B. Acromioclavicular joint sprain
C. Rotator cuff tear
D. Labral tear

Appendix B: MSK Post-Test

1. A patient dislocates his knee in a car accident. What structure(s) is/are at risk for injury and therefore must be evaluated?

   Popliteal artery

2. A 43-year-old male comes into clinic with worsening back pain for the last week. The pain is located in the lumbar region and is noted to be severe in nature. On exam, there is no bony tenderness but there is decreased sensation on the medial aspect of the thighs bilaterally. Review of systems reveals overflow incontinence for two days. What is the most appropriate next step in management?

   A. NSAIDs and follow up in two weeks
   B. Physical therapy
   C. Corticosteroid injection
   ✓D. Urgent MRI

3. Acute septic arthritis of the knee may be differentiated from inflammatory arthritis by which laboratory test?

   Cell count analysis of fluid from aspiration OR gram stain analysis of fluid from aspiration OR culture analysis of fluid from aspiration

4. A 41-year-old woman presents with a one-day history of a painful and swollen left elbow. She reports sustaining a puncture wound to her elbow several days prior but denies any major trauma. On exam, her elbow is erythematous and extremely tender to palpation with a deep puncture wound noted on lateral aspect of the elbow. Active and passive range of motion is markedly limited by pain. Vitals signs notable for temperature of 100.4 F (38^{o}C).What is the best next step in management?

   A. Prescribe a course of antibiotics and follow up after completed
   B. Treat empirically with colchicine and allopurinol
   ✓C. Arthrocentesis
   D. Relative rest, ice, and NSAIDs

5. What are the five most common sources of cancer metastatic to bone?

   Breast, prostate, lung. kidney, and thyroid

6. A 22-year-old male soccer player falls on an outstretched hand. He comes to clinic the next day complaining of wrist pain. On exam, he has tenderness over the anatomic snuffbox. X-rays of the wrist are negative. Of the choices below, the best next step in management is:

A. Immediate referral to orthopedics for surgical management
B. Relative rest and NSAIDs for pain
✓C. Short-arm thumb Spica cast and follow up in two weeks
D. Long-arm cast for 6-8 weeks

7. In elderly patients, displaced fractures of the femoral neck are typically treated with joint replacement, whereas fractures near the trochanter are treated with plates and screws. Why?

   Blood supply to femoral head OR avascular necrosis OR non-union

8. An 18-year-old female who runs cross country comes into clinic with one month of worsening right-sided deep groin pain. Pain is made worse with any weight-bearing activities. Review of systems is remarkable for amenorrhea and a BMI of 19. What is the best next step?

   ✓A. Imaging
   B. Physical therapy
   C. NSAIDs
   D. Intra-articular corticosteroid injection

9. How is compartment syndrome treated?

   Fasciotomy OR surgery

10. A tall, lanky 13-year-old boy presents with vague left knee pain and a limp for one week, but a normal knee exam and pain with internal rotation of the hip. AP pelvis and frog-leg view of the L hip are shown below. What is the next step in management?


A. Allow to return to sports as tolerated
B. Refer for physical therapy and follow up in 4-6 weeks
C. Joint aspiration and synovial fluid analysis
✓D. Immediately make non-weightbearing and refer to orthopedics

11. How is motor function of the median nerve tested in the hand?

Any median function OR metacarpophalangeal finger flexion OR thumb opposition, flexion, abduction

12. A 16-year-old female distance runner comes into clinic with left-sided anterior knee pain. She says the pain feels like it is beneath her knee-cap and is worse with going up and down stairs and running. What is the most appropriate management of this condition?

✓A. Addressing the underlying cause with targeted physical therapy
B. Order MRI now
C. Referral to orthopedics for surgical management
D. Straight knee immobilizer for 2 weeks and gradual resumption of activity

13. A 68-year-old male comes to the physician with worsening neck pain with radiation down his right arm, consistent with cervical radiculopathy. Which of the following findings would necessitate immediate referral to a spine surgeon?

