The Development of a Postgraduate Family Medicine Artificial Intelligence Curriculum Framework

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ABSTRACT

Background: To advance the implementation of artificial intelligence (AI) in clinical practice, physicians need to have a better understanding of AI and how to use it within clinical practice. Consequently, medical education should introduce AI topics and concepts into the curriculum. Curriculum frameworks are educational road maps to teaching and learning. Therefore, any existing AI curriculum frameworks have to be reviewed and, if none exist, such a framework must be developed. As AI tools can vary between specialties, a framework must be established for each level of education and specialty. As the field of family medicine and primary care experiences an increase in the introduction and integration of clinical AI-based tools, medical education and training will need to address these emerging competencies in their curricula. It is imperative that family medicine residency programs develop AI specific training curricula to ensure that graduating family medicine physicians are well prepared to understand, integrate, and evaluate the use of AI in clinical practice.

Objectives: The purpose of this thesis is twofold: 1) to synthesize knowledge from the literature on curriculum frameworks and current educational programs that focus on the teaching and learning of AI for medical students, residents, and practicing physicians, and 2) to co-develop a comprehensive curriculum framework for teaching and learning AI to family medicine residents.

Methods: For objective one, a scoping review was conducted. The review followed the Joanna Briggs Institute methodology for scoping reviews and was further guided by Arksey and O'Malley (2005) and by Levac et al. (2010). Seven databases including the grey literature were searched. Articles were limited to the English and French languages, from the year 2000 until 2023. This review included articles that describe curriculum frameworks for teaching and learning AI in medicine, irrespective of country. Two authors independently screened articles

and extracted data using a validated data extraction form. Following the results of the scoping review, for objective two, two expert panel discussions were conducted with the aim of co-developing the curriculum framework. We invited two sets of participants, 1) family medicine educator experts interested and/or have an expertise in AI education, and 2) family medicine resident experts interested in AI education. The 2-hour long online experts panels were conducted and subsequently analyzed using content analysis.

Results: From the 5,104 articles scanned, 21 studies relevant to our eligibility criteria were identified. Nineteen (90%) papers altogether described 30 current or previously offered educational programs and two (10%) papers described elements of a curriculum framework. No papers described a theory, pedagogy or framework which guided the 30 educational programs. A total of 14 expert panelists participated in the expert panel discussions. Following the discussions, a curriculum framework was developed titled, "Artificial Intelligence training in postgraduate Family Medicine Education (AIFM-ed) Curriculum Framework."

Conclusions: The review summarized the most recent literature of AI curriculum frameworks and educational programs within medical education. Due to the limited research of this field, future studies should use a multidisciplinary approach to curriculum redesign, begin discussions surrounding curriculum planning of AI, and have increased research on the development, implementation and evaluation of future educational programs. The systematic approach in the development of a comprehensive family medicine AI curriculum framework has the potential to aid educators across diverse contexts and educational levels in creating their own AI curricula.

RÉSUMÉ

Contexte: Pour faire avancer la mise en œuvre de l'intelligence artificielle (IA) dans la pratique clinique, les médecins doivent avoir une meilleure compréhension de l'IA et de son utilisation dans la pratique clinique. Par conséquent, l'éducation médicale devrait introduire des sujets et des concepts d'IA dans le programme d'études. Les cadres de curriculum sont des cartes routières éducatives pour l'enseignement et l'apprentissage. Par conséquent, tous les cadres de curriculum existants sur l'IA doivent être examinés et, s'il n'y en a pas, un tel cadre doit être développé. Comme les outils d'IA peuvent varier entre les spécialités, un cadre doit être établi pour chaque niveau d'éducation et de spécialité. Alors que le domaine de la médecine familiale et des soins primaires connaît une augmentation de l'introduction et de l'intégration d'outils cliniques basés sur l'IA, l'éducation médicale et la formation devront aborder ces compétences émergentes dans leurs programmes d'études. Il est impératif que les programmes de résidence en médecine familiale développent des programmes de formation spécifiques à l'IA pour garantir que les médecins en médecine familiale diplômés sont bien préparés à comprendre, intégrer et évaluer l'utilisation de l'IA dans la pratique clinique.

Objectifs: Le but de cette thèse est double: 1) synthétiser les connaissances issues de la littérature sur les cadres de curriculum et les programmes éducatifs actuels qui se concentrent sur l'enseignement et l'apprentissage de l'IA pour les étudiants en médecine, les résidents et les médecins en exercice, et 2) codévelopper un cadre de curriculum complet pour l'enseignement et l'apprentissage de l'IA aux résidents en médecine familiale.

Méthodes: Pour l'objectif un, une revue de la portée a été menée. La revue a suivi la méthodologie de l'Institut Joanna Briggs pour les revues de la portée et a été guidée par Arksey et O'Malley (2005) et par Levac et al. (2010). Sept bases de données, y compris la littérature grise,

ont été consultées. Les articles étaient limités aux langues anglaise et française, de l'année 2000 à 2023. Cette revue comprenait des articles décrivant des cadres de curriculum pour l'enseignement et l'apprentissage de l'IA en médecine, indépendamment du pays. Deux auteurs ont indépendamment passé en revue les articles et extrait les données à l'aide d'un formulaire d'extraction de données validé. À la suite des résultats de la revue de la portée, pour l'objectif deux, deux discussions d'experts ont été menées dans le but de codévelopper le cadre de curriculum. Nous avons invité deux ensembles de participants, 1) des experts en éducation en médecine familiale intéressés et/ou ayant une expertise en éducation à l'IA, et 2) des résidents en médecine familiale intéressés par l'éducation à l'IA. Les panels d'experts en ligne de deux heures ont été menés et analysés ultérieurement à l'aide d'une analyse de contenu.

Résultats: Parmi les 5 104 articles examinés, 21 études pertinentes par rapport à nos critères d'éligibilité ont été identifiées. Dix-neuf (90 %) articles décrivaient au total 30 programmes éducatifs actuels ou précédemment offerts et deux (10 %) articles ont décrit des éléments d'un cadre de curriculum. Aucun article ne décrivait une théorie, une pédagogie ou un cadre qui guidait les 30 programmes éducatifs. Au total, 14 experts ont participé aux discussions du panel d'experts. À la suite des discussions, un cadre de curriculum a été élaboré sous le titre "Formation en intelligence artificielle dans l'éducation postdoctorale en médecine familiale (IAMF-ed) Cadre de curriculum".

Conclusions: La revue a résumé la littérature la plus récente sur les cadres de curriculum en IA et les programmes éducatifs dans l'éducation médicale. En raison de la recherche limitée dans ce domaine, les futures études devraient adopter une approche multidisciplinaire pour la refonte du programme d'études, amorcer des discussions sur la planification du curriculum en IA et intensifier la recherche sur le développement, la mise en œuvre et l'évaluation des futurs

programmes éducatifs. L'approche systématique dans le développement d'un cadre de curriculum complet en IA pour la médecine familiale a le potentiel d'aider les éducateurs dans des contextes et à des niveaux éducatifs divers à créer leurs propres programmes d'IA.

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PREFACE

This Master of Science of thesis adheres to the preparation and formatting guidelines of a traditional-style thesis (i.e., non-manuscript-based thesis). I, Raymond Tolentino (student), confirm that I conducted my thesis under the main supervision of Dr. Samira Rahimi (primary supervisor), as well as support from my thesis team including Dr. Fanny Hersson-Edery (committee member). The aforementioned members have no conflicts of interest to declare.

CONTRIBUTION OF AUTHORS

I, Raymond Tolentino (RT), completed this Master of Science thesis under the guidance and supervision of my primary supervisor, Dr. Samira Abbasgholizadeh-Rahimi (SAR); and my committee member, Dr. Fanny Hersson-Edery (FHE). Dr. Pierre Pluye (PP) was my co-supervisor and he provided expert guidance and many meaningful contributions to this thesis, prior to his passing in August 2023. The original conception of the research protocol and study methods were developed together by RT, SAR and PP. The research protocol of this thesis was then reviewed and further refined by FHE. RT wrote the introduction and review of the literature with feedback and editorial revisions supported by SAR and FHE. RT wrote the methodology with feedback and editorial revisions supported by SAR and FHE. Regarding the scoping review section contribution, support from a specialized librarian, Genevieve Gore (GG) and Dr. Ashkan Baradan (AB) was received. GG helped develop and run the search strategy while AB was the second reviewer who assisted in screening relevant studies. RT wrote the results section and created the mentioned figures and tables with feedback and editorial revisions supported by SAR and FHE. RT wrote the discussion, conclusion and remaining chapter sections (e.g., table of content, abstracts, acknowledgement, preface and contribution of authors) with feedback and editorial revisions supported by SAR and FHE. RT prepared the final version of this manuscript with SAR and FHE approving the final version of the thesis.

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LIST OF ABBREVIATIONS

AI: Artificial intelligence

UME: Undergraduate medical education

PGME: Postgraduate medical education

CME: Continuing medical education

JBI: Joanna Briggs Institute

WHO: World Health Organization

EHR: Electronic health record

UNESCO: United Nations Educational, Scientific and Cultural Organization

CHAPTER 1: INTRODUCTION

There are several definitions for curriculum/curricula such as, “a planned educational experience that encompasses behavioral goals, instructional methods and actual experiences of the learners” [1]. Other scholars describe the term as, “the reconstruction of knowledge and experience that enables the learner to grow in exercising intelligent control of subsequent knowledge and experience” [2]. However, a curriculum framework is slightly different due to the addition of ‘framework’, which must be considered carefully. A framework implies a method for methodically arranging and managing content (e.g., procedures, concepts, etc.). The United Nations Educational, Scientific and Cultural Organization (UNESCO) thus defines a curriculum framework as a document that, “sets the parameters, directions and standards for curriculum policy and practice” [3]. Furthermore, a framework also suggests an adaptability and flexibility of the curriculum. Therefore, as long as the main principles and standards are adhered to, variation in implementation of the framework is possible [3]. This is especially important for emerging topics such as artificial intelligence (AI) which is actively evolving in all fields including medicine.

The term, artificial intelligence or AI was first originated in 1955 by Stanford University Professor John McCarthy while leading a Dartmouth Summer Research Project. He defined AI as, “the science and engineering of making intelligent machines, especially intelligent computer programs” [4]. Although the implementation of AI within family medicine has been slow [5], the rise of AI technology has been increasing. This technological phenomenon as described by Brinker (2016) as Martec’s Law states, “that technology changes exponentially while organizations change logarithmically” [6]. This incongruity in change between technology and organizations will further exacerbate the difficulty in both accessing and implementing this technology due to knowledge gaps or resistance to change. However, in order for individuals to interact with and use these AI

technologies effectively, proactive coaching, education, training, and cultural change are required [7]. Therefore, in order to move forward with the utilization of AI in family medicine, AI-focused training programs must be developed and implemented. Although the lack of AI education is one of the many reasons for limited AI implementation, there are other factors including inadequate usability, data privacy concerns, and cultural resistance. However, it can be proposed that increased education in AI can resolve these factors leading to the responsible use of AI in health. The development of AI medical education is a recommendation by national medical associations, medical institutions and several publications. For example, the Royal College of Physicians and Surgeons of Canada (RCPSC) established a task force of experts in AI and medical fellows in the Royal College which released a report of the current efforts to integrate AI and digital literacy concepts within the Canadian medical education curriculum [8]. Medical AI curricula should be specialized as each specialization has different uses for AI. Within the medical education structure, undergraduate medical education follows a general curriculum with fundamental principles in which AI could be integrated [1]. Afterwards, postgraduate medical education should build upon the fundamentals as it relates to AI and develop a curriculum tailored to the needs of each specialty. Therefore, in order to create effective AI training programs, a curriculum for each specialty should be considered or referenced.

Therefore, the purpose of this research was twofold: 1) to synthesize knowledge from the literature on curriculum frameworks and current educational programs that focus on the teaching and learning of AI for medical students, residents, and practicing physician and 2) to develop a comprehensive curriculum framework for AI education to family medicine residents. This is the first co-developed curriculum framework for AI education within family medicine postgraduate training where it can be utilized for developing specific AI curricula.

CHAPTER 2: LITERATURE REVIEW

In this chapter, I will first briefly give an overview of the growing emergence of artificial intelligence (AI) in medicine, particularly in family medicine. Then, I will provide context for the different stages of medical education as well as understanding the planning and development of curriculum. I will then briefly discuss the current efforts of integrating AI education into medical education, specifically in family medicine education. Finally, I will end this section by summarizing the main points in the development of this curriculum framework as seen through the culmination of a scoping review and expert panel discussions.

2.1. Artificial Intelligence in Medicine and Family Medicine

2.1.1. The Emergence of Artificial Intelligence in Medicine

Artificial intelligence (AI) continues to be an emerging and revolutionary innovation which has made and continues to make significant changes within healthcare and medicine [9]. It is predicted that every clinician no matter what field will be using AI technology and digital tools [7,10]. There is no universal consensus on the definition of AI; however, the World Health Organization (WHO) describes AI as, "the performance by computer programs of tasks that are commonly associated with intelligent beings" [11]. This can include performing complex decision-making tasks, automated tasks, or make predictions, generate contents and provide recommendations [12,13]. AI is thus essential, as it has the capability of reducing physician burden and increasing efficiency in the delivery of care [12]. Current medical fields utilizing this type of technology includes radiology [14], cardiology [15], psychiatry [16], nuclear medicine [17], ophthalmology [18], and surgery [19], among other fields of medicine [10]. These AI-related medical innovations can be seen through patient-care assistance [20], disease diagnosis, prevention and risk assessments [21,22], drug development and customization [23], automation of administrative activities [24] and more [10, 25, 26]. This emergence can be further emphasized through several global efforts urging the medical community to consider AI's impact in medicine. For example, this can be seen through the WHO's report in ethics and governance of AI for health [11]. Another example can be seen through the International Telecommunication Union-WHO Focus Group on "AI for Health" whose aim was to develop international evaluation standards for AI solutions in health [27]. Other aspects can be seen with the rise of AI health organizations and policies being established within medical institutions, as well as the increase research in the development and implementation of AI health technology [28]. For example, a University of

Toronto's Centre for Artificial Intelligence Research and Education in Medicine in Canada [29] and the Department of Artificial Intelligence and Human Health at the Icahn School of Medicine at Mount Sinai [30]. Therefore, AI will continue to evolve and expand in all fields of medicine.

2.1.2. Family Medicine and Artificial Intelligence

Family physicians in this digital age spend a large portion of their time on non-direct patient care and interactions. Therefore, physicians must find a solution on how to provide more time to their patients without compromising quality and patient care. This is especially relevant to the field of family medicine where patient-provider interaction is essential. Topol (2019) describes that over time AI has the potential to rehumanize medicine through improvements in a physician's accuracy, productivity, and workflow [10]. These potential solutions can be found within digital technologies which can include AI-based technologies, robotics, wearable biosensors, mobile health applications, and even integrating AI algorithms in current family medicine technology such as an electronic health record (EHR) [31,32]. EHRs also known as electronic medical records are patient health histories in a digital format, storing comprehensive data (e.g., examinations, blood tests, medications, surgeries, etc.) [33]. For example, integrating AI algorithms in EHRs have the potential to decrease administrative tasks (e.g., filing forms or documentation) [33]. However, Topol (2019) highlights this paradoxical claim of integrating more technology to rehumanize medicine and the skepticism if AI will help improve patient-provider relationships or further exacerbate the division of patient and provider [10].

The application of AI within family medicine is increasing with several publications of guides and primers [34-38]. There are several ways AI is transforming the practice of family medicine. This includes risk prediction and intervention [37, 39, 40], population health

management [37], medical advice and triage [37, 39], remote patient monitoring and digital health coaching [37, 40], chart review and documentation [37, 39, 40], diagnostics and clinical decision-making [37, 39, 40], practice management [37, 40], increased mental healthcare capacity and support [40]. The recent reviews on AI and primary care research demonstrated that most AI subfields are focused on supervised machine learning and expert systems including its use for natural language processes [5, 41]. Although AI solutions designed for primary healthcare have begun to appear, their implementation has been slow [41]. This can be attributed to gaps in knowledge and skill regarding the development, implementation, and evaluation of AI in primary healthcare [5, 41]. In addition, previous research has noted that on average, it takes 17 years for research findings to be translated into clinical practice [42].

While the application of AI in family medicine is still in its infancy, the field of family medicine must be involved in the development of clinically relevant AI tools, relevant for family physicians and patients. [43]. The WHO Global Primary Healthcare Conference in 2018 placed a strong emphasis on the necessity of efficiently utilizing available data and technology to drive innovations that would improve healthcare for both people and populations [44]. In 2017, 85% of Canadian family physicians were utilizing EHRs [45]. One study reported that 52% (5.9/11.4 hours) of a family physicians' workday, which is almost 6 hours, are spent with EHRs during and after clinic hours, a significant amount of time on non-direct patient tasks [46]. Due to its large data platform, family physicians can start by introducing AI to their practice such as by integrating AI algorithms within EHR to improve comprehensive treatment for a diverse range of patients from different backgrounds [39]. For example, one study used an AI system to compile information from an EHR to aid family physicians with decision support tools to help diabetic patients comprehend their health and well-being [47].

