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Embracing AI/ML in Genetic Counseling: A Nationwide Survey on Program Leaderships' Perspectives and Curriculum Integration

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Abstract

This study aimed to examine the attitudes and preparedness of genetic counseling program directors and faculty leadership in incorporating artificial intelligence and machine learning (AI/ML) into their curricula and its effect on core competency proficiency. AI/ML has been instrumental in creating and maintaining vital analytical tools and models employed by genetic counselors (GCs). However, research on the attitudes of faculty leadership in charge of training future GCs is limited. A nationwide survey conducted between November 2022 and February 2023 gathered 15 respondents holding diverse academic positions in genetic counseling program curriculum development. The majority of respondents had encountered AI/ML in academic settings, primarily through conference presentations (66.7%). They demonstrated neutral attitudes toward the challenges and limitations of integrating AI/ML into the curriculum, with an average mean score of 4.17 (SD = 1.61) on a 7-point Likert scale. Nevertheless, respondents somewhat disagreed that AI/ML integration is unnecessary (M = 3.57) and somewhat agreed that insufficient faculty expertise poses a potential barrier (M = 4.86). Respondents considered AI/ML to have the least impact on interpersonal, psychosocial, and counseling skills, highlighting the value of human expertise in these areas. No significant correlations emerged between program age and faculty members' perceptions of barriers and limitations to AI/ML integration. However, a positive correlation was observed between program age and the belief that AI/ML curriculum integration is unnecessary (r = 0.48). Despite low response rates and restricted generalizability, our findings indicate that AI/ML integration in genetic counseling education is in its infancy and requires further investigation