A. Pain exacerbated by forced extension of the neck
✓B. Hyperreflexia of the lower extremities
C. Decreased sensation to light touch in the lateral arm
D. Pain isolated to the shoulder girdle

14. A patient comes to the office complaining of low-back pain that wakes him up from sleep. What two diagnoses are you concerned about?

1. Tumor
2. Infection

15. A 59-year-old woman presents with pain and numbness in her thumb, index finger, and long finger. She says the pain is worse at night and is relieved by shaking or flicking her wrist. Inspection of the hand reveals atrophy of the thenar eminence. What is the next best step in management?

A. Refer to occupational therapy
B. Corticosteroid injection

C. Lifestyle modification
✓D. Referral to orthopedics

16. Rupture of the biceps at the elbow results in weakness of both elbow flexion and ____ ?

Supination

17. A 42-year-old woman comes into clinic with three weeks of right-sided anterolateral shoulder pain that is made worse when reaching overhead and laying on the affected side at night. Forward flexion of the shoulder to 90 degrees and forced internal rotation reproduces her pain. What is the initial step in management of this condition?

A. Intraarticular corticosteroid injection
B. MRI for suspected rotator cuff tear
C. Arthroscopic subacromial decompression
✓D. Activity modification and physical therapy

18. What nerve is compressed in carpal tunnel syndrome?

Median nerve

19. What is the function of the normal anterior cruciate ligament at the knee?

To prevent anterior displacement of the tibia on the femur

20. A 20-year-old injured his knee while playing football. You see him on the same day, and he has a knee effusion. An aspiration shows frank blood. What are the three most common diagnoses?

Ligament tear, fracture, peripheral meniscal tear, capsular tear, patellar dislocation

Appendix C: Survey

Section A: Learning Tool Experience Questionnaire

Please provide a rating from 1 (strongly disagree) to 5 (strongly agree) on the following statements regarding the self-directed learning tool:

1. At the start of the orthopedic rotation, I received clear information and guidance on what the self-directed learning tool covered and on how assessments will be conducted

2. My understanding of orthopedic MSK conditions has increased as a result of using the learning tool

3. The learning tool content was relevant to the orthopedics rotation

4. The assessment at the end of the orthopedic rotation seemed more interested in testing what I had memorized than what I had understood

5. The learning tool made orthopedics interesting

6. The structure used in the modules helped me to learn

7. The self-assessment questions provided within the learning tool were helpful to my learning

8. The learning resources provided within the modules (videos/simulations) were helpful to my learning

9. The objectives provided within the learning tool were sufficiently detailed and helped guide my learning

10. The learning tool prepared me well for the assessment at the end of the orthopedics rotation

11. The amount of content in the self-directed learning tool was appropriate

12. Overall, I found the self-directed learning tool to be an effective way of learning orthopedic MSK conditions

Section B: Improvements

In the dropdown options below, please indicate the 3 aspects of the learning tool that are most in need of improvement. Please note that you're able to choose "Other" for each of the options in order to provide your own answer.

Section C: Successes

In the dropdown options below, please indicate the 3 best aspects of the learning tool. Please note that you're able to choose "Other" for each of the options in order to provide your own answer.

Options provided for sections B and C included: the structure of the modules, the content of the modules, the delivery of the learning tool, the objectives outlined in the learning tool, the explanations for the self-assessment questions, the self-assessment questions, and the selection of learning resources provided in the modules.

Section D: Supplementary Data Collection
Is there anything else you would like to add to your answers or any suggestions you may have to improve the learning tool?