2.2. Curriculum Planning and Renewal for Medical Education

2.2.1. The Changing Medical Curriculum

Medical curricula should constantly be reviewed, modified and renewed [48, 49]. This is to ensure the curricula is responding to new developments in healthcare, education and societal trends [50, 51]. In Canada, the College of Family Physicians of Canada (CFPC) "establishes the standards for and accredits postgraduate family medicine training" [52]. The CFPC recommends a competency-based curriculum model titled, Triple C [53] which is based on the CanMEDS–Family Medicine framework [54] and the assessment objectives for certification in family medicine [55]. There are ongoing efforts of curriculum reform and renewal through the Outcomes of Training project [56, 57]. The RCPSC has added AI education as an important training component and promotes subspecialization of trainees in this field [8] which could potentially influence the CFPC to follow and add their own AI-specialized education.

2.2.2. Curriculum Planning and Development in Medical Education

Medical educators can develop their curriculum through several different methodologies such as Harden's (1986) ten key questions to be addressed while developing a curriculum [58], Harden's (2001) curriculum mapping method [59] and Kern's (1998) six steps approach for curricular development [60]. As society moves forwards and changes, the curriculum must change as well. There have been several examples of new competencies and topics that have been integrated into the curriculum due to the changing needs of society and its impact on medicine. For example, there have been added curricula topics in leadership [61], social determinants of health [62], and ethics training [63] in postgraduate medical education. In family medicine

postgraduate medical training, global health is an emerging competency as education surrounding this topic focuses on addressing disparities in marginalized communities, locally or internationally [64-66]. Physician burnout and wellness concerns among family physicians which have led to the development of resident wellness curricula [67-69]. Curriculum frameworks allow for a visual and detailed roadmap to develop and implement a curriculum [3]. In order to develop curriculum frameworks for AI in medicine, there must be an interdisciplinary team consisting of medical educators, AI experts and end-users, researchers and curriculum designers due to the multiple fields incorporated [12].

2.2.3. Curriculum Frameworks in Medical Education

A curriculum framework is a document which describes "the educational environment in which syllabuses (or subject specific outlines of objectives, outcomes, content and appropriate assessment and teaching methodologies) can be developed" [70]. The United Nations also defines curriculum frameworks as a document that, "sets the parameters, directions and standards for curriculum policy and practice" [3]. The Organization for Economic Cooperation and Development provides a more relevant definition stating that a curriculum framework is, "a nationally approved and/or empirically validated document detailing content, approaches to learning and teaching and/or learning outcomes" [71]. Most curriculum frameworks are developed and published by national or regional government organizations [72]; however, this thesis focuses on creating an "empirically validated document." Curriculum frameworks can be described as educational road maps for teaching and learning specific skills and subjects where these frameworks have been introduced in a variety of subjects, levels of education and environments. Some examples include a curriculum framework for clinical prevention and population health for

nursing students [73], a curriculum framework for computational thinking for elementary school (kindergarten to grade 6) [74] and water resource education curriculum framework for all types of educators (elementary, secondary, post-secondary) [75].

Medical educators work regularly with frameworks to inform the appropriate learning, assessment and performance of the healthcare workforce [76]. Frameworks are tools that can inform the delivery of teaching and curricula development, as well as inspire innovation in healthcare education. Various domains can be included in curriculum frameworks and can be adapted for other disciplines. A recently published curriculum framework divided their core domains as values, teaching objectives and teaching principles (e.g., learning environment and clinical exposure, student assessment and evaluation) [77]. Another study focusing on a curriculum framework for rural medical education provided their framework according to the 3P Model (place, people, and practice) [78]. The place was referred to the rural context, the people (e.g., patients, families and others that make up the rural community), and the necessary skills for medical practice in rural communities [78]. Meanwhile, Redwood-Campbell et al. (2011) displayed their global health curriculum framework by outlining the educational content, methods of delivery, primary and secondary learning topics, related values and principles, and learning objectives [79]. This approach was followed by two other studies pertaining to homeless health [80] and refugee health, both for undergraduate medical education [81]. Finally, the Canadian Federation of Medical Students developed a wellness curriculum framework outlined as goals and objectives as well as implementation, educational strategies and evaluation facilitators [82].

Obadeji (2018) provides [83] six common elements of curriculum frameworks for health professional education as established by Tyler (1949) [84] which include: 1) the need and the purpose of a curriculum or a program, 2) learning objectives and outcomes, 3) course content that

will facilitate the accomplishment of the objectives or learning outcomes, 4) organization of the content, 5) implementation of curriculum (divided to educational strategies and methods of assessment) and, 6) curriculum evaluation and refinement.

2.3. Integrating Artificial Intelligence Education and Family Medicine Education

2.3.1. Current State of Medical Education and AI

One of the first applications of AI in medicine was a computer program which used a AI-based techniques (i.e., expert systems) and modelled the interactions between physicians and patients. It was used to serve as a clinical consultant for selecting a type of therapy for patients with infectious diseases [85]. However, machine learning, a sub-field of AI, was first applied in 1992 in the field of radiology to detect microcalcifications on mammography [86]. Medical education on AI was introduced within the highly technological field of radiology due to its relevant clinical applications. In 2021, the Canadian Associations of Radiology (CAR) recently released a new curriculum named, "Artificial Intelligence in Radiology: Foundations to Current Applications", as a way for teaching radiology residents and other radiology-associated trainees [87]. Although AI tools have been integrated into clinical practice, medical education has lagged behind with few curricula at the undergraduate level including the fundamental concepts of AI or other advanced digital health technologies [89]. A recent survey by Stanford Medicine found that 44% (230/523) of physicians and 23% (48/210) of medical students and residents reported their education had not been helpful in preparing for new technologies such as AI, genetic screening, and wearables in healthcare [90]. Currently, there are no mandatory accreditation requirements related to AI education for any level of medical education [91]. The knowledge gap between AI experts, clinicians and scientists continue to grow as healthcare moves to a more digital environment which will ill-prepare young physicians who will work with AI tools [92, 93].

AI is also beginning to enter the field of medical education through its uses in student learning support and assessments of students' learning [12]. For example, AI can support learning by providing immediate and direct feedback on student performance [94]. In regards to using AI

for assessment, AI-based tools can automate the scoring of students' work allowing for objective assessments and reduced time and costs [95]. Besides AI's use in medical education, there are several publications urging institutes and clinical educators to begin integrating AI educational concepts into their medical curricula [91-93, 96-98]. For example, one paper summarizes that, "faculty teaching staff need to rapidly adapt to the integration of AI tools and develop AI literacy by being trained in multiple AI tools for teaching and assessment" [99]. Wartman & Combs have emphasized that a crucial focus of curriculum reform should focus on teaching medical students how to be a successful physician while navigating a "healthcare environment transformed by artificial intelligence" [89]. There have been efforts to include AI education globally within each level of medical training. For example, in the United Kingdom (UK), medical and dental trainees can apply for a fellowship in clinical AI where those accepted will be working on the deployment and validation of AI solutions in clinical settings [100]. Further efforts are spearheaded by national medical associations such as the UK's National Health Service (NHS) [101], the United States (US) American Medical Association (AMA) [102] and Canada's Royal College of Physicians and Surgeons of Canada (RCPSC) [8]. These internationally recognized organizations have released documents recommending policies for integrating AI within their respective medical educational institutions [8, 101, 102]. This can be seen with the AMA's Council of Medical Education adopting ten polices which ensures that AI advances were supported by medical education [103]. These policies were aimed to determine the best approaches to incorporate AI in license requirements and how to best adapt the curricula to incorporate training modules that were specialty-specific. Their goal was also to evaluate the quality of AI instruction and assess the differences in institutional access to AI [103]. This highlights the importance of the work on the intersection of medical education and AI around the world. To our knowledge, there are no medical schools with

formal required courses on AI in healthcare. While still uncommon, the importance of AI medical education has been identified and acted on at some institutions, such as, Duke University which offers a training course called “Machine Learning School for the School of Medicine” [88].

Other institutions have also developed elective courses, such as in radiology, with one titled “AI for Doctors: Medical Imaging” [104]. This can be further seen with McGill University’s Department of Experimental Surgery and Department of Family Medicine which offer courses on “AI in Medicine” and “AI and Analytical Decision-Making in Healthcare”, respectively [29]. Furthermore, training in AI literacy for healthcare professionals should focus on building core capabilities surrounding AI (e.g., learning basic of data science) rather than technical skills such as programming or complex topics such as cognitive computing [7]. As AI is increasingly integrated in medical care, physicians are expected to understand and use AI technologies competently, effectively and responsibly [7]. This means future physicians should understand the basic functionalities of the AI technologies they may use. They should understand how and when to properly use these technologies, emphasizing effective and responsible utilizations. For example, if a physician uses an AI-empowered technology for their medical practice, they must inform their patients of such usage and ensure that their patients’ data is protected and secured [105]. The failure to prepare future physicians on AI technologies in medicine may lead to consequences such as the exploitation of data, increased health disparities and decreased quality of care [106]. For example, a physician who is not well-trained in AI ethics may be overly reliant and trusting on AI technologies, neglecting to develop critical thinking and problem-solving skills which may lead to inappropriate use of AI-enabled systems for diagnoses or treatments [107]. Thus, AI-focused medical education should be guided by the responsible innovation in health policy framework [108]. This concept of “responsible innovation in health” clarifies ways to

design, develop, and use innovations of increased societal benefit such as AI which has the ability to tackle health inequalities, support an equitable healthcare system and tackle contemporary medical challenges [10, 108]. The use of responsible AI has the potential to advance the Quintuple Aim of better health, improved care experience, clinician well-being, lower cost, and health equity throughout [109].

2.3.2. Knowledge and Perception of AI Training in Medical Education

In addition to national medical organizations' efforts of integrating AI training to the medical curriculum around the world, several global institutions have also conducted surveys of medical trainees in order to understand their knowledge and attitudes towards incorporating AI into the medical curriculum [110-113]. Many countries around the world have conducted either multi-institutional or single-centre surveys. Although the length of medical training around the world can vary, the content of medical curricula remains relatively similar [114].

Over two-thirds (71%), 187/263 of medical students within three German universities agree for the need of AI to be integrated within medical education. Most of the respondents were aware of AI technology and their applications, specifically in radiology. Additionally, students were not worried of the replacement of AI to radiologists with 218/263 (83%) of medical students disagreeing with statements that human radiologists will be replaced [115]. Nineteen medical schools in the UK expressed similar attitudes where 378/484 (78%) of respondents believed that there should be an AI requirement incorporated within their curricula [116]. UK medical students understand the importance of AI within healthcare where 430/484 (88.8%) of respondents believe that teaching AI will be beneficial towards their careers [116]. A similar study was conducted at two medical universities in Pakistan where 246/384 students (64%)

agreed on the introduction of AI in medical education. Over 60% (237/384) of students did not have any previous knowledge of AI, but were excited to adopt the technology [117].

Additionally, in Canada, a multicentre survey in Ontario conducted a similar study in which 72% (207/287) of medical students agree that AI competencies should be integrated within medical education [118]. Many students were also hopeful for AI's contribution to medicine spanning from surgical procedures to administrative tasks. However, 113/288 (39%) students agree that AI will reduce the number of jobs in specific medical specialities. This has already impacted the choice of speciality for 71/288 (25%) of respondents [118]. Similar findings were also seen at a university in Oman as medical students were generally receptive to incorporating AI into medical school curricula where 470/610 (77%) of students believe AI should be part of medical training [119]. Although students' opinions are important for AI medical education, faculty response must also be taken into consideration. A single university in the US conducted a study for both faculty and students' and found similar attitudes toward AI where both populations are interested in this technology, yet they both recognize the limited digital literacy in medical education [120].

Overall, most of the mentioned studies demonstrated similar findings where much of the student populations agrees that AI concepts should be integrated within the medical curricula. The plethora of studies support the need for future educators and institutions around the world to begin enacting AI tools within training and education.

2.3.3. Family Medicine Postgraduate Training in AI

To integrate and implement AI-based systems properly within family medicine and in practice, the introduction of training is essential. A main theme from a dialogue of primary care

participants (e.g., patients, providers, health system leaders) from across Canada is that training of family physicians is lacking in our current context and is necessary for the effective and safe implementation of AI tools in primary medical care [40]. Three priority areas were identified for learning AI in family medicine training, specifically in continuing medical education including 1) basic AI literacy, 2) algorithm critical appraisal, and 3) workflow integration [40].

In addition, Dr. Liaw and colleagues have recently proposed six competency domains for family medicine training [121]. Competencies can be described as the ability to carry out a certain task or action at a basic or acceptable level [122]. Therefore, the authors of this special report presented six abilities that family physicians must acquire for effectively utilizing AI technologies. The six introduced competencies include, "(1) foundational knowledge (what is this tool?), (2) critical appraisal (should I use this tool?), (3) medical decision making (when should I use this tool?), (4) technical use (how do I use this tool?), (5) patient communication (how should I communicate with patients regarding the use of this tool?), and (6) awareness of unintended consequences (what are the "side effects" of this tool?)" [121]. These initial competencies can be integrated within current residency training such as through existing sessions on health informatics or evidence based medicine [121]. However, the authors emphasized these competencies as a "point of departure," and must be further worked on [121]. The development of these competencies demonstrates the beginnings of AI education within family medicine training.

Furthermore, the CFPC has demonstrated proactive leadership in integrating AI and family medicine [123]. Initiatives began with the 2019 Leaders Forum, where family physicians, leaders in family medicine, and AI experts collaborated [124]. Further initiatives include the development of a continuing professional development three-module e-course titled, "Artificial

Intelligence for Family Medicine" [125]. The first module reviews the basic functionality of AI with applications in family medicine, while the second modules focuses on core terminology and related concepts as well as potential harms or risks associated with AI. The last module reviews the concepts of the last two modules and focuses on learning how to tell if AI-based tool is working well. Even though the use of AI technologies in family medicine is still limited, family physicians can benefit from current AI-based education within their residency. This can be seen as residents can become familiar with these tools and gain the initial expertise during their residency. Once, AI technologies become widespread in primary care, physicians will be ready to use and understand them in the future.

2.4. Development of Curriculum Framework Aim, Rationale and Objectives

2.4.1. Thesis Aim

To summarize, curriculum development of AI training for family medicine education is paramount for the advancement of AI-trained physicians. A systematic approach is required for developing effective curriculum [126]. To develop a comprehensive curriculum framework for AI in family medicine, it is essential to form an interdisciplinary team comprising medical educators, AI experts, end-users, researchers, and curriculum designers. This is necessary due to the diverse range of fields involved in the process. Therefore, I aimed to co-develop a curriculum framework for family medicine postgraduate training through a) a scoping review and b) rounds of expert panel discussions.

2.4.2. Scoping Review Rationale and Objectives

Due to the broad nature of this topic and its prospective limited data, a scoping review is the most appropriate method. Previous reviews exploring topics surrounding AI and medical education have focused on the application of AI in medical education [12, 127] attitudes of medical students toward AI [128] and gaps of AI learning within medical education [129]. A recent review of AI educational programs and competencies for healthcare professionals was published [130]; however, due to some limitations and a broad population, further reviews must be conducted. Furthermore, the authors of this recent review had some limitations that our review will resolve such as the exclusion of continuing medical education as well as the lack of investigating learning theories, pedagogies and frameworks of their identified AI educational programs. Our review focuses specifically on the medical education continuum where developed AI educational programs for medical students, residents and practicing physicians have been

published. This can help medical educators navigate the learning pathway for current and future physicians by understanding what current teaching materials and methods are present and useful. This is important as each healthcare profession has different pathways of education and uses for AI. For example, the nursing educational structure is different than that of a physician and both professions may have different uses for AI [131, 132]. Therefore, the review was specified to only medical professionals, but broad enough to encompass all specialities and levels of educations. Furthermore, there are no reviews which have focused on examining curriculum frameworks which guide AI concepts within medical education. Thus, I conducted a scoping review of published studies on AI curricula being used in medical education.

With this scoping review, I aimed to examine the elements and content of current curriculum frameworks that exist in the literature used by medical education institutions that focus on the teaching and learning of AI education to trainees and practicing physicians. This scoping review also aims to present details of current educational programs specifically investigating a) the framework, pedagogy or theory used, b) the delivery of the educational program, c) the curricular content, and d) the evaluation of the program. In regard to this thesis, the scoping review helped inform the development of the AI curriculum framework for family medicine residents.