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Chapter 4

General Discussion and Conclusions

4.0 General Discussion and Conclusions

4.1. Preface

The first chapter of this thesis began by outlining the history of how we came to identify inadequacies within MSK medical education and the work that has been done over the last decade to improve the state of MSK curricula. This history started with the concept of exercise as medicine in ancient civilizations and moved to the chain of events that lead to the Bone and Joint Decade, an initiative that had the aim of improving the quality of life for people with MSK disorders across the world (1-4). One of the primary goals of the Bone and Joint Decade was to increase the MSK education of healthcare providers given the identified inadequacies in MSK knowledge at all levels of medical training (5, 6).

Although the decades after the inception of the Bone and Joint Decade have yielded meaningful progress in fostering curriculum reform in select countries, MSK medicine continues to be underrepresented in medical education as a whole, and medical trainees still demonstrate poor passing rates on validated MSK knowledge examinations around the world (7-14). The primary barriers to implementing comprehensive MSK education are a paucity of resources dedicated to the subject, and the intensive time demands that are already placed on medical curricula (15-17). Thus, there is a need to investigate time and resource efficient learning modalities that can be implemented in medical curricula without placing additional strain on faculty members, students, and the existing curriculum structure. We proposed that self-directed learning presents a potential solution to this problem as it has been identified as an effective learning modality in other

areas of health professions education and may be implemented in a way that does not impact time spent on other important aspects of undergraduate medical training (18, 19).

4.2 Thesis Summary

This thesis developed, implemented, and evaluated a novel self-directed learning tool for improving medical students understanding of MSK medicine during their orthopedic clerkship rotation. This was accomplished through a sequential exploratory mixed methods design using the CIPP program evaluation model to guide our approach (20, 21). The first step of a sequential exploratory mixed methods design involves using qualitative methodologies to inform the development of a tool or instrument using stakeholder perspectives. This step was outlined in Chapter 2 of this thesis and corresponds to the context and input phases of the CIPP program evaluation model. The second step of this mixed methods designs involves the development of the tool using themes obtained from the first qualitative phase of the study. The success of the tool was then evaluated in the third phase of the mixed methods approach using quantitative methods, which was outlined in Chapter 3 of this thesis. This chapter also aligns with the process and product phases of the CIPP program evaluation model. The fourth and final phase of the sequential exploratory mixed methods approach examined how the quantitative results connect to the initial qualitative development process and explored the key findings demonstrated throughout the study. These features will be provided in this fourth and final chapter.

4.3 Key Findings

4.3.1 Qualitative Strand

The qualitative portion of this mixed methods design used interpretive description to evaluate student and orthopedic faculty members' perspectives of the strengths and weaknesses of the MSK curriculum at the DeGroote School of Medicine to inform a novel self-directed learning approach. The themes obtained from this study were split into two broad categories: (1) perceptions of the current curriculum's strengths and weaknesses, or "What needs to be done?" in the current curriculum, and (2) perceptions of the potential efficacy feasibility and viability of a self-directed learning tool, or "How should it be done?" with respect to the novel self-directed learning approach. These categories represent the context and input phases of the CIPP program evaluation model respectively which will be discussed in further detail below.

4.3.1.1 Context Results

Through the context evaluation phase, we found eight major themes regarding student and faculty perceptions of the MSK curriculum's strengths and weaknesses. Although some components of the curriculum were identified as being highly effective such as the clinical skills sessions and problem-based learning tutorials, there were also gaps that were identified to contribute to inadequate MSK knowledge prior to students entering their orthopedic clerkship rotation. This included a lack of longitudinal repetition and integration of MSK concepts throughout students' training, as well as the vast amount of content students are expected to learn for this subject which is compressed into a month of time during their foundational curriculum. Students and faculty also discussed

pedagogical methods that were perceived as being ineffective, such as large group lectures, and an underemphasis of MSK anatomy content due to the voluntary structure of anatomy sessions. Moreover, students and faculty identified a lack of intrinsic motivation for many students to learn MSK content, due to perceptions that MSK is not a priority for students unless they are interested in MSK-focused specialties such as orthopedics. When compounded with the lack of formative testing throughout their foundational MSK subunit and the voluntary anatomy sessions, students described portions of the MSK subunit as being somewhat "elective" in nature. After exploring faculty members and students' perceptions of the strengths and weaknesses of the MSK curriculum, further questions were posed regarding the potential use of a self-directed learning tool to fill the identified gaps.

4.3.1.2 Input Results

During the input evaluation phase, six broad themes were constructed concerning students and faculty members' perspectives of the potential efficacy, feasibility and viability of a self-directed learning tool. First, self-directed learning was identified as an accepted learning modality to augment MSK clinical experiences, specifically for use within the orthopedic clerkship rotation. In terms of its particular structure, students and faculty suggested that the tool be comprised of online, interactive modules covering "high-yield" content such as common fractures and soft-tissue injuries, orthopedic red flag and emergencies, as well as common pediatric MSK conditions. Students and faculty also emphasized the importance of having faculty outlined and supportive objectives within the learning tool to clearly direct students to relevant content areas, as well as

integrating relevant MSK anatomy and physical examination skills. Additionally, self-assessment questions and case-based applications were suggested as strategies to help students apply their knowledge of MSK medicine to real patient encounters. These themes informed the construction of the self-directed learning tool.

4.3.2 Tool Development and Quantitative Strand

Based on the results of the qualitative context and input phases, a self-directed learning tool was developed. The tool was created using MacVideo to produce a series of online modules spanning the topic areas being identified of critical importance during the input evaluation. This included the following four areas: Common Soft Tissue Injuries, Common Fractures, Orthopedic Red Flags and Emergencies, and Pediatric Orthopedics. The subtopics covered within each of these areas were informed by the Bone and Joint Decade's Undergraduate Curriculum Group core curriculum recommendations, which were validated for use in Canadian settings by MSK educators (22, 23). The learning tool also contains a list of comprehensive objectives based on these core curriculum recommendations for students to guide their learning. Each module produced covers the relevant MSK conditions within the four broad content areas. Within each module, a general approach to identifying and treating the MSK problem is outlined, and the relevant clinical anatomy and physical examinations are provided. Additionally, self-assessments in the form of multiple-choice and case-based short answer questions are integrated into the learning tool to reinforce key concepts and provide students with opportunities to test their knowledge and apply the concepts outlined in each module to clinical scenarios.

To test the efficacy of this tool, a two groups pre-test post-test design was used in addition to cross-sectional mixed-methods survey. The mixed methods survey assessed the implementation of the learning tool within the process phase of the CIPP program evaluation model by asking students to identify successes and improvements to enhance the learning tool, and evaluate whether it was implemented as planned. The pre-test post-test design used two MSK assessments constructed from validated sources to measure improvements in students' knowledge throughout their orthopedic clerkship rotation. These MSK knowledge assessments were also used to examine the impact of the self-directed learning tool and comprised the product evaluation of the CIPP program evaluation model, which had the intent of evaluating whether it was successful in improving orthopedic clerks' MSK knowledge. Students who completed their orthopedic clerkship rotation from January to March of 2021 did not have access to the learning tool and served as the control group, and students who completed the rotation from March to May of 2021 served as the intervention group and were provided with the learning tool.

4.3.2.1 Process Evaluation

Through the process evaluation's cross-sectional mixed methods survey, students identified the self-directed learning tool as being an effective way to increase their understanding of MSK conditions during their orthopedic clerkship rotation. The self-assessment questions and module content were the most frequently identified successes of the tool. Moreover, students emphasized the broad utility of the tool and its potential application to other clerkship rotations in addition to its usefulness in studying for the end of rotation assessment for orthopedics.