2.4.3. Expert Panel Discussion Rationale and Objectives

Expert panels are a crucial tool when defining consensus on controversial subjects [133, 134]; this can include AI which is an emerging and uncertain topic in healthcare, especially in family medicine education. Expert panel discussions are qualitative consensus-finding method which "combine evidence and clinical acumen, the opinions are made transparent and subjected

to critical appraisal" [135, 136]. The use of qualitative consensus methods for curriculum development can allow for a wide range of relevant parties (e.g., physicians and curriculum developers) to assess and validate expert knowledge [137]. The use of expert panel discussions for the purpose of creating curricula have been established in pedagogical research and development [138]. This includes within different fields of medicine such as social determinants of health for UME [139], telemedicine education for PGME [140] as well as dignitary medicine (specialized care of diplomats, heads of state, and high-ranking officials) and geriatric oncology for CME [141, 142].

With these expert panel discussions, I aimed to co-develop the curriculum framework for AI family medicine education, specifically on: 1) the need and the purpose of a curriculum or a program, 2) learning objectives and outcomes, 3) course content that will facilitate the accomplishment of the objectives or learning outcomes, 4) organization of the content, 5) implementation of curriculum: a) educational strategies and b) methods of assessment. In regards to this thesis, the expert panel discussions of family medicine educators and residents contributed to the co-development of the AI curriculum framework for family medicine residents.

CHAPTER 3: METHODOLOGY

Based on recently developed curriculum frameworks for medical education, I followed a similar process in developing our curriculum framework for Canadian family medicine residency programs. Each curriculum framework developmental process differs slightly from one another within the literature, but all follow a similar evidence-informed approach. This approach generally includes defining key questions, searching the literature as well as the existing curricula and finally discussing with experts in the field through consensus methods. Furthermore, I followed a collaborative research approach through the expert panel discussions, and engaged key relevant parties, including family medicine residents and educators in the interpretation and integration of our findings in the curriculum framework. A relevant example comes from Redwood-Campbell et al. (2011) who developed a global health curriculum framework for family medicine training [79]. Multiple methods have allowed us to identify elements of an AI curriculum for family medicine residency education more comprehensively than any single method alone.

3.1 Scoping Review Methodology

Scoping reviews can be described as a form of knowledge synthesis which allows for a systematic and iterative approach to identify and synthesize an existing or emerging body of literature on a given topic [143, 144]. This includes identifying key concepts, theories, sources of evidence, and gaps within the literature. There are several reasons on conducting a scoping review such as when the research question is broad, or the purpose of the study is exploratory. However, there are four common indicators on when to choose this review methodology which include: 1) to examine the extent, range and nature of the research, 2) to determine the value of undertaking a systematic review, 3) to summarize and disseminate research findings and 4) to identify research gaps in the existing literature [143]. Based on the thesis' first objective and the exploratory nature of the research within medical education as well as the limited knowledge on this topic, a scoping review methodology was the best choice to select. The utilization of the scoping review methodology can help the reader better understand the content and context of the literature and assist in mapping out this understanding.

3.1.1. Protocol and Registration

The protocol for this review was developed in accordance with the Joanna Briggs Institute (JBI) Reviewers Manual for Evidence Synthesis and guided by the methodological framework developed by Arksey and O'Malley (2005) supplemented by Levac et al. (2010) [143-145]. The Preferred Reporting Items for Systematic Reviews and Meta-analysis extension for Scoping Reviews (PRISMA-ScR) [146] was used when reporting results, and a copy of this is reported in Appendix 1. The protocol was registered on Open Science Framework Registries and published on JBI Evidence Synthesis [147].

3.1.2. Eligibility Criteria

The eligibility criteria will be presented using the PICO/PECO (population, intervention/exposure, control, outcome) framework which has been a widely known strategy in establishing a research question and facilitating the identification of relevant information. [148, 149].

3.1.2.1. Participants

To be eligible for inclusion, the participants of the studies had to fall under the populations that provides or receives medical education which includes medical students (undergraduate medical education), residents (postgraduate medical education) and practicing physicians (continuing medical education) at any healthcare area (primary, secondary and tertiary care).

3.1.2.2. Intervention / Exposure

Included studies must describe either a curriculum frameworks and/or programs for AI education within medicine. The frameworks and programs must focus on learning about understanding AI and/or how to use AI-specific tools for the medical profession.

3.1.2.3. Outcome

For the purpose of this review all elements of a curriculum framework as described by Obadeji (2018) [83], either in part or as a whole, were considered and reported. Included papers may also describe current and developed educational programs for AI training in medicine. These educational programs have already been developed or evaluated and articles describing recommendations of what to teach or programs not yet developed were not considered. This

review specified of any framework, theory or pedagogy mentioned within the program, the delivery of the educational program (e.g., course, workshop), curricular content (e.g., learning topics, learning objectives) and if the educational program was evaluated, it will be described according to the Kirkpatrick Model of Training Evaluation [150]. Level 1 describes the degree to which learners find the training favorable, engaging, and relevant, Level 2 describes the degree to which learners acquire the intended knowledge, skills, confidence, and commitment based on their participation in the training, Level 3 describes the degree to which learners apply what they learned during training when they are back to work and Level 4 describes the degree on how the training program contributes to the success of the organization as a whole [150].

3.1.3. Type of Sources

All types of articles were included such as theoretical work, program descriptions, and empirical studies. This includes commentaries, reviews, perspectives, opinions as well as position papers and any companion papers associated. All study designs for empirical studies using qualitative, quantitative, or mixed method studies were eligible for inclusion. These include experimental and quasi-experimental studies (such as randomized controlled trials, quasi-randomized controlled trials, non-randomized clinical trials, interrupted time series, and controlled before-and-after studies), observational studies (such as cohort, case control, cross-sectional, and case series), qualitative studies (such as ethnography, narrative, phenomenological, grounded theory, and case studies), and mixed methods studies. Conference abstracts and protocols were excluded.

3.1.4. Search Strategy

The following search strategy has been developed by a specialized librarian. The text words contained in the titles and abstracts of relevant articles, and the index terms used to describe the articles were used to develop a full search strategy (see Appendix I). The search strategy took an iterative approach, initially using general terms such as "artificial intelligence," with the later addition of variations and synonyms such as "deep learning" and "machine learning." In addition, terms for the concepts of medical education and curriculum were added. An initial limited search of MEDLINE (PubMed) was conducted to identify relevant articles on this topic. An information specialist performed a comprehensive search in the following bibliographic databases: OVID MEDLINE, OVID EMBASE, CENTRAL (Cochrane Library), CINAHL (Cumulative Index to Nursing and Allied Health Literature) and Scopus. To identify any unpublished frameworks, web searches of Google, New York Academy of Medicine Grey Literature Report, and medical learning institutional websites were searched. Reference lists of all included research papers and all relevant reviews were back-searched, and Google Scholar was used for forward citation tracking to identify further studies.

Articles were restricted to English and French. Articles were restricted by date beginning in the year of 2000, up until the most recent data in May 2023. During the 1950s to the late 1990s, AI was in its early phase, thus the searches were restricted to 2000 onward [151]. The initial search was conducted in November 2021 and later updated in May 2023.

3.1.5. Selection of Sources of Evidence

Following the search, all identified records were collated and uploaded into a reference management system, EndNote v.20.3 (Clarivate Analytics, PA, USA) where duplicates were

removed. Following a pilot test with two reviewers using 10% of the studies, titles and abstracts were then screened using Rayyan, an open-source software by two independent reviewers for assessment against the inclusion criteria for the review. The full text of selected citations were assessed in detail against the inclusion criteria by two independent reviewers. Any disagreements that arose between the two reviewers were resolved by a third reviewer.

3.1.6. Data Extraction

Data was extracted by two reviewers using a data extraction tool developed and validated by the authors. The data extraction tool was created and validated by using previously validated data extraction tools and looking at key characteristics in regards to curriculum framework elements and educational program details. Any disagreements that arose between the two reviewers were resolved by a third reviewer. Data on article characteristics (e.g., authors, title, country of origin, type of study, year of publication), curriculum framework elements (e.g., 1) the need and/or purpose of curriculum, 2) the learning objectives and outcomes, 3) course content that will facilitate the accomplishment of the objectives or learning outcomes, 4) the organization of the content, and 5) implementation of curriculum) and educational program details (e.g., framework, theory or pedagogy that may have been used, the delivery of the educational program, curricular content and if the educational program was evaluated) were extracted on a validated extraction form using Microsoft Excel.

3.1.7. Data Analysis and Presentation of Results

The results of the review are presented as a table of the data extracted from the included studies to highlight the key findings with respect to the objectives of this scoping review. A numeric

summary using descriptive statistics (e.g., frequency) was used when reporting article details, study details, education program details. For curriculum frameworks described, reviewers presented main elements including: 1) the need and/or purpose of curriculum, 2) the learning objectives and outcomes, 3) course content that will facilitate the accomplishment of the objectives or learning outcomes, 4) the organization of the content, and 5) implementation of curriculum.

For current educational programs described, reviewers independently recorded and presented data on the framework, theory or pedagogy that may have been used, the delivery of the educational program, curricular content and if the educational program was evaluated, it described according to the Kirkpatrick Model of Training Evaluation. A narrative summary [152] accompanied the charted results and described what and how AI curriculum content is being delivered to trainees of various medical education stages.

3.1.8. Quality Appraisal of Included Studies

Due to the nature of this review, the methodological quality or risk of bias of the included articles was not appraised, which is consistent with scoping review guidelines [153].

3.2. Expert Panel Discussion Methodology

Expert panel discussions also known as 'roundtable discussions' can be defined as a group of experts who are selected to answer questions relevant to a particular study [154]. These discussions may occur one-on-one or together as a group and in contrast to other consensus techniques, expert panels do not require several rounds of discussion [135, 136]. Furthermore, by inviting the population that this curriculum framework will ultimately affect (e.g., educators and residents), this expert panel process is intended to increase the chances that this framework will be implemented in the future medical educational systems [155].

3.2.1. Theoretical Framework and Qualitative Methodology

Each developmental process for curriculum frameworks differs slightly from one another within the literature, but they all usually follow an evidence-informed approach. Therefore, in order to create a relevant and applicable curriculum framework, a similar methodological structure of Redwood-Campbell et al. (2011) was followed [79]. This is because their curriculum framework was for Canadian medical schools and created specifically for family medicine residents. In addition, this methodology was followed by two other studies which referenced Redwood-Campbell et al.'s study, one pertaining to homeless health [80] and refugee health [81], both for undergraduate medical education. Following Redwood-Campbell et al.'s approach, a two-step process was utilized: 1) a review of the literature and 2) a working group using qualitative or consensus methods. As the framework was concerned with the initial co-development of conceptual insights, I decided to utilize a modified participatory expert panel discussion methodology for step two [155]. Furthermore, our curriculum framework will be presented in the structure described by Obadeji (2018) as their structure encompasses all elements required for a

curriculum framework. This includes: 1) the need and the purpose of a curriculum or a program, 2) learning objectives and outcomes, 3) course content that will facilitate the accomplishment of the objectives or learning outcomes, 4) organization of the content, 5) implementation of curriculum (divided to educational strategies and methods of assessment) and, 6) curriculum evaluation and refinement. Due to the constraints of this Master level thesis, 6) curriculum evaluation and refinement were not considered or reported.

In order to guide these expert panel discussion, a qualitative description approach was employed as described by Sandelowski (2009) [156]. This methodology allows for a naturalistic approach to inquiry and thus allows the data to be presented in plain, everyday language [157]. This is an important aspect due to the interdisciplinary research topics which combines health, AI and education. Therefore, easily understood language provided by qualitative description is essential as the participants and researchers are coming from different backgrounds. Furthermore, the expert panel discussions aimed to clarify important elements that should be considered when teaching and learning AI for family medicine residents. Therefore, this was an ideal design choice as qualitative descriptions capture the participants' experiences and thoughts as close to an individuals' terms as possible.

3.2.2. Participant Eligibility Criteria

In order to fully understand the breadth of this topic, a multidisciplinary team including AI experts, researchers, educators and end-users were necessary in order to co-develop this curriculum framework. However, in order to capture these multiple disciplines, individuals with interdisciplinary backgrounds were invited. In this thesis, an expert can be defined as an individual who has comprehensive knowledge of or skill in a specific area [158]. Therefore in

order to capture this, two sets of participants were included within this expert panels, Panel 1) family medicine educator experts interested and/or have an expertise in AI education, and Panel 2) family medicine resident experts interested in AI education. Although the participants are classified as experts, panelists can have multiple identities with interdisciplinary backgrounds. For example, a member of the first panel must have the appropriate characteristics to be included, but they may also be a curriculum designer, researcher or an AI expert.

The first expert panel must include participants who are Canadian family medicine educator experts who are interested and/or have an expertise in AI. A clinical educator expert can be defined as a professional who is responsible for training and education development for clinical/healthcare workers [159]. Clinical educators can take many roles including being a physician, curriculum designer or even a researcher. However, for the purposes of this expert panel discussion, clinical educators must be focused on providing education for current or future family physicians to be included in the study. Furthermore, educators must at least be interested in AI and its applications within family medicine. Due to the fact that AI in medicine is an emerging field and that this research is based upon the intersection of AI, family medicine and postgraduate education, recruitment of participants was expected to be low due to this niche topic. Therefore, those eligible educators could be either interested in AI and/or have an expertise in AI.

The second expert panel must include participants who are current family medicine residents, have an interest in AI and attended the Department of Family Medicine, School of Medicine, Faculty of Medicine and Health Sciences, McGill University. In this context, residents act as the end-users of the curriculum framework and therefore it is important to understand their perspective on their educational needs and how to best integrate an AI curriculum into their

residency training. Residents were included in a second panel as this follows the learner-centered approach which allows learners to guide their own learning in the creation of the curriculum [157]. Furthermore, residents must at least be interested in AI and its applications within family medicine to be included.

3.2.3. Sampling and Recruitment Strategy

Participants of this expert panel discussion were sampled purposively. As the specific fields (AI, family medicine, curricula development and postgraduate education) unique to this research are limited, participants must be selected "that are most likely to yield appropriate and useful information" [160, 161].

Family medicine (clinical) educator experts were invited from affiliated universities and professional organisations via email across Canada to the first panel discussion. Educator experts were identified with the help of my supervisor who was aware of educators interested and/or have an expertise in AI. This was further supplemented by contacting other Canadian educators who have published works according to AI. Family medicine resident experts were invited from the Department of Family Medicine, Faculty of Medicine and Health Sciences, McGill University. Resident experts were identified with the help of my supervisor who was aware of residents interested in AI. According to Evans (1997), an expert panel usually consists of an average of 8 members with a median of 6 panelists which is consistent with our included sample sizes [154].

Each participant voluntarily participated in the study by providing their explicit consent and agreement, which was confirmed through email correspondence. In order to uphold

confidentiality, data was safeguarded through limited, secure data access, the disposal of audiotapes post-transcription, and the anonymous analysis of transcripts.

3.2.4. Data Collection

For data collection, I conducted two recorded sessions of the expert panel via Zoom version 5.16.10 (Zoom Video Communications, Inc., San Jose, California), 1) family medicine educator experts interested and/or have an expertise in AI education, and 2) family medicine resident experts interested in AI education. The use of an online expert panel minimizes costs associated with travel and mitigates potential biases linked to panelists, allowing participants to participate at their own convenience [135].

Each online expert panel discussion was approximately two hours long and both discussions were facilitated by myself and moderated by my supervisor. As a facilitator, I guided the expert panel discussion while my supervisor moderated the conversation and kept track of discussions in the chat. Both expert panels followed the same format. I first started off by providing a brief presentation on the results of the scoping review, summarizing the curriculum frameworks and educational programs for AI in medical education. Then, I presented each of the elements of the curriculum framework in order from the need and the purpose (element 1) to implementation of curriculum (element 5). When presenting each element, participants were invited to respond and discuss their opinions and thoughts related to each element, allowing for the co-development and redesigning of the framework together.

3.2.5. Data Analysis

Expert panel discussion data was analyzed using content analysis strategies as it has been previously conducted in a similar study [162]. This is a "systematic coding and categorizing approach used for exploring large amounts of textual information unobtrusively to determine trends and patterns of words used, their frequency, their relationships, and the structures and discourses of communication" [163, 164]. Content analysis is used to describe the characteristics of the document's content by asking key questions such as who says what, to whom, and with what effect [165].

According to Elo & Kyngäs (2008), content analysis includes three steps, 1) Preparation, 2) Organizing and 3) Reporting [166]. The preparation phase includes transcribing the data, being immersed in the data and obtaining the sense of whole through reading the transcript multiple times. Once the data from the expert panel discussions was received, the author listened to the entire recording and subsequently transcribed verbatim. The next stage of data analysis is the organizing phase where open coding and creating categories was conducted as well as grouping codes under higher order headings. As the analysis of data used an inductive approach, no prior coding systems were used and therefore coded categories were derived directly from the data [167]. The final step includes reporting the results through a narrative of the findings and by presenting the final curriculum framework after analyzing the content of the codes and categories.