In contrast, the most frequently identified area for improving the learning tool was its delivery. Students indicated that the utility of the learning tool needed to be conveyed in a clear manner at the beginning of the orthopedics rotation for students to plan their study schedules appropriately. Moreover, it was suggested that the vast number of resources provided to students during the rotation tends to dilute those that are the most useful to the students during clerkship. Thus, future work will involve modifying the learning tool's delivery to emphasize its use during this particular clerkship rotation, thereby ensuring that students are able to access the resources that are most valuable to their learning. Ultimately, the survey results indicated that the self-directed learning tool was accepted by students as a way to augment their clinical experience during their time in orthopedics, and that it was a helpful resource in understanding MSK conditions.

4.3.2.2 Product Evaluation

The pre-test results reflected a similar theme to what was identified during the qualitative phase of this mixed methods design- students at this medical school are entering their orthopedic clerkship rotation unprepared to deal with MSK-related problems in clinical settings. Both the learning tool group and the control group's average pre-test scores fell below the basic competency benchmark of 73.1% established by Freedman and Bernstein (24). Each group achieved an average score of approximately 58%, indicating significant knowledge gaps in this area.

However, both the learning tool group and the control group demonstrated a significant increase in MSK knowledge scores between their pre- and post-test assessments of approximately 22%, which elevated the average score beyond the basic

competency benchmark of 73.1% to around an 80% average for each group. No significant differences were found between the learning tool group and the control group's post-test MSK assessment scores. Although there was not a significant difference in MSK knowledge scores between the control group and the learning tool group, the improvement in knowledge scores over time demonstrates the importance of ensuring medical students have the opportunity to be exposed to clinical settings in which there are a high proportion of MSK conditions.

4.4 Discussion

4.4.1 The Necessity of Canadian MSK Curriculum Reform

Aside from Wadey et al.'s validation of the Bone and Joint Decade's core curriculum recommendations for MSK instruction in undergraduate medical education in 2007 (23), there has yet to be a cohesive and concentrated effort to reform MSK curricula within Canadian medical schools. Curriculum evaluation efforts in this country have also been limited, but those that do exist indicate that there is work that needs to be done at the undergraduate level to ensure that students are entering postgraduate training better prepared to manage patients with MSK conditions (17, 25). Pinney et al.'s evaluation in 2001 revealed that 2.26% of the average curriculum as a whole in Canadian medical schools is dedicated to MSK instruction, and that many of the program directors perceived their programs to be inadequate overall. Similar results were obtained in 1987 by the Association of American Medical Colleges (AAMC) who determined that only 2.4% of the total available pre-clinical curriculum hours in Canada were dedicated to teaching about MSK disorders (26). While the results of these evaluations have existed

for over two decades, there is a paucity of literature on whether these issues have been addressed. However, curriculum reform efforts within this area may have gone undocumented, and thus a more up-to-date evaluation of the present state of MSK education in Canada's undergraduate medical training programs is necessary.

4.4.2 Using Qualitative Methodologies to Evaluate MSK Curricula

The vast majority of MSK curriculum evaluation work that has been completed has involved using primarily quantitative methods such as MSK knowledge testing and surveys assessing the confidence of medical trainees and physicians to manage patients with MSK-related complaints (15, 16). We chose to evaluate the MSK curriculum at the DeGroote School of Medicine using a different approach. Chapter 2 outlines an evaluation process using qualitative interpretive description to assess the strengths and weaknesses of the MSK curriculum in this particular setting. Although the results in this chapter reflect some previous findings in MSK medical education research, they also provide for a more nuanced understanding of issues that may be encountered in MSK curricula. For example, this study identified the implicit signalling created by the structure of the curriculum as being part of the issue in motivating students to learn MSK content; ultimately, the lack of formative testing, voluntary nature of anatomy sessions, and the small portion of the curriculum allocated to the subject area signalled to students that MSK medicine was not of importance to their medical training. Moreover, this qualitative approach allowed us to explicitly examine what students perceived to be the ideal way to construct the self-directed tool to meet their needs during their orthopedic clerkship rotation.

Although qualitative work is commonly criticized for its "lack of generalizability", the richness provided by this approach allowed for a more in-depth understanding of the issues encountered by students in this particular context (27). In turn, this understanding allowed us to develop a self-directed learning tool catered to the needs of the students. Moreover, generalizability was not the intent of this study; the purpose behind this evaluation was to assess the gaps specific to the MSK curriculum at the DeGroote School of Medicine. Ultimately, this approach allowed us to develop a self-directed learning tool catered to the needs of the students and in consideration of their input and perceptions. Future MSK curriculum evaluations should consider employing qualitative methodologies or in conjunction with quantitative methods as part of broader mixed methods designs to gain a complete understanding of the strengths and weaknesses behind their instructional techniques.

4.4.3 The Importance of Using Multiple Approaches and Evaluation Methods to Reform MSK Curricula

Since the creation of Freedman and Bernstein's cognitive MSK examination, using multiple choice and short answer knowledge testing has been the primary method of assessing medical trainees' competence in MSK medicine (28). Other popular approaches have involved administering surveys to program directors, faculty members, students and physicians to assess their confidence in their ability to perform physical examinations or identify and treat MSK-related symptoms (14, 29-33). Although basic knowledge testing and evaluating perceptions through surveys may be necessary components of evaluation, there are limitations in relying on these two sources to

examine the preparedness of trainees to manage MSK-related complaints. Multiple evaluation methods must be used and triangulated to provide for a more comprehensive picture of trainees understanding of MSK medicine, including objective structured clinical examinations and faculty evaluations in addition to knowledge testing with validated sources and surveys assessing confidence.

During the era of MSK curricula reform throughout the Bone and Joint Decade and beyond, many have called for the use of technology in augmenting clinical and pre-clinical instruction (15, 16, 23). Although the concept of using novel technology to enhance MSK curricula is promising, there also needs to be a recognition by medical education institutions that this cannot be the only method used to improve the state of MSK instruction. The first chapter of this thesis provided a summary of the various approaches that have been used in attempts to enhance MSK instruction in medical schools. These approaches have included involving a wide variety of specialists and instructors in curricula development as well as incorporating pedagogical methods such as interprofessional and interdisciplinary education (34-39), experiential and active learning (40-42), e-learning (43-48), and peer or patient-assisted learning into pre-clinical and clinical education (49-59). Although these methods have primarily been examined in isolation, it is critical that we consider the importance of combining these approaches to create holistic and comprehensive MSK curricula. Moreover, the presence of an MSK curriculum itself does not guarantee that students will leave their undergraduate training with an adequate knowledge base to treat patients with these conditions; a multi-modal and longitudinal approach to teaching students MSK medicine is necessary (15). When

considering the challenges at the DeGroote school of Medicine in particular, there are various steps that should be taken in addition to the implementation of this self-directed learning tool- this includes introducing formative testing methods throughout the pre-clinical MSK curriculum, providing additional clinical opportunities in settings with high frequencies of MSK-related complaints, and ensuring that MSK medicine itself is not perceived as an "elective" portion of the curriculum. The challenges posed to implementing robust MSK curricula are multi-faceted; thus, to overcome these challenges, we must take a multi-faceted approach to addressing the issues that exist in this subject area.

4.5 Conclusions

As the burden of MSK disorders on our healthcare system is only projected to increase with the aging population, it is critical that medical trainees are receiving robust training to prepare them to manage these conditions (16). This thesis provides an evaluation framework for use by medical education institutions to identify the strengths and weaknesses that reside within their own MSK curricula, and subsequently use the results of the assessment to inform novel learning interventions to fill the identified gaps. The challenge of creating an engaging curriculum with limited time and resources may be partially addressed by our novel self-directed learning tool, but it is important to consider multiple approaches to enhancing MSK curricula and ensuring that medical students are receiving the training they need to feel confident in their encounters with MSK conditions in clinical settings. Future work in this area should involve holistic reform and using

multiple evaluation methods to examine the success of the approaches implemented in Canadian undergraduate medical education programs.

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