CHAPTER 4: RESULTS

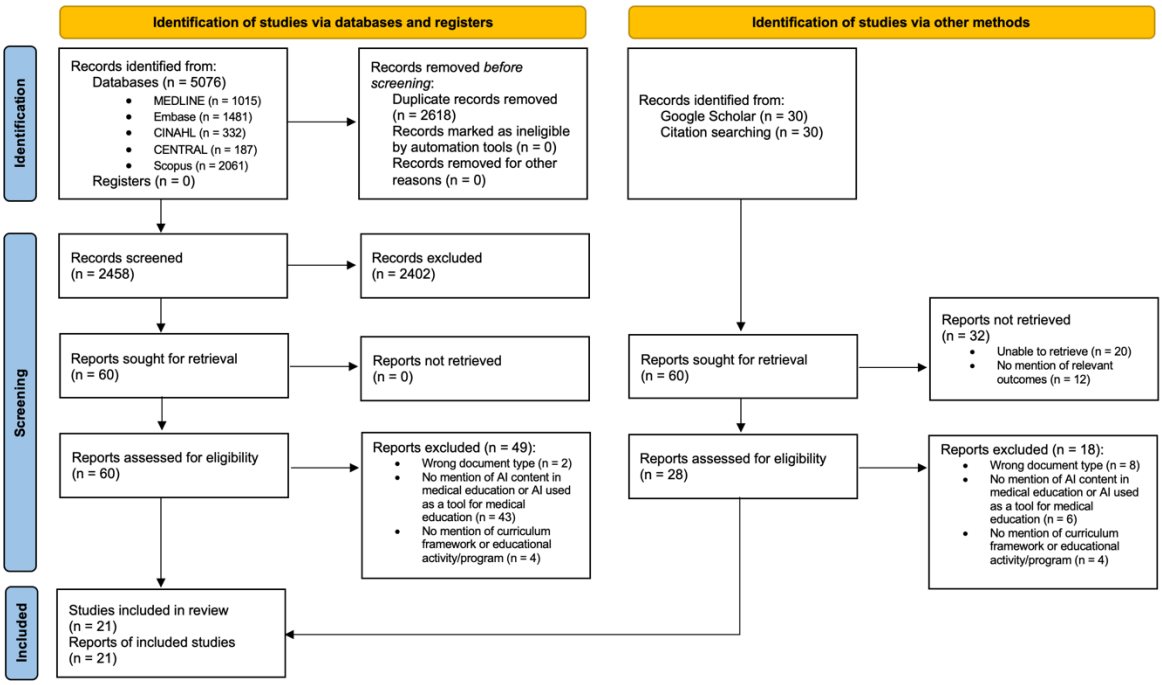
4.1. Scoping Review Results

The following results are reported in line with the aims of the scoping review. First, the results of the literature search are explained and supplemented with a PRISMA diagram [168]. Second, the study characteristics of the included papers are reported. Thirdly, papers describing elements of current curriculum frameworks are outlined and lastly, current educational program are described.

4.1.1. Search Results

From the systematic search, 5,076 total papers were identified. These papers were extracted from online databases, and the computer software EndNote was used to manage these references. Following removal of duplicates on EndNote, 2,458 papers were uploaded to Rayyan and screened by title and abstract. After abstract and title screening against the eligibility criteria, 60 papers remained for full-text screening. A grey literature search of 60 papers were identified from Google Scholar and reference lists which later returned 28 papers for full-text screening as 32 papers were not retrieved or irrelevant. Following full-text screening of both online databases and grey literature, 21 papers remained for analysis [88, 104, 128-130, 169-184]. Refer to PRISMA diagram (Figure 1) for the flow diagram of literature searches.

Figure 1. PRISMA flowchart



4.1.2. Characteristics of Included Studies

Data was collected from 21 studies and summarized in Table 1. Twelve of the studies were published in the United States, six were in Canada, and one each from Germany, Korea and Oman (Figure 2). The earliest publication retrieved was from 2016 with fifteen papers (77%) [104, 128-130, 169, 170, 172-174, 176-178, 181-184] published in the last three years, since the pandemic began as seen in Figure 2. From the 21 studies, six (29%) were reviews [128-130, 172, 180, 181] four papers (19%) were commentaries [171, 174, 177, 178], four papers (19%) were opinions [88, 175, 176, 183], three papers (14%) were perspectives [170, 182, 184], three papers (14%) were empirical studies using a cross-sectional survey design [169, 182, 184], and one position paper (5%) [173]. In terms of setting, nine papers (43%) mentioned multiple levels of education ranging from undergraduate medical education (UME), postgraduate medical education (PGME) and continuing medical education (CME) [88, 128-130, 173, 177, 178, 181, 183] while five papers

(24%) specified on UME [169, 171, 174, 180, 182], five other papers (24%) specified PGME [172, 175, 176, 179, 184] and two papers (9%) focused on CME [104, 170] (Figure 3). There are two papers (10%) [183, 184] describing elements of a curriculum framework while the remaining 19 papers (90%) [88, 104, 128-130, 169-182] altogether described 30 current or previously offered educational programs.

Table 1. Study characteristics of scoping review (n=21)

Author (Year)	Type of Paper	Country	Aim of Paper	Setting	Curriculum Framework or Educational Program
Alderson et al. (2021) [169]	Empirical (cross-sectional survey)	USA	"[…] sought to introduce pre-clinical students to the importance of AI methodologies and medical applications using modular short courses focused on active learning	UME; precision medicine	Educational Program

			with precision medicine as a primary use case.".		
Balthazar et al. (2020) [170]	Perspective	USA	"[…] describe one such initiative [AI Journal Club] led by radiology residents in collaboration with the American College of Radiology […] discussing the role of Radiologists as Knowledge Experts in a world of Artificial Intelligence."	CME; radiology	Educational Program
Barbour et al. (2019) [171]	Commentary	USA	The commentary describes lessons learned during the	UME; general	Educational Program

			development and implementation of an educational program (summit) discussing on AI in healthcare.		
Charow et al. (2021) [130]	Review	Canada	"[…] provides an overview of the types of current or past AI education programs that pertains to the programs' curricular content, modes of delivery, critical implementation factors for education delivery, and outcomes used to assess the	Multiple (UME, PGME, CME; multiple)	Educational Program

			programs' effectiveness."		
Forney & McBride (2020) [172]	Review	USA	"[…] [describes that residents should have] an understanding of the fundamentals and types of AI in radiology, the broad areas AI can be applied in radiology, how to assess AI applications in radiology, and resources available to build their knowledge in AI applications in radiology."	CME; radiology	Educational Program
Grunhut et al. (2021) [128]	Review	USA	"[…] review the current literature that covers the	Multiple (UME,	Educational Program

			attitudes of medical students towards AI, implementation of AI in the medical curriculum, and describe the need for more research in this area."	PGME, CME; multiple)	
Harish et al. (2020) [173]	Position paper	Canada	"[…] outline recommendations to develop AI learning objectives aligned with the core CanMEDS roles of Advocate, Leader, and Medical Expert, equipping medical students with the necessary competencies to	Multiple (UME; radiology, UME; general)	Educational Program

			navigate the health care environments of tomorrow."		
Hedderich et al. (2021) [104]	Empirical (cross-sectional survey)	Germany	"[…] report on [an] initial experience with [an] educational program and how the participants perceived it […] [and] assessed the participants' opinions on AI in medical imaging, as well as their self-rated skills pertaining to the topic in order to inform other institutions seeking to develop	CME; medical imaging	Educational Program

			educational programs for [medical doctors] in medical imaging."		
Hu et al. (2022) [174]	Commentary	Canada	"[…] describe an AI training curriculum that was developed and delivered to Canadian medical undergraduates and provide recommendations for future training."	UME; general	Educational Program
Kang et al. (2017) [175]	Opinion	USA	"[…] describe [their] work to organize and present the mini-course to residents […] and summarize survey	PGME; radiology	Educational Program

			responses gathered to date from the participants about their experiences in the course."		
Lee et al. (2021) [129]	Review	USA	" […] to identify gaps and key themes in the peer-reviewed literature on AI training in [Undergraduate Medical Education]."	Multiple (UME, PGME, CME; multiple)	Educational Program
Lindqwister et al. (2021) [176]	Empirical (cross-sectional survey)	Canada	"[…] presents [an] institution's efforts to address [the rise of AI within radiology] […] as a model for a successful introductory	PGME; radiology	Educational Program

			curriculum into artificial intelligence in radiology titled AI-RADS."		
Masters (2020) [183]	Opinion	Oman	"[…] provide an AI conceptual and practical framework for medical education administrators and educators, so that they may have a clearer understanding of the current situation, and may be better placed to guide future AI developments to meet their needs in medical education."	Multiple (UME, PGME, CME; general)	Curriculum Framework

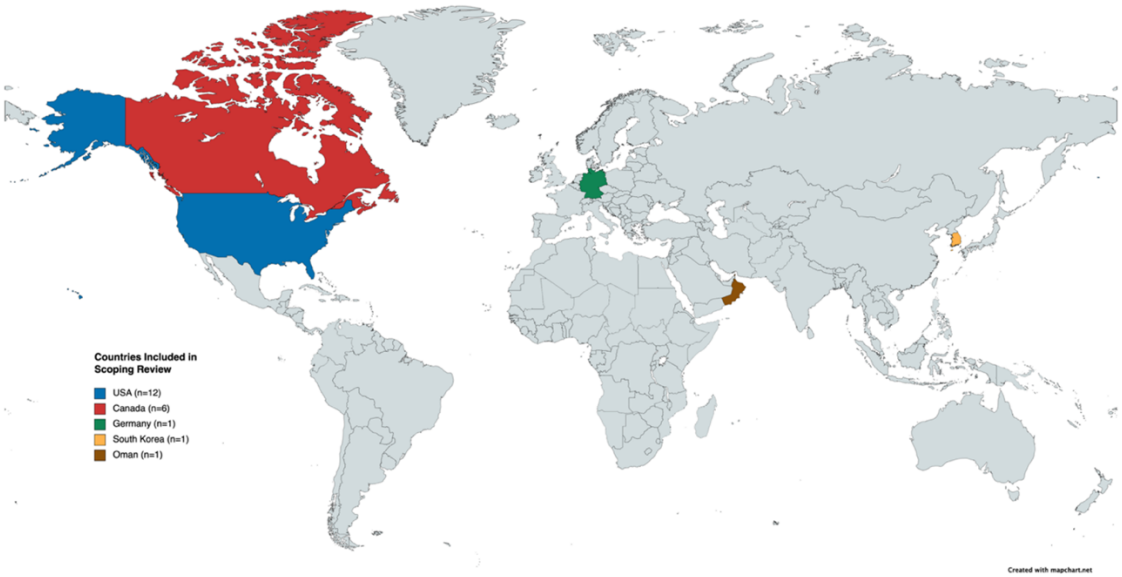
McCoy et al. (2020) [177]	Commentary	Canada	"[…] advocate for a dual-focused approach: combining robust data science-focused additions to baseline health research curricula and extracurricular programs to cultivate leadership in this space."	Multiple (UME; general)	Educational Program
Nagy et al. (2022) [178]	Commentary	USA	"[…] argue that foundational ML principles should be taught broadly to medical students across the country."	Multiple (UME; N/A, CME; N/A)	Educational Program

Nguyen & Shetty (2018) [179]	Opinion	USA	"[…] [describes the] gap in training [and] where does a radiologist in training begin […]"	PGME; radiology	Educational Program
Paranjape et al. (2019) [88]	Opinion	USA	"[…] addressed the state of medical education at present and have recommended a framework on how to evolve the medical education curriculum to include AI."	Multiple (UME, PGME, CME)	Educational Program
Park et al. (2019) [180]	Review	Korea	"[…] provide a succinct summary of the current state of AI from a medical	UME; general	Educational Program

			viewpoint and suggest what medical students should do to prepare for the era of AI in medicine."		
Sapci & Sapci (2020) [181]	Review	USA	"[…] evaluate the current state of AI training and the use of AI tools to enhance the learning experience."	Multiple (UME, PGME, CME)	Educational Program
Tschirhart et al. (2022) [182]	Perspective	Canada	"[…] describe an example of a rigorous labelling program using lung ultrasound (LUS) images that confers both AI fluency and domain expertise	UME; general	Educational Program

			for interested medical students."		
Valikodath et al. (2021) [184]	Perspective	USA	"[…] explore AI in ophthalmology, perceptions of AI among the medical community, the need to adopt AI in medical education while preserving the humanization of medicine, and recommendations for an AI curriculum for medical students, residents, and fellows in ophthalmology."	PGME; ophthalmology	Curriculum Framework

Figure 2. Countries and years of publications included in the review.



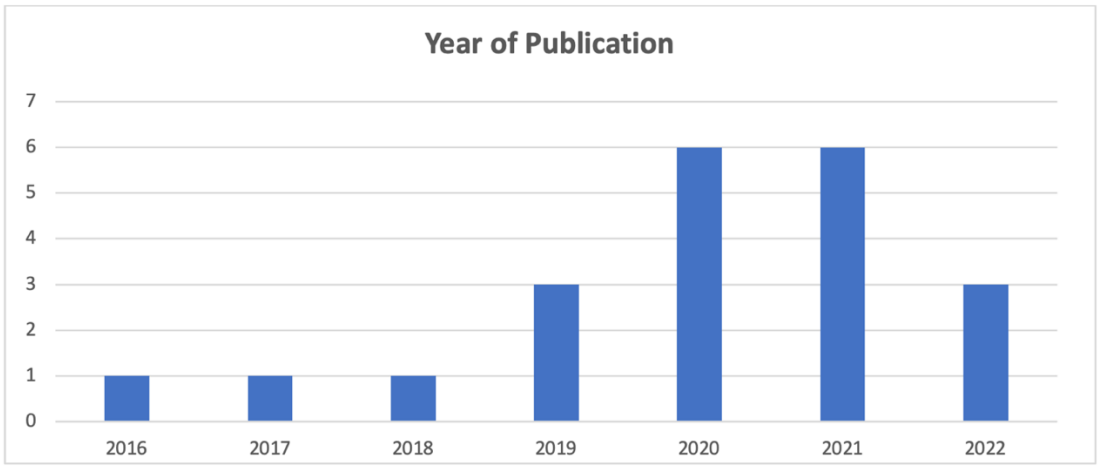
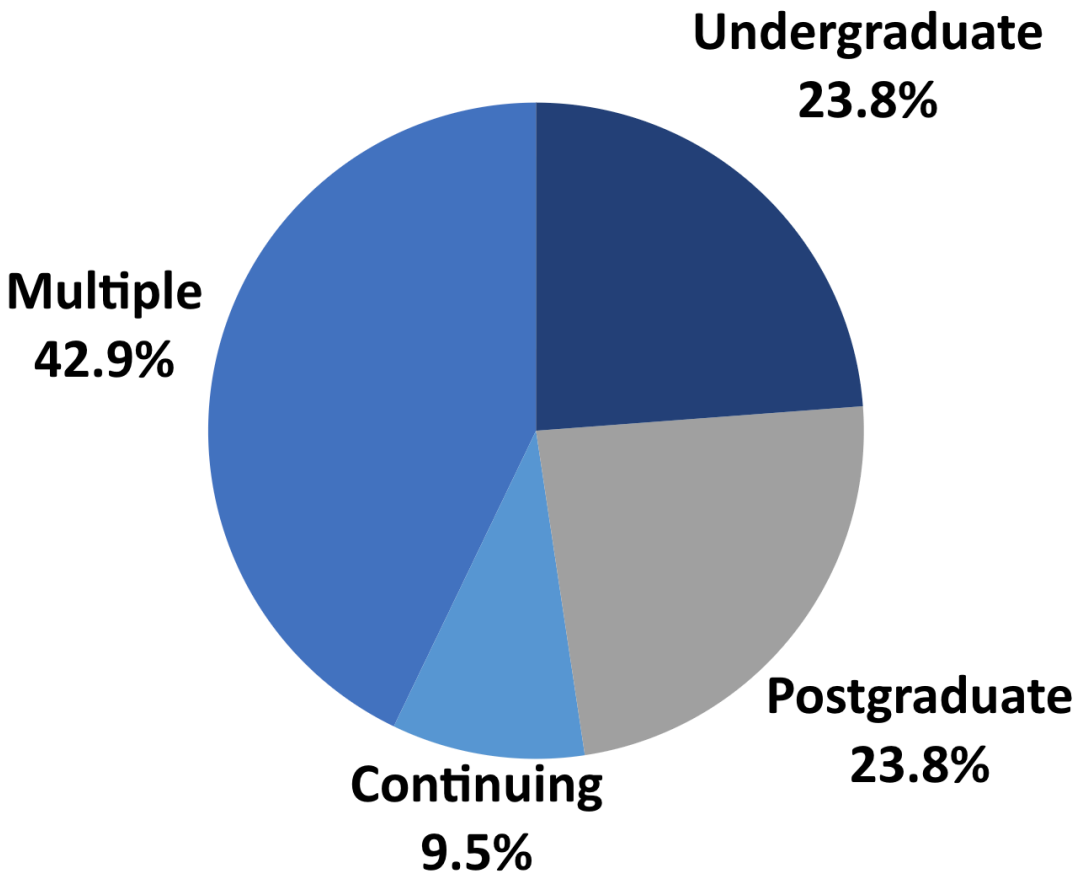


Figure 3. Level of medical education for included papers



4.1.3. Elements and Content of Curriculum Frameworks

From the 21 papers identified, only two papers described the main elements of a curriculum framework (Table 2) [183, 184]. The first paper was an opinion article by Masters (2020) focusing on general medical education which mentions three of the five elements of a curriculum framework [150]. The paper outlines the first element: the necessity and purpose of an AI curriculum. The author intends for medical schools to assess their AI education position, implement programs for understanding, and develop projects based on their needs. Masters (2020) also mentions course content with four major topics including: 1) AI as AI (learning basic AI literacy and a basic understanding of AI concepts, models and terminology), 2) AI in Medical Systems (learning the

mechanics and processes of AI systems that they will be expected to use), 3) Self-Awareness (learning that AI will impact patient interaction empathy) and 4) Ethical, Legal and Social Implications (learn the ethical, legal and social implications of AI and the questions they raise). In terms of organization of content, brief descriptions include that students with little to no exposure to AI should learn basic concepts and review introductory AI papers while more advanced students in AI should have modifications to their curriculum, electives and projects focusing on AI applications in solving medical problems [183].

The second paper to describe elements of a curriculum framework was Valikodath et al. (2021) which provides information for all five elements [184]. The main purpose of an ophthalmology AI curriculum involve acknowledging significant studies and discoveries in AI related to ophthalmology, understanding the limitations of AI, and exploring potential applications in clinical practice. The remaining elements which include the learning objectives, course content, curricula organization and potential curricula implementation methods are outlined in Table 2.

Table 2. Curriculum Framework Studies Characteristics (n=2)

	Masters (2020) [183]	**Valikodath et al. (2021) [184]**
Program Audience	Multiple (UME, PGME, CME; general)	PGME; ophthalmology
Curriculum Framework Elements		

Need and/or Purpose	This general framework will: • Allow medical schools to assess their own position in relation to AI projects, • Place these projects within that framework so as to better understand them, • Develop new projects based upon their needs.	The goals of a core AI curriculum in ophthalmology include: • recognizing major studies and discoveries of AI with regard to ophthalmology, • identifying the limitations of AI, • learning about potential applications in clinical practice
Learning Objectives	N/A	**L.O.1**. To understand the basic components of AI **L.O.2.** To identify the limitations of AI especially in healthcare and research **L.O.3.** To summarize current uses of AI in ophthalmology and evaluate primary literature **L.O.4**. To know how to potentially apply AI into

		clinical practice including telemedicine and virtual visits
Course Content	Topic 1. AI as AI Option A: The Basics "[…] we need now to teach AI literacy and a basic understanding of Data Management and AI concepts, models and terminology (such as big data (and the growing number of Vs), data mining, machine learning, deep learning, supervised and unsupervised learning, natural language processing and neural networks) […]" Option B: More Advanced "[…] the curriculum will need to be adjusted, and electives, projects dealing	Topic 1. Basic mathematics and statistics Topic 2. Fundamentals of AI, machine learning, deep learning Topic 3. How to evaluate AI literature Topic 4. Review of seminal articles Topic 5. Clinical applications Topic 6. Surgical applications Topic 7. Ethics Topic 8. Medicolegal implications Topic 9. Health disparities Topic 10. Humanization of medicine

	with AI applications in solving medical problems, and assessing AI evaluations would be a starting point […]" Option C: Common for All "In all cases where AI is taught, the current limitations of AI need to be identified […] Understanding these systems will be necessary to evaluate the applicability and appropriateness of solutions. […]" Topic 2. AI in Medical Systems "Students will need to know the mechanics and processes of AI systems that they will be expected to use […]"	

	Topic 3. Self-Awareness "There needs to be a self-awareness, in which the doctor is not merely using the tool, but is engaged in a cooperative exercise with the tool. This co-operation does not imply compliance, but rather operating together […]" Topic 4. Ethical, Legal and Social Implications "Related to the health professionals' perception of themselves and their role in healthcare, a host of Ethical, Legal and Social Implications emerge, and medical students will need to consider these and the questions they raise [...]"	

Organization of Content	N/A	Year 1 and 2: Understand basic statistics and mathematics Year 1-3: Become familiar with components and functions of AI Year 1-4: Utilize web-based learning tools (articles, lectures, modules, case-based learning) Year 2-4: Assess primary literature on current AI systems in ophthalmology Year 3 and 4: Understand integration of AI into clinical practice
Implementation of Content	N/A	*Teaching Tools (Curriculum Delivery and Assessment Methods)* • Background reading: articles on concepts in AI

		• Case studies • Online lecture series from experts in the field (regularly updated) • Interactive webinars and modules • Surgical simulation-based training • Standardized tests

4.1.4. Current Educational Programs

From the 21 included papers, the remaining 19 papers described a total of 30 current or previously offered educational programs (Table 3) [88, 104, 128-130, 169-182]. Some educational programs were repeated in other included papers and thus were noted and not duplicated in the following results. Thirteen papers (n=13/19, 68%) described, mentioned or presented 24 educational programs [88, 128-130, 170, 172-174, 177-181] while six papers (n=6/19, 32%) described and assessed six educational programs [104, 169, 171, 175, 176, 182] using evaluation methods (e.g., survey, test scores). No papers described a theory, pedagogy or framework which guided their educational program.

Table 3. Educational Program Characteristics (n = 30 educational programs described in 19 papers)

Characteristic	**Frequency, n (%)**
Presentation/Assessment	
Presentation	13/19 papers present 24 educational programs
Presentation and Assessment	6/19 papers present and assessed 6 educational programs
Type of Educational Program	
Course	15 (50%)
Project	4 (13%)
Lecture (dedicated to AI)	4 (13%)
Webinar	3 (10%)
Educational Summit/Conference	2 (7%)
Workshop	2 (7%)
Pathway of Education and Program Audience	
Undergraduate Medical Education: 17 (57%)	
General topics	16
Radiology	1
Postgraduate Medical Education: 5 (17%)	
Radiology	5

Continuing Medical Education: 8 (26%)	
General topics	4
Radiology	3
Cardiology	1
Delivery Setting	
Medical School	23 (77%)
National/International Medical Association	7 (23%)

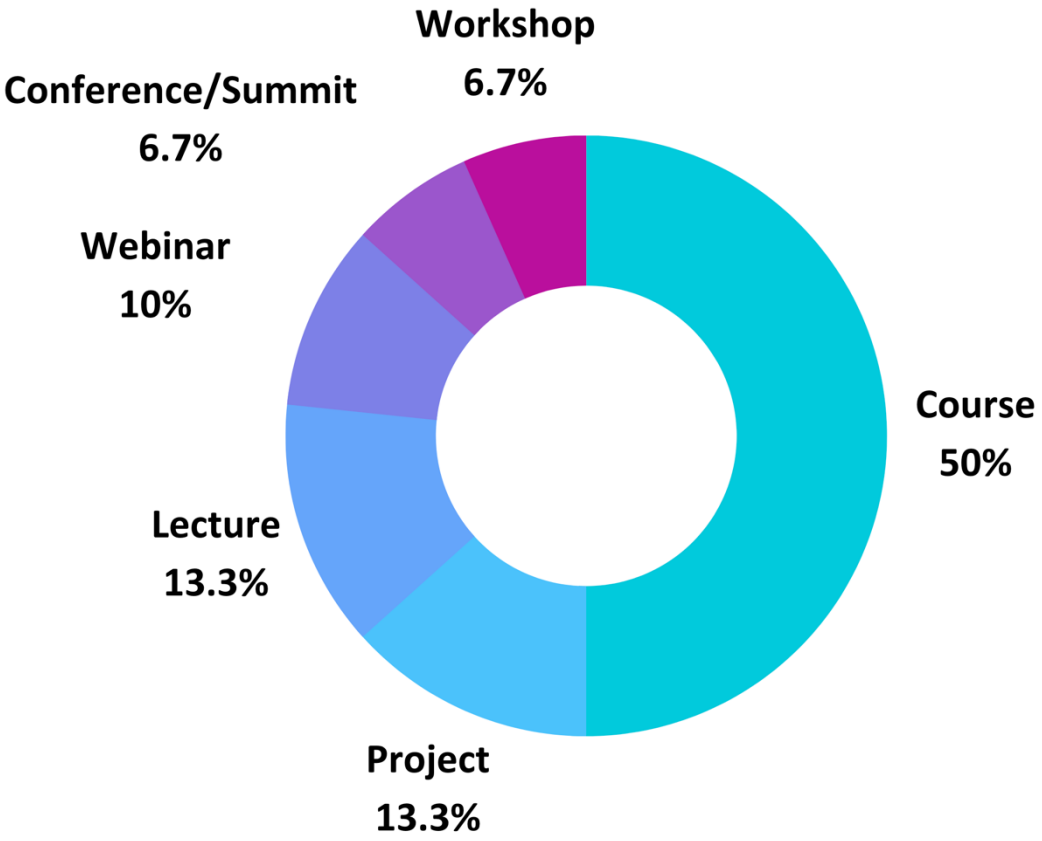
4.1.5. Educational Program Delivery and Audience

Of the 30 educational programs described collectively in the 19 remaining papers, 15/30 (50%) programs were courses, four out of 30 were project-related initiatives, four out of 30 (13%) were didactic lectures dedicated to AI, three out of 30 (10%) were webinars, two out of 30 (7%) were an educational summit or conference and two out of 30 (7%) were one-day workshops (Figure 4). AI courses were selected as those courses, usually electives that were focused on AI-based education. Didactic lectures dedicated to AI are one or two lectures which mention AI education, but not a full course. There were 23/30 (77%) educational programs delivered from a medical school while seven out of 30 (23%) were delivered from recognized national or international medical associations. Furthermore, it is important to clarify that some papers used multiple educational program delivery approaches. For example, an included paper explained their educational intervention was a course, but this course included didactic lectures, mentorship, and a final project. However, the reporting of this educational program's delivery is

classified as only a course and not counted as another delivery approach in order to minimize confusion.

Of the 30 educational programs described collectively in the 19 remaining papers, 17/30 (57%) UME educational programs were targeted towards medical students with 16 UME educational programs focused on general topics of AI in medicine and one UME educational program focused on radiology concepts. Five out of 30 (17%) postgraduate educational programs were for residents who were in the radiology specialty. Eight out of 30 (26%) educational programs were specified for practicing physicians of which four CME educational programs focused on general topics of AI in medicine, three were radiology for CME education and one was in cardiology for CME. The educational program characteristics are seen in Table 3.

Figure 4. Delivery of the 30 identified educational programs



4.1.6. Curricular Content of Educational Programs

The following curricular concepts were adapted and framed from previous, similar reviews [129, 130]. The curricular content and concepts were divided into two types: theoretical curricular concepts and application-based curricular concepts. The sub-categories and their descriptions are outlined in Table 4. The following describe the theoretical curricular concepts: fundamental of AI for using AI systems (n=15/19, 79%) [88, 104, 128-130, 169-174, 176, 178-180], fundamentals of health care data science for using AI systems (n=10/19, 53%) [88, 104, 128-130, 172 ,174, 176-178], strengths and limitations of AI (n=9/19, 47%) [128-130, 172-176, 179] and, ethical, legal and economic considerations of AI systems (n=11/19, 58%) [88, 104, 128-130, 169, 172-175, 179]. The following describe the application-based curricular concepts:

applications of AI systems (n= 19/19, 100%) [88, 104, 128-130, 169-182], operating AI systems in health care settings (n=10/19, 53%) [88, 104, 128-130, 170, 173, 174, 179, 182], impact of AI on clinical reasoning and medical decision-making (n=7/19, 37%) [88, 104, 128-130, 170, 182], communication of AI results to patients (n=4/19, 21%) [88, 128-130] and critical appraisal of AI systems (n=7/19, 37%) [88, 128-130, 177, 180, 181].

Table 4. Curricular concepts mentioned in educational program included papers (n=19)

AI Curricular Concept	Description of Curricular Concept	Reference
Theoretical Curricular Concepts (Learning What is AI in Medicine) The following concepts encompass foundational learning that serves as the basis of medical AI educational philosophy and clinical practice.		
Fundamental of AI for using AI systems	Providing an overview of AI definitions and concepts including machine learning, natural language processing, and the basics of data acquisition, cleaning, analysis and visualization.	[88, 104, 128-130, 169-174, 176, 178-180]
Fundamentals of health care data science for using AI systems	Providing an overview of the environment supporting AI which includes biostatistics, big data, and the utilization and processing of data by algorithms and machine learning.	[88, 104, 128-130, 172 ,174, 176-178]
Strengths and limitations of AI	Promoting learners' comprehension of the advantages and limitations of various AI systems such as factors that affect AI accuracy (e.g., sources of error and bias).	[128-130, 172-176, 179]

Ethical, legal and economic considerations of AI systems	Developing a comprehensive understanding of ethics, equity, inclusion, patient rights, and confidentiality, alongside regulatory frameworks, policy considerations, liability, and intellectual property issues related to using AI systems as well as grasping the potential alterations to business or clinical processes resulting from the integration of AI technologies.	[88, 104, 128-130, 169, 172-175, 179]
Application-based Curricular Concepts (Learning How to use AI for Clinical Practice) The following concepts prioritize the practical applications of AI knowledge and skills in a clinical context		
Applications of AI systems	Familiarizing with clinical application of AI systems in clinical practice to understand how they are used.	[88, 104, 128-130, 169-182]
Operating AI systems in health care settings	Understanding how to embed and engage with AI tools into clinical settings and workflows (e.g., learning to engage in data mining tools or how to properly communicate with AI systems to receive meaningful results)	[88, 104, 128-130, 170, 173, 174, 179, 182]
Impact of AI on clinical reasoning and medical decision-making	Having the ability to understand, interpret, and apply results of AI systems in clinical practice.	[88, 104, 128-130, 170, 182]

Communication of AI results to patients	Communicate findings to patients in a personalized and meaningful manner, and engage in discussions regarding the use of AI in the medical decision-making process	[88, 128-130]
Critical appraisal of AI systems	Acquiring proficiency in assessing diagnostic and therapeutic algorithms powered by AI to ensure safe and effective integration and utilization in clinical practice	[88, 128-130, 177, 180, 181]

4.1.7. Assessment of Educational Outcomes for Educational Programs

Of the remaining 19 papers which described an educational program, only six studies described and presented the results of their evaluation of an educational program (Table 5) [104, 169, 171, 175, 176, 182]. I used the Kirkpatrick Model of Training Evaluation [150] to categorize educational outcomes evaluations (Figure 5). Two papers described level 1 evaluation outcomes (e.g., learner reaction and satisfaction with the educational program) in which participants were overall very satisfied with the AI content learned with one study reporting a shift in positive attitude towards AI. Four papers described level 2 evaluation outcomes (e.g., change in attitude, knowledge or skill) in which learners demonstrated acquisition of a variety of competencies (linear algebra pertaining to AI, basics of AI) and skills (e.g., incorporate medical decisions given by an algorithm, implementing AI in clinical practice). There were no outcomes that could be categorized as level 3 or level 4; thus, the program evaluations did not comment on the change in behavior or affect at the organizational level or on patient outcomes.

Figure 5. The Kirkpatrick Four-Level Training Evaluation Outcomes and their meaning.

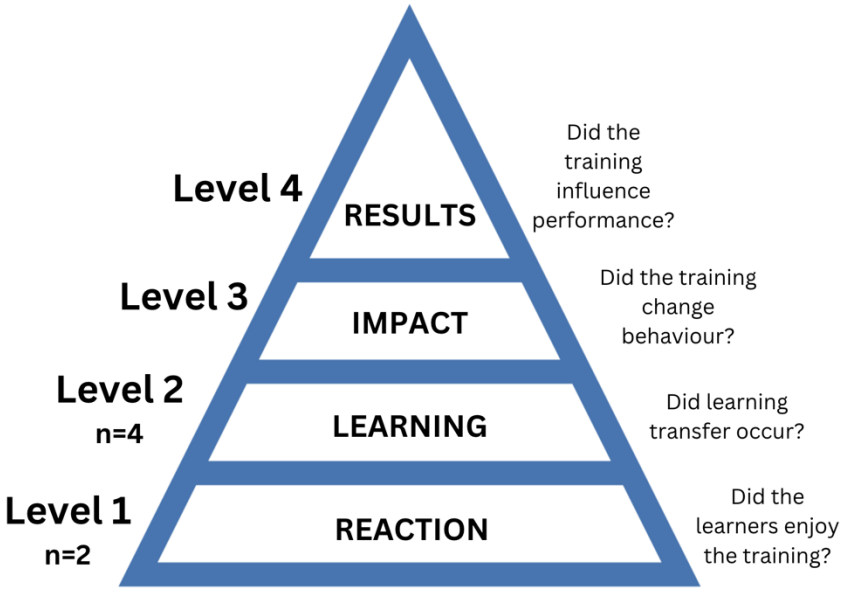


Table 5. Papers describing evaluation outcomes (n=6)

Reference	Educational Program	Kirkpatrick Model of Training Evaluation Levels and Outcomes
Alderson et al. (2021) [169]	Course	• Level 1: " […] satisfaction scores of 4.4/5.0 (n = 13) […]"
Barbour et al. (2019) [171]	Educational Summit	• Level 2: "[…] there was a general belief [about 70% from the figures] that AI would make health care less humanistic." • Level 2: "[…] did not observe a meaningful shift in attitudes regarding the desire to take a

		leadership role in developing or implementing AI […]" • Level 2: "Attendees arrived believing they had a poor baseline understanding of AI's role in health care, and left the summit with an enhanced understanding of the topic […]"
Hedderich et al. (2021) [104]	Course	• Level 1: "The participants were overall very satisfied with the study material and the organization of the course, and deemed the content of the course important for their work as a clinician or scientist." • Level 2: "[…] self-perceived skills improved in all areas, for understanding Python code as well as for understanding concepts of linear algebra pertaining to AI." • Level 2: "[…] participants felt more confident to analyse a research paper in the field, to implement an AI algorithm in a clinical environment and to incorporate the decisions given by an algorithm into their clinical decision making."

		• Level 2: “Most of the participants felt more competent at dealing with AI in medical imaging after the course.”
Kang et al. (2017) [175]	Workshop	• Level 1: “Ninety percent of the residents […] reported that the course was helpful or very helpful […]” • Level 1:”[…] 94% of the participants […] felt that the lectures were of high or very high quality.” • Level 1: “Eighty-two percent […] reported that they planned to pursue additional educational or research training in CER or big data analytics after the course […]” • Level 1:”[…] 98% of the respondents felt that health services and big data research are important or very important for the future of radiology.’
Lindqwister et al. (2021) [176]	Course	• Level 1: “Exit surveys demonstrated a high degree of learner satisfaction, with an aggregate rating of 9.8/10.” • Level 2: “There is a statistically significant difference between all pre- and post-lecture

		question results ($p < 0.04$) by Wilcoxon Sign-rank test.”
Tschirhart et al. (2022) [182]	Workshop	• Level 2: “[…] considerable improvement in the first independent dataset, with further improvement in subsequent datasets […]”

4.2. Expert Panel Discussion Results and Presentation of Curriculum Framework

4.2.1 Participation

A total of 37 educator and resident experts were invited, 16 individuals accepted the invitation and the final 14 educator and resident experts participated. The main reason provided for those who did not participate was due to their unavailability of time where non-participants did not differ from participants. Specifically, in the first expert panel discussion, 14 educators were invited and 10 educators accepted the invitation. At the end, eight family medicine educators interested and/or have an expertise in AI education participated in the panel for co-development. In the second expert panel discussion, 23 residents were invited where six residents accepted the invitation. At the second panel, six family medicine residents interested in AI participated for co-development. Members of these panels were chosen on the basis of their knowledge in the field, availability of time and interest in the subject. The characteristics of those included in the expert panel discussion are displayed on Table 6.

Table 6. Characteristics of those educator experts (N=8) and resident experts (N=6) included in the expert panel discussions.

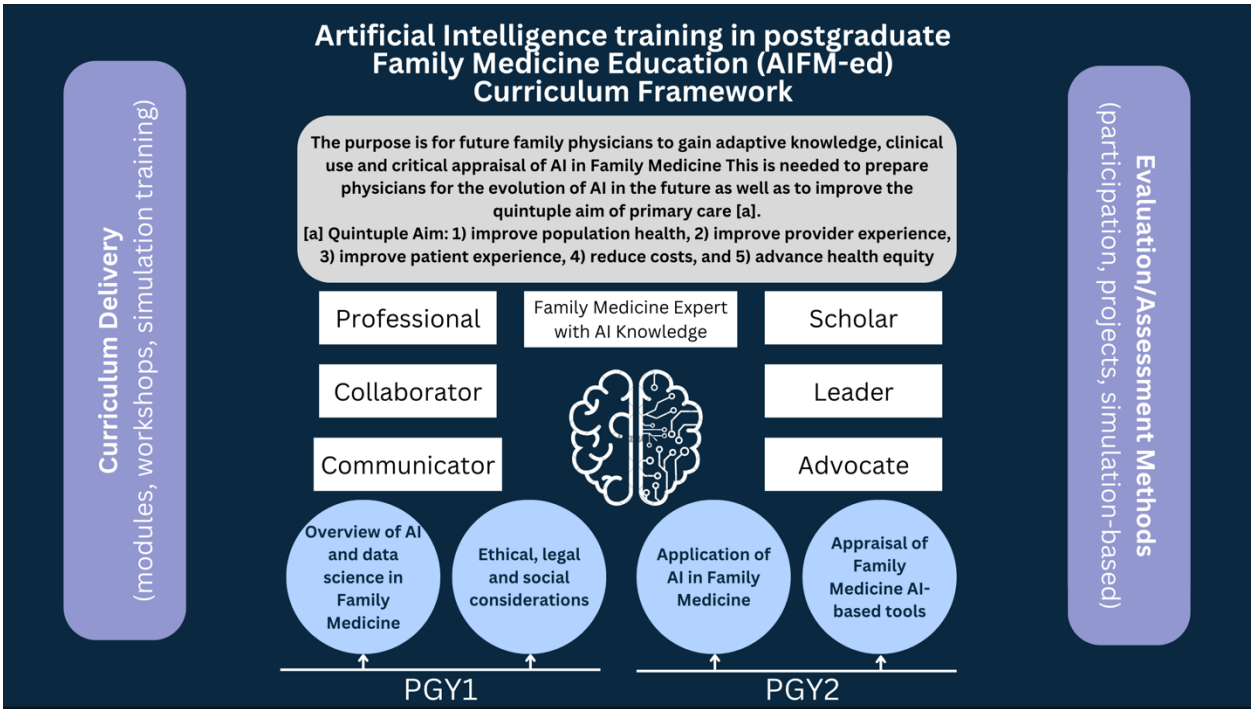
	Educator Experts **N=8** **n(%)**	**Resident Experts** **N=6** **n(%)**
Gender		
Male	3 (38%)	4 (66%)
Female	5 (62%)	2 (33%)

Educational Background		
Doctoral	7 (88%)	0 (0%)
Master	1 (22%)	2 (33%)
Bachelor	0 (0%)	4 (66%)
Affiliation		
McGill University	5 (62%)	6 (100%)
Other academic institution	3 (38%)	0 (0%)

4.2.2 Presentation of Artificial Intelligence training in postgraduate Family Medicine Education (AIFM-ed) Curriculum Framework

The following results will outline the five elements of the curriculum framework, titled "Artificial Intelligence training in postgraduate Family Medicine Education (AIFM-ed) Curriculum Framework": 1) Need and Purpose of the Curriculum, 2) Learning Objectives, 3) Curriculum Content, 4) Organization of Curriculum Content and 5) Implementation of Curriculum. The sixth component of Evaluation and Redesign were not discussed due to the time constraints and pragmatic expectations of this thesis. Each element section includes a concise explanation of each element with educator and resident experts narrative explanations and finally the content of each element in the curriculum framework. A condensed and overall visual representation of the AIFM-ed curriculum framework is displayed in Figure 6.

Figure 6. A visual representation of the AIFM-ed curriculum framework including all elements.



4.2.3. Element 1. Need and Purpose of the AIFM-ed Curriculum

When modifying a curriculum in family medicine postgraduate training, it's important understand why it must be changed and what is its purpose. In the current context of Canadian postgraduate family medicine curricula, both panels have discussed the reduced urgency and priority of AI curricula. Residents have emphasized this perspective due to the two year length in residency training and lack of exposure in training and practice. Nevertheless, both panels overall agreed that the integration of an AI curriculum will inevitably become imperative, recognizing its potential as an essential toolset in practice. One educator summarizes this thought by saying, "*AI will continue to evolve quickly, so a curriculum must be built for the future.*"

The need and purpose for AI education in family medicine was developed as, "*The purpose of an AI curriculum for family medicine residents is for future family physicians to gain adaptive knowledge, clinical use and critical appraisal of AI in Family Medicine. This is needed to prepare physicians for the evolution of AI in the future as well as to improve the quintuple aim of primary care (i.e., improving population health, improving the provider and patient experience, reducing costs, and advancing health equity).*"

A general definition of AI was provided as, "A broad interdisciplinary field evolving from the computer sciences. At a high level, AI involves the use of computers and technology to perform 'intelligent tasks' that can be independent from human control." Using various definitions of AI, the educator panel debated and heavily discussed what constitutes AI especially in family medicine. The term, "AI-based tools" was used throughout the results of this thesis as a way of describing technological tools with AI algorithms used to support clinical practice. This term has been employed in previous literature on AI in the context of family medicine training [121].

4.2.4. Element 2. AIFM-ed Learning Objectives

Learning objectives are statements that describe significant and essential learning that learners have achieved, and can reliably demonstrate at the end of a course. Learning objectives identify what the learner will know and be able to do by the end of their educational program [185]. CanMEDS-FM 2017 serves as a competency framework applicable to all family physicians, irrespective of practice type, location, or populations served. In addition to other frameworks, it paints a comprehensive picture of the roles and responsibilities of Canadian family physicians, encompassing the competencies essential to uphold their professional practice [54]. A similar approach by Gruner et al. (2022) whose curriculum framework's learning

objectives were structured using the CanMEDS-FM 2017 framework was used [81]. The following describes AI training's learning objectives as it aligns with the CanMEDS and Family Medicine roles, thus providing context for enabling competencies. Table 7 presents each CanMEDS role with their affiliated learning objectives for AI family medicine education.

Table 7. Learning objectives of AI in relation to CanMEDS roles.

CanMEDS Roles	The learner engaged in AI education will be able to…
Family Medicine Expert with AI Knowledge *Family physicians are skilled generalists who should be able to understand and utilize technology including AI tools to provide high-quality, responsive, community-adaptive care across the lifecycle, from prevention to palliation, in multiple settings, and for diverse populations.*	• Explain a basic understanding of AI and basic concepts in relation to family medicine. • Demonstrate the technical use of AI-based tools for family medicine by showing how to use the tool and analyze the output. • Critique and decide on when to use an AI-based tool over another health care resource. • Recognize perceived biases and discriminatory behaviour and results demonstrated by AI-based tools where the learner will be able to solve and prevent further effects.
Communicator *Family physicians foster life-long therapeutic relationships with patients and their families. This*	• Explain to patients the current AI-based tool they are using, why and their function in relation to the context of the situation (e.g., prevention, personalized treatment).

incorporates the dynamic exchanges that occur before, during, and after the medical encounter that facilitate gathering and sharing essential information for effective patient-centred health care.	• Address relevant gaps of understanding of AI tools among patients such as differing cultural perspectives, and digital health literacy.
Collaborator *Family physicians work with patients, families, communities, and other health care providers to provide safe, high-quality, patient-centred care.*	• Practice a collaborative team-based approach, including establishing positive and continuing working relationships with relevant parties in relation to developing, implementing and improving the quality of AI tools.
Leader *Family physicians must actively contribute to implementing and maintaining a high-quality health care system, and take responsibility for delivering excellent patient care. This includes prioritizing and utilizing healthcare resources efficiently, execute tasks collaboratively with*	• Identify which AI-based tools are appropriate for clinical practice. • Allocate AI-based tools, when available, to specific tasks (e.g., administrative work) in order for optimal patient care and practice management. • Analyze incidents of AI-based use of AI-based tools, appraise AI-based tools and resolve any issues to avoid patient harm.

colleagues and contribute to ongoing quality improvement initiatives within their own practice and its management	
AI-Health Advocate *Family physicians work in partnership with patients and communities, contributing their expertise and influence to improve health through an understanding of needs, as agents of change, and the mobilization of resources.*	• Explore strategies of AI health advocacy for implementation of AI resources in the field of family medicine (e.g., promoting funding and awareness for AI resources). • Extend AI-based tools and resources, when available and known, with other family physicians and family medicine communities • Advocate for established AI-based tools, when available, to patients with the aim of improving their health outcomes.
Scholar *Family physicians demonstrate a lifelong commitment to excellence in practice through: continuous learning and teaching others; gathering, combining, and evaluating evidence; and contributing to the creation and dissemination of knowledge*	• Participate in scholarly activities related to AI that benefit professional growth, clinical practice and patients. • Maintain and/or enhance their knowledge and skills through professional educational activities related to AI and ongoing self-directed learning.

Professional *Family physicians are committed to the health and well-being of their patients and society through competent medical practice; accountability to their patients, the profession, their colleagues, and society; profession-led regulation; ethical behaviour; and maintenance of personal wellbeing*	• Recognize and appropriately respond to ethical, legal and social issues encountered in practice as it relates to AI-based tools and family medicine by communicating to the proper channels and resources

4.2.4.1. Family Physician with AI Knowledge

Family physicians are skilled generalists who work across the lifecycle of patients, from prevention to palliation, in multiple settings, and for diverse populations. Due to the complex responsibilities and tasks of physicians, physicians need to be knowledgeable and skilled in the AI-based tools they use, if they choose to use it. Both panel groups deliberated on the extent of AI knowledge that a family physician should possess. Educator and resident panels groups emphasize that at a minimum, family physicians should be cognizant and possess a basic knowledge of AI as it relates to family medicine, specifically how AI-based tools will support clinical practice. Educators stress that family physicians should not be expected to explain the theoretical and technical concepts of AI or AI-based tools. This topic was echoed from residents who explain that usability and interpretation of AI-based tools as it relates to patient health and

clinical use should be the extent to their training. If patients are eager to access this information, family physicians can redirect to other information sources. Furthermore, both groups have emphasized understanding when and how to use an AI-based tool for their practice. Therefore, rather than being an expert in all aspects of AI and technology, the family physician with AI knowledge will be skilled in understanding the basics of AI-based tools as it relates to their family medicine practice. This includes understanding the foundational knowledge (basic concepts of what the AI-based tool is), the technical use (how to use the tool and what its output means), decision-making (when to use the AI-based tool over other tools) and recognition of its negative effects and how to prevent or remove them (being aware of perceived social biases, liability issues, and risks).

4.2.4.2. Communicator

As a communicator, family physicians foster life-long therapeutic relationships with patients and their families. These exchanges occur before, during, and after the medical encounter that facilitate gathering and sharing essential information for effective patient-centred health care. Both expert panel groups stressed the importance of not being AI experts. Consequently, they would not be accountable for communicating with patients about the fundamentals of AI and AI-based tools. However, both groups were aware that if asked, they should be able to explain to patients the use of the tool and its subsequent function. This is important if patient data is collected as family physicians must be transparent of their use of AI, the subsequent results and its role in a family physician's decision making. Therefore, family physicians should be able to communicate to patients about current AI-based tools they are using, why and their function in relation to the context of the situation (e.g., prevention,

personalized treatment). Furthermore, family physicians should be able to address relevant gaps of understanding of AI-based tools among patients with different cultural perspectives, and digital health literacy.

4.2.4.3. Collaborator

As a collaborator, family physicians must work with several populations and communities including patients, families, family physicians and other relevant parties to provide safe, high-quality, patient-centred care. The integration of AI-based tools into clinical practice involves a diverse range of individuals. Educators emphasize that family physicians should be encouraged to participate and actively collaborate with researchers and AI developers in order to create AI-based tools for family physicians. In addition, residents highlight that when collaborating, everyone will have different levels of AI knowledge and skill. Therefore, it is essential for family physicians to communicate in a manner that is commonly understood, which emphasizes the communicator role of a family physician. Overall, family physicians must continue to build interdisciplinary teams to establish positive and active working relationships with relevant parties in relation to developing, implementing and improving the quality of AI-based tools.

4.2.4.4. Leader

As a leader, family physicians must actively contribute to implementing and maintaining a high-quality health care system, and take responsibility for delivering excellent patient care. This includes prioritizing and utilizing healthcare resources efficiently, execute tasks collaboratively with colleagues and contribute to ongoing quality improvement initiatives within

their own practice and its management. Family physicians equipped with AI-based tools as well as AI knowledge and skills can enhance their leadership and management skills within the health care system. Both educators and residents recognize the usefulness of AI-based tools and how they can affect patient care and safety, health care resources and overall flow within a family physician's practice.

This is evident when residents emphasized the significance of patient care and safety, which encompasses data safety, physical harm and medical harm (e.g., ill-advice, wrong treatment) as a result of AI-based tools. Therefore, as leaders, family physicians should analyze incidents of AI-based use and appraise AI-based tools to avoid any patient harms. This is in accordance with planning and managing a professional practice in an efficient and ethical manner. Furthermore, the leaders in family medicine must engage in stewardship of health care resources. Thus, educators emphasize, when available, family physicians should properly and judiciously allocate AI-based tools for optimal patient care and practice management. In regards to overall flow, family physicians could use AI-based tools to provide high-quality care by alleviating tasks such as administrative work. Thus, this prompted the learning objective in which family physicians should be able to judicially identify which AI-based tools are appropriate for their practice, when such tools are available, and analyze and appraise such tools for efficient and ethical practice management.

4.2.4.5. AI-Health Advocate

Family physicians work in partnership with patients and communities, contributing their expertise and influence to improve health and wellbeing through an understanding of needs. Family physicians have the capacity to assist in or take charge of the mobilization of financial,

material, and human resources. Educators have emphasized that family physicians have no funding or support to implement AI-based tools within their practice. Thus, family physicians should explore strategies to advocate for implementation of AI resources in the field of family medicine. Furthermore, educators and residents both agree that AI-based tools for patient support can be beneficial for both family physicians and patient; reducing the family physician workload while providing extra assistance and information for patients. For example, a cross-sectional study of 100 practicing physicians in the US have found benefits of using online chatbots for patients such as for nutrition, treatment compliance as well as logistical tasks as it allows for fast, relevant, and accurate health information [186]. However, educators emphasized that they are unaware of many AI-based tools for patient support and are then apprehensive advocating for AI-based tools. Therefore, family physicians should share AI-based tools and resources, when available and known, with other family physician and family medicine communities to increase advocacy. Additionally, educators highlight that patients may possess a greater understanding and awareness of these tools compared to family physicians. Therefore, residents have suggested that before advocating or suggesting AI-based tools, an official list must be developed and released from a medical organization such as the College of Family Physicians of Canada (CFPC). Thus, family physicians should be able to advocate for established AI-based tools, when available, to patients with the aim of improving their health outcomes.

4.2.4.6. Scholar

Family physicians demonstrate a lifelong commitment to excellence in practice through continuous learning and teaching others; gathering, combining, and evaluating evidence; and contributing to the creation and dissemination of knowledge. As AI-based tools begins to

progress within clinical and administrative areas of their practice, it is important for family physicians to participate in scholarly activities related to AI that benefit their professional growth, their clinical practice and their patients. Educators have suggested that as a scholar, family physicians should collaborate with researchers such as participation in AI development, implementation and evaluation studies for clinical practice. Furthermore, residents emphasized that AI-based tools and AI in general will have substantial change in the future. Thus, residents reinforce the concept of continuous learning by assuring their commitment to continuing professional development in AI when they are experienced family physicians. Therefore, family physicians should be able to maintain and/or enhance their knowledge and skills through professional educational activities related to AI and ongoing self-directed learning.

4.2.4.7. Professional

Professionalism forms the foundation of the tacit agreement between the medical profession and society. As professionals, family physicians are committed to the health and well-being of their patients, self and society. This can be seen through competent medical practice; accountability to their patients, the profession, their colleagues, and society; profession-led regulation; ethical behaviour; and maintenance of personal wellbeing. As AI grows rapidly within society, family physicians must recognize its impact to clinical practice and the medical profession as a whole. Residents are aware of this rapid shift as seen through discussions of using ChatGPT, an AI-based chatbot launched by OpenAI which can be used as a virtual consultant (e.g., simple inquiries about diagnoses and treatment plans). However, both educators and residents express their hesitation when it comes to ethical, legal and social risks of AI-based tools. Although the hesitation to use AI-based tools are present, residents suggest that being properly trained in

identifying and addressing these risks can potentially overcome this tentativeness. For example, one resident stressed that although they use ChatGPT at times, they are cautious of the information as they are aware that ChatGPT can make mistakes and always consult other resources. Therefore, when available and in use, family physicians should be able to recognize and appropriately respond to ethical, legal and social issues encountered in practice as it relates to AI-based tools and family medicine by communicating to the proper channels and resources (e.g., AI ethics experts and lawyers).

4.2.5. Element 3. AIFM-ed Curriculum Content

When developing a curriculum, a crucial element is to identify relevant subjects, skills, attitudes, and behaviors that will facilitate the achievement of the learning objectives [83]. The development of curriculum content is based on the changing Canadian medical educational structures. Currently, there is no required AI education prior to residency education in Canada. However, both educators and residents agree that in order for AI to be efficiently introduced in family medicine residency, AI education must be introduced earlier in UME. This will provide the basic principles and curricular concepts of AI much earlier, allowing residents to build upon the knowledge, attitude and skills developed in UME.

During the panel discussion, two streams of education were presented due to the unknown changing landscape: 1) AI concepts not introduced in UME and 2) AI concepted introduced in UME. The first stream emphasized learning the fundamentals and background of AI with application and critical appraisal of AI-based tools. The second stream summarizes the fundamentals and instead focuses on learning how to use AI-based tools (application) and the decision of when to use and evaluate them (critical appraisal). In regards to these two streams,

both educators and residents agree that the second stream is more applicable, relevant and pragmatic within residency training.

Residents mention that a review of theoretical concepts (e.g., review of AI concepts as well as ethical, legal and social considerations of AI) should be condensed and should serve as a review or refresher of topics. Residents noted that understanding how AI-based tools are used in clinical practice are preferred. A resident provided further context by providing an example using ChatGPT, where they explained that they do not need or want to learn the history of ChatGPT, but rather how to write effective prompts within this natural language processing chatbot. Therefore, the content should reduce its focus on the foundations of AI and instead increase AI education surrounding the application and appraisal of AI-based tools in family medicine practice. Table 8 demonstrates the co-developed key concepts and areas of interest that family physicians should learn and content to include in the curriculum.

Table 8. The curricular concepts and areas of interest that family physicians should learn and subtopics to include in the curriculum

Main Curricular Topic	**Subtopics**
Overview of AI and Data Science in Family Medicine Providing an overview of AI definitions and concepts including machine learning as well as topics related to data science and clinical epidemiology for family medicine.	• Review of AI (definitions and concepts) as it relates to Family Medicine • Introduction to AI and Fundamentals of Data Science in Family Medicine • Strength and Limitations of AI-based Tools

Ethics, Legal and Social Considerations Understanding the ethical, legal and social concerns of AI as it impacts family medicine clinical practice.	• Ethics, Patient Rights, Data Security and Confidentiality • Liabilities, Regulatory and Policy Considerations • Equity, Bias and Access of AI
Application of AI in Family Medicine Understanding how to choose and engage with AI-based tools into clinical settings and workflows with the ability to understand, interpret, and apply results of AI systems in clinical practice.	• Operational Efficiencies and Practice Management • Preventative Care and Risk Profiling (e.g., mental health, chronic disease) • Patient Self-management • Physician Decision Support • Physician Wellness and Resilience • Social Determinants of Health
Appraisal of Family Medicine AI-based Tools Assessing and reviewing AI-based tools to ensure safe and effective integration and utilization in clinical practice.	• Identification of Adverse Effects and Potential Solutions • Quality Improvement

4.2.6. Element 4. Organization of AIFM-ed Curriculum Content

Family medicine postgraduate training is of 24 months length in Canada. The current curriculum organization for family medicine training in Canada is complex and packed. Educators and residents alike have emphasized that the addition of another competency could be

a burden to both educators and resident learners. However, both panel groups agree that an AI curricula will eventually need to be added and thus an organized structure should be established. Residents believe that the curriculum should be incorporated within the 24-month core family residency, stressing the importance of longitudinal learning. Residents suggests that the AI curriculum could appear in short educational programs (e.g., dedicated AI lectures or mini-projects), revisited multiple times.

Educators emphasize that program directors ultimately decide how and when to add certain AI curriculum elements to the core family medicine curricula. According to the curriculum content described in Element 3, the organization involves AI knowledge-based training during the first postgraduate year, followed by the development of AI-based clinical skills in the second postgraduate year (e.g., application of AI-based tools and deciding when to use them). However, for deeper AI education, an Enhanced Skills program can be further proposed, a third-year which would consist of a reduced number of residents, about one or two interested and skilled residents. Furthermore, additional time would be ideal in order to effectively introduce an AI core curriculum.

4.2.7. Element 5. Implementation of AIFM-ed Curriculum

The implementation of a curriculum ranges from identifying the appropriate resources (e.g., educators and materials), to determining the educational strategies that will facilitate the learning and determining the evaluation methods needed to gauge the extent of their learning. The implementation of curriculum will be divided into two sub-elements: 1) curriculum delivery and 2) assessment and evaluation methods.

4.2.7.1. Curriculum Delivery

Curriculum delivery comprises of identifying the learning theory (constructivist, behaviourism, cognitivist, humanism) providing the basis of teaching and learning as well as determining the teaching and learning methods (e.g., online learning, small group discussions, problem-based experiential learning). In addition, this sub-element includes recognizing the faculty needed to facilitate these teaching and learning methods and the materials needed.

Prior to delivering a curriculum through an educational program, a learning theory and pedagogy should be determined [126, 138]. There are many learning theories utilized in family medicine education; however, it is important to be aware of the context of what one will be learning. In this context, residents highlight that AI education must be longitudinal as it must be built upon throughout the medical education continuum. Furthermore, educators emphasized that residency is student-centred with learners coming from diverse backgrounds where they must replicate the actual tasks performed during in practice. Therefore, the learning theory of constructivism appears to be a sound and advantageous choice. This learning theory posits that learners actively construct their own learning by drawing upon their prior experiences [187]. Constructivism establishes learning as an active, personalized process, unique to each student. In summary, constructivism underscores the importance of contextual learning and the establishment of an adaptive learning environment, essential aspects for learning AI in family medicine residency.

There are several methods to implement an AI education curriculum to family medicine residents; however, there are certain methods that are recommended by both educators and residents. In terms of learning about the knowledge and background of AI (e.g., review of AI concepts or the ethical, legal, and social considerations of AI), hybrid (online and in-person)

courses with asynchronous online modules and in-person workshop, problem-solving sessions could be applied. Residents emphasized that didactic large group lectures especially in regards to a novel topic such as AI would be unwise. The learning of such content should be considered a refresher with emphasis on the context of AI in family medicine. Both educators and residents then suggest that the in-person sessions would serve as a space for questions and answers and problem-solving activities.

However, the learning of the application and critical appraisal of AI-based tools require further attention and detail. In regards to learning when to use AI-based tools and how to competently, effectively and responsibly use them, simulation-based training with AI-based tools in clinical practice sessions could be added. Residents believe that simulation of these tools are beneficial as it allows residents to enjoy the learning process and realize how these AI-based tools would operate in actual clinical settings. During these sessions, educators highlight reviewing the AI-based tool's capabilities and basic functions. For example, an educator mentioned an AI-based tool, EyeArt AI (EyeNuk, Inc., Woodland Hills, CA, USA) which allows for screening of diabetic retinopathy and identifying which patients are at risk of losing their vision [188]. Another example includes AutoScribe (Mutuo Health Solutions, Toronto, ON, Canada) an AI-based tool that transcribes dialogues between clinicians and patients and automatically generates medical notes [189]. In addition, educators have also commented on facilitating AI learning by integrating family medicine AI-based tools in quality improvement projects.

In order to execute these educational methods, human and material resources are pertinent. Educators and residents highlighted that experts in the field of AI and family medicine would be ideal; however, educators emphasized the faculty challenges such as the current

number of experts are limited to provide this education. To overcome this, residents suggested that once an AI curriculum is established, further educators could be sourced from recently graduated residents who completed the AI in family medicine curriculum. With respect to material resources, AI-based tools must be added and validated for family physicians to physically use these tools.

4.2.7.2. Assessment and Evaluation Methods

Assessment and evaluation methods ensure that learning objectives of the curriculum are achieved. These methods can provide a preview into the degree of a student's learning of knowledge, skills and attitudes and the attainment of learning objectives. Different assessment methods include surveys, interviews and objective structured clinical examinations (OSCE). Residents emphasize that the assessment and evaluation methods for the curriculum should be simple in context and focus on learners' participation and exposure. More specifically, learners should be able to have the capacity to demonstrate how to use AI-enabled tools and techniques in a healthcare setting. This can be seen through the completion of projects and problem-based and simulation-based assessment. Educators on the other hand emphasized taking into account Kirkpatrick's four levels of training evaluation model where assessments should be directly related to the activity's learning objectives. An example of how to assess each level of an AI training activity in residency are as follows. Level 1 focuses on residents' response and satisfaction to the learning experience which can be ascertained through a questionnaire or survey. Level 2 focuses on the acquisition of knowledge, skills, and attitudes after the learning experience, this can be measured through pre-test and post-test using clinical skills examinations. Level 3 centres on behaviour change as in determining if learning of AI transferred to clinical

practice. This can be evaluated using an observation checklist or interviews, assuring that residents are appropriately and confidently using these tools in practice. Finally, level 4 outlines the level of change in performance and organizational practices as well as any benefits to patients as a result of an AI curriculum. The measurement method would be contingent on the specified learning objectives. For example, if the training had learning objectives of using AI-based tools to increase patient satisfaction in a clinic, then an educational team must collect data on pre- and post- patient satisfaction rates in order to determine a change.

CHAPTER 5: DISCUSSION

The development and implementation of AI in medical education has greatly increased within the last decade, specifically with the COVID-19 pandemic where there was a global shift into the digital world accelerating the development of AI technology [190]. This can be seen as the majority (70%) of included papers within our scoping review were published since the pandemic began in 2020. Although there is a growing field within research and practice, AI medical education, specifically within curricula development is still limited. Therefore, the proposed multimethod curriculum framework, "AIFM-ed" was developed through a scoping review and expert panel discussions.

The scoping review examined the current breadth of educational planning (as seen through curriculum frameworks) and the execution (as seen through educational programs) of AI education within medicine, specifically in UME, PGME, and CME. The expert panel discussions was a co-development process, allowing for a relevant and user-informed framework.

In the following chapter, I first discussed the limited availability of curriculum frameworks for AI medical education where further research is needed. Second, I examined the current state of AI educational programs where there is a lack of theory, framework or pedagogy used, and the programs are usually focused on generalized content and diverse implementation methods. For the programs evaluated, they were met with positive outcomes. Third, I provided areas of improvement specifically the need for in-depth curriculum planning of AI medical education. Then, I described the development of the AI curriculum framework, specifically highlighting the innovative nature and challenges. Finally, I discussed the next steps of this framework where further validation and subsequent implementation is recommended.

5.1. The Changing Landscape of AI Medical Education

5.1.1. Current State of Curriculum Frameworks for AI Medical Education

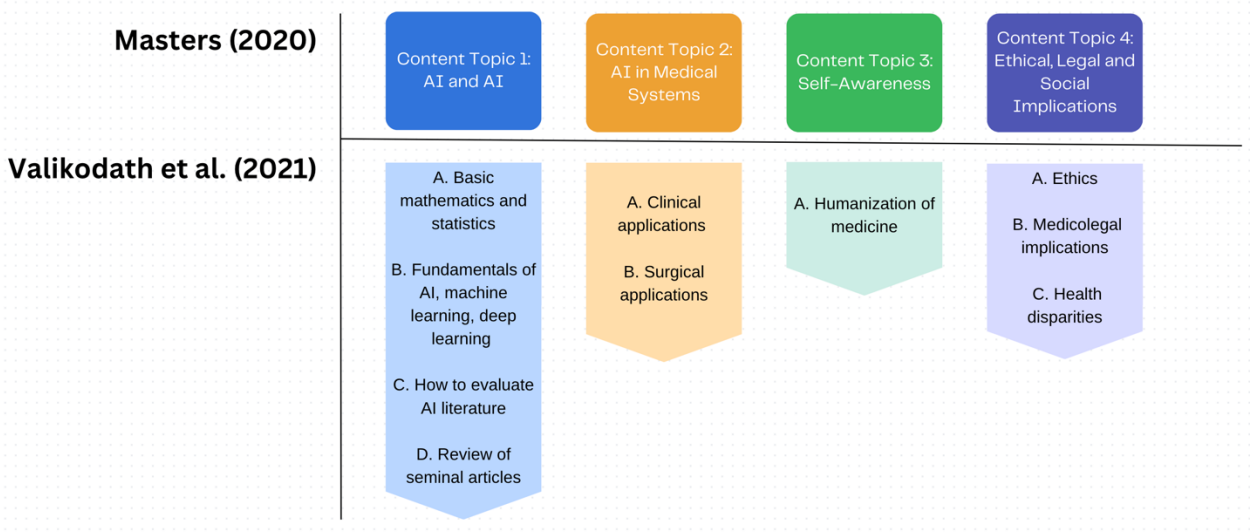
To the best of our knowledge, this is the first scoping review to identify curriculum frameworks for AI in medical education and our findings demonstrate they are very limited. Although the literature is abundant in terms of recommendations and potential plans of actions for integrating AI education within medical education, there are few formal curricula or frameworks [98, 191, 192]. Many published curricular recommendations lack specific learning outcomes and are not based on a particular education theory as they usually focus solely on the content or competencies that should be taught [129, 183]. Although understanding what concepts should be taught in AI is important, curriculum frameworks must be as detailed as possible when developing curricula.

From the identified frameworks in our review, Masters (2020) [183] outlines a broad framework for any level of education while Valikodath et al. (2021) [184] outlines a complete framework for ophthalmology residency education. Their frameworks' elements were presented and described differently in all aspects except in how their course content was described. I noticed similarities among these two frameworks in relation to what medical trainees should learn as emphasized in Figure 7. From our comparisons, I found that the main curricular topics as presented by Masters (2020) appropriately corresponded to the curricular topics presented by Valikodath et al. (2021). For example, a main curricular topic of "AI in Medical Systems" which describes the way in which students should learn the mechanics and processes of AI systems that they will be using in the future. This corresponds to "Clinical Applications" and "Surgical Applications" in which the content is targeted into learning how to use AI applications for

ophthalmology. It appears that Masters' framework on course content can work as the foundation on what curricular concepts a program should include.

As seen with these two articles, the lack of curriculum frameworks in the literature is staggering. Frameworks are vital in AI education, offering adaptability and guidance. However, an ophthalmology curriculum framework proves inadequate for family medicine residency due to the diverse, community-based nature of family medicine, which differs significantly from the highly technological and hospital-based focus of ophthalmology. Further studies should focus on the development of these frameworks and start thinking on how to plan for the impending changes such as AI in medical education. As Valikodath et al. (2021) [184] demonstrated their AI curriculum framework for ophthalmology, other specialties should follow suit as AI affects each specialty differently [10]. Overall, the current state of curriculum framework for AI in medical education appears to be far from sufficient in the existing literature and further research is needed.

Figure 7. The comparison between the course content described by Masters (2020) and Valikodath et al. (2021).



5.1.2. Current State of AI Medical Educational Programs

In comparison to curriculum frameworks, several AI educational curricula programs have been reviewed recently, the majority in the past three years [128-130] which may reflect the rapidly changing use of AI in clinical care. As research in AI medical education evolves quickly I sought additional descriptors of published curricula. I specifically looked at the framework, pedagogy or learning theory described, the content and its audience, and if the program was evaluated for outcomes which were used to assess its effectiveness, according to the Kirkpatrick Model.

5.1.2.1. The Lack of Learning Theories and Pedagogies

No papers referenced a curriculum framework, pedagogy or learning theory which guided the development of their educational program (e.g., course, workshop, project). However, the use of frameworks, pedagogies or learning theories is important for informing the development of valid, accurate and competent educational programs [193-195]. By using these types of guidelines, educators can choose the most effective instructional techniques, learning objectives,

assessment and evaluation approaches which can best help their students to learn [196]. A recent paper which fell outside the scope of our search date describes the use of constructivist theory and backwards design learning principles which guided the development of their AI course [197]. Further studies should implement and report on a learning theory, framework or pedagogy as they have a role in medical education [196].

5.1.2.2. The Generalized AI Medical Content

The integration of AI concepts and topics within medical education remains generalized throughout the different levels of medical education as seen with the educational programs described in our review. Twenty educational programs were described as focusing on general topics such as introductions to AI or information on AI and its application to medicine. The only postgraduate and continuing educational programs which had an AI-specific educational material were the speciality fields of radiology, ophthalmology and cardiology. This can be attributed to various reasons including the constant evolution and novelty of AI technologies which may describe why generalized educational programs for AI (e.g., Intro to AI in Healthcare) appear across the medical educational continuum as seen in UME and CME. Out of the three specialties, radiology had the highest number of educational programs and was seen in all levels of medical education. Another reason could be because radiology is a highly technological field than most specialities. It is encouraging to see that specialties such as ophthalmology and cardiology have increased interest in AI education; other specialties and medical institutions should begin to follow suit. This is encouraging as it demonstrates that other specialties besides the highly technological field of radiology has been learning AI within medical education. Furthermore, most of the educational programs were found in UME and within medical schools which is ideal

as it introduces a large audience of medical students to the concept of AI and its applications early in their careers.

5.1.2.3. The Success of Current AI Educational Programs

The included studies in our scoping review demonstrated that current efforts are being made to evaluate the outcomes of AI-related educational initiatives. According to the Kirkpatrick Model, an internationally recognized tool for evaluating and analyzing the results of educational, training and learning programs [150], current AI programs have overall been positively received by medical learners. This was represented by the positive reactions, opinions and attitudes towards AI after completing an educational program (level 1) as well as the acquisition of AI-related knowledge, skills and confidence (level 2). These findings were also presented using the Kirkpatrick Model in a similar review in which the AI educational programs they identified also had positive outcomes categorized as level 1 or level 2 [130]. However, further studies must assess educational programs for outcomes in relation to behavioral changes (level 3), specifically if there has been a transfer of AI-related knowledge, skills, and abilities into their daily work. Further studies should also assess how the acquisition and application of these AI-related knowledge, skills, and abilities has affected the organization as a whole (e.g., has the increase in AI educated physicians improved overall efficiency at the hospital?) or on patient outcomes (e.g., has there been an improvement in the patient's functional status or safety as a result of AI educated physicians?) (level 4). By assessing for these additional outcomes, educators and medical organizations can understand how current AI educational programs have affected physician performance with AI technology. Increased research on the evaluations of educational programs can help further validate current educational tools and be used as inspiration for other

institutions to create their own educational material. As seen in the review [130], there is a lack of consistency in the measures of these outcomes, as self-constructed and non-validated instruments were also used. Future studies should develop a validated tool to evaluate educational outcomes for a comprehensive synthesis.

5.1.3. The Need for Further Curriculum Planning and Framework Development of AI Medical Education

Curriculum planning as in the process of designing and organizing an educational program of AI educational initiatives within medical education is insufficient. Although limited studies of curriculum frameworks were published, curriculum pre-planning can be seen in the literature. Some medical institutions have conducted pre-planning stages with AI perception surveys [118,120], curriculum needs assessment surveys [198-200] and an interview [201] to understand what should be integrated into the AI medical curriculum. These studies are promising and contribute to the overall efforts to understanding how current educators, medical students, residents, and physicians consider AI within their educational system.

The absence of curriculum frameworks is staggering despite the fact that AI competence will likely be added to the skills required of medical graduates [202]. The development of AI curricula and frameworks have already been gaining traction across other fields of education and levels. This can be seen as early as childhood education in which Su and Zhong (2022) present their own curriculum framework which outlines their concepts, teaching methods, teaching activities, projects, and assessment suggestions for AI education [203]. From a global perspective, the United Nations Educational, Scientific and Cultural Organization (UNESCO), a specialized agency of the United Nations, released a document outlining the current practices of

developing and implementing AI curricula in primary and secondary school education (K-12) [204]. From their report, several types of frameworks for AI literacy have been suggested such as the AI Literacy Competency Framework, the AI4K12: Five Big Ideas Framework and the Machine Learning Education Framework. These recent reports and articles suggest increased efforts to integrate AI education prior to post-secondary school, which further stresses the importance of developing AI curricula and frameworks in medical education. When compared to other allied health professionals such as pharmacy, physical therapy or occupational therapy, their respective curricula have not evolved to include AI. However, within the nursing field, there have been current efforts for curriculum reform with the planning and development of a proposed competency framework in Quebec, Canada [205]. Their five competencies include: 1) an introduction to AI health technologies in nursing practice, 2) gaining knowledge of AI data and how the data are created and stored, 3) communicating with health care professionals, patients, and family, 4) understanding the ethical and social implications and 5) engaging with AI as an end-user or subject matters expert. The nursing AI competencies developed share similar thematic curricular concepts analyzed from the findings of the scoping review in this thesis. Therefore, it appears as nursing is another impacted healthcare field that is preparing for the changes that AI will cause. Overall, educational frameworks for AI education are currently being developed in other fields and levels of education and thus medicine must follow suit. Thus, each level of medical education and their corresponding medical speciality must have their own specialized curricula to tailor the educational needs of the learners.

The concept of continuity in AI education, involving the progressive development of knowledge and skills, remains largely unexplored across the academic journey from undergraduate medical education to postgraduate training and continuing professional

development. The introduction of AI in medicine must be coherent and relevant within UME, PGME and CME. Therefore, curriculum frameworks should be properly created through different levels of education and specialties. This has been emphasized by other reviews which call for integration of AI education in all levels and thus all specialties of medicine [93, 130]. For example, a curriculum framework for UME will be different than a curriculum framework for PGME in dermatology. Curriculum frameworks can be adapted and they most likely will be, especially since AI education in medical education is still in its infancy. This is where leaders in UME, PGME and CME organizations (e.g., policymakers, medical educators, researchers, etc.) must communicate effectively to structure AI education across the continuum and review important recurrent information. Consolidating knowledge and skills acquisition through repetition is a positive and desired outcome [206]. New technology and innovations in relation to AI and medicine will inevitably occur; however, it's important to be aware of the fundamentals of AI and how it will affect a physician's practice at the time. Sufficient planning of an AI curricula will deliver effective education for physicians who will increasingly be using AI technology in the near future, therefore medical educators and institutions must begin to consider curriculum planning now.

5.2. The First Curriculum Framework for AI in Family Medicine (AIFM-ed)

This thesis introduces a novel and evidence-based curriculum framework, i.e., AIFM-ed developed for AI literacy education in family medicine postgraduate training. In addition to being the first AI curriculum framework for family medicine, this was the first out of all previously identified AI curriculum framework in medicine to develop this framework using a systematic approach. Previously identified AI curriculum frameworks were developed by one

author [183] and the other paper did not mention their developmental techniques [184]. However, our framework utilized a combination of validated methods including a comprehensive literature review, resident and educator panel discussions and the involvement of interdisciplinary experts in the field. As no other studies have completed similar curriculum framework developments for AI education in medicine, I believe this thesis can provide as an example or reference for future studies. Therefore, educational researchers can follow this successful framework developmental process within their own program context.

As the pioneering example, this curriculum framework comprises core educational elements from the main purpose, to core learning objectives and curriculum content, its organization as well as proposed implementation methods that underlie the education regarding AI education. This practical guide aims to enhance the current curriculum development and approach of medical institutions in relation to AI across the nation. Due to the CFPC's role in standardization and accreditation, Canadian family medicine residency programs are quite similar and thus this framework can extend to these programs. Although the context of this framework is specified for family medicine training, other programs and institutions in other medical specialties and levels of education can modify our AI curriculum framework. Program directors can add and edit what they find relevant in relation to their time, setting, organization, type of pedogeological activities, and priority of topics.

5.3. Curriculum Framework Challenges

During the development of this curriculum framework, there were several challenges in effectively integrating an AI curriculum framework to a family medicine residency training program. The following section will outline the challenges which include the lack of AI

definition standardization, the reduced urgency in practice due to the lack of time and resources as well as the capacity to balance theoretical and practical curricular content.

During the expert panel discussions, many experts emphasized the issue regarding the lack of standardization with the definition of AI. Although a definition of AI was chosen for the purpose of the panel, a specific and committed definition of AI within medical education has not been established [88, 128, 129]. Panelists argued that an AI definition must be properly explained to avoid confusion or misrepresentation. There are current efforts from medical organizations to provide definitions of AI within a medical context, this includes Canada's Royal College of Physicians and Surgeons [8]. In relation to family medicine, a recent primer for AI in primary care was published which provided the definition, "The field of AI is broad and rapidly expanding. The field is centred on how computers might be able to perform humanlike 'intelligent tasks,' such as summarizing large amounts of information or making inferences about a situation" [36]. The discussions regarding this framework highlight the necessity of a standardized AI definition for better development of teaching and learning content. This is especially true when specializing into different fields of medical education, including family medicine and primary care.

There is a need to introduce AI education within family medicine; however, the low urgency and priority to integrate this type of education at the moment was noted throughout the discussions. This can be due to the lack of AI tools for family physicians currently being developed, tested and implemented in practice [207, 208]. Furthermore, some residency programs lack the appropriate AI tools or are in lower-resource settings. As a result of the minimal exposure family physicians have with AI, their motivation to learn about the topic can also be reduced. This reduced priority of AI education competes with the CFPC 105 priority

topics of family medicine curricula [209]. This is exacerbated by the fact that Canada is in a unique position in which the length of residency training is only two years. In addition, the rapid advancement of AI introduces an extra layer of complexity. As new AI-based tools emerge and existing ones advance, educators and family physicians must frequently reassess and update their knowledge and skills. For example, the recent introduction of generative AI and tools such as ChatGPT have gained widespread popularity in medical and academic settings [210]. Thus, it is difficult to maintain a robust framework due to the inevitable rapid changes of AI in healthcare. Therefore, the eagerness to integrate this type of education within the curriculum should be met with caution to manage the expectations of both educators and learners.

A key observation made throughout the panel discussion was in regard to the AI content and how much should a family physician know about AI. During the discussions, many of the panelists voiced support on the application and appraisal of AI tools. However, the learning of the theory of AI is equally as important in understanding the use of AI tools [211]. This is especially challenging when residency is only 24 months and there are no required AI educational programs presented in the Canadian undergraduate medical education system. Therefore, within the learning objectives in regard to how much a family physician should know about AI remains undetermined. Further research must be conducted to investigate the level of education a family physician should be aware of. Overall, the aforementioned challenges must be addressed in order for this curriculum framework to be effectively implemented.

5.4. Next Steps

Following the development of the curriculum framework, further testing through consensus methods (e.g., Delphi technique) should be the next step in order to assess the validity

of the resultant framework. After validation, the following steps will be implementation and evaluation. This process follows the ADDIE (Analysis, Design, Development, Implementation and Evaluation) model for instructional design where this thesis covers the first three stages of analysis, design and development [212]. The next step will first be implementation of an educational program such as a course or workshop originating from the curriculum framework. Second, the AIFM-ed curriculum framework must be evaluated and modified accordingly by evaluating educational training programs guided by the framework. This evaluation can be done according to the Kirkpatrick Model.

As mentioned, the training for family medicine is already packed and thus the implementation of this framework will depend on several factors including current use of AI-based tools in family medicine training, previous training in AI (e.g., undergraduate foundation of AI) and capacity of experienced teachers. However, if implemented, certain success indicators will need to be evaluated to understand its impact as well as any areas for improvement. These indicators may include the perceived impact of the framework, degree of implementation, and knowledge and skill apprehensions [83].

5.5. Strengths and Limitations of This Work

The strengths of the scoping review include the comprehensive search strategies, the inclusion of a variety of information sources and rigorous methodological approaches that are replicable. For example, study selection was completed by two reviewers, which was validated by another investigator, disagreements were resolved by discussion or consensus involving a third investigator. Furthermore, a scoping review protocol was registered and published to improve transparency of the methodological process. In regards to the strengths of the panel

discussion, a national and multidisciplinary family medicine educator panel was conducted which ensured diverse perspectives and enriching discussions with varied expertise and insights. This allowed for the understanding of practical implications and current mindsets regarding AI education in family medicine postgraduate training. Additionally, by involving both educators and residents, the curriculum framework ensures representation from key relevant parties involved in the teaching and learning of AI education. In regards to the overall development of this framework, a multimethod systematic approach was used which include a systematic scoping review and two validated expert panel discussions. This approach allowed us to identify and build on existing AI curriculum topics and resources while also creating new ones.

Although this study was conducted in a structured and systematic manner, there are some limitations that are important to consider. Regarding the review, a limited number of articles were retrieved during the search and selection process where those included were mostly based on expert-opinion. Only two articles reported having a curriculum framework with one reporting a full curricula plan related to AI in medicine. This can be due to the fact that AI is emerging and continuing to change within medicine and it has been limiting in terms of educational advances. Because of the nature of the scoping review, the quality of each identified study was not assessed. In addition, the scoping review included all types of studies and focused on a breadth of literature, reporting of educational program details was inconsistent and wide-ranging based on the study's scope. The limitations with respect to co-developing the framework may include the applicability to other countries due to the different medical education structures globally and their current relationships with AI. Furthermore, the expert panels had a relatively small sample size. Additionally, expert panel diversity was limiting where the resident panel came from a single institution which may further limit the generalizability of the framework. Furthermore, as

the participants for the panel discussion were not randomized and were purposively recruited, the results may be subject to selection bias.

CHAPTER 6: CONCLUSION

Medicine is rapidly evolving from the information age to the age of AI where machines will become an integral part of medical practice. Thus, medical education needs to keep pace with changes in medical practice. Institutions must begin equipping future physicians with the knowledge, skills and confidence to effectively use AI applications as it will continue to grow within the field of healthcare. In order for the responsible integration of AI curricula into the continuum of medical education, discussions surrounding curriculum planning of AI should begin. Therefore, through the use of a scoping review and expert panel discussions, a postgraduate curriculum framework was created. This framework for family medicine residency training outlines its curricular purpose, learning objectives, AI topics, delivery methods and evaluation strategies to be used by medical institutions. The systematic process employed in developing curriculum frameworks holds immense importance due to its potential for generalizability across various contexts and educational levels. By systematically developing frameworks, educators can ensure relevance and inclusivity, considering cultural and pedagogical nuances. Through this structured and reproducible methodology, other educators from different fields can embark on their own path in curricula development. Furthermore, the systematic approach ensures a robust foundation that can be used by other educators and researchers to develop training programs (e.g., courses) following the established framework. AIFM-ed curriculum framework ultimately aims to enhance the education of future family physicians in order for them to effectively utilize AI tools for their practice and patients. It is hoped that this framework will provide further advocacy, productivity and gradual change within the area of curriculum development and AI medical education.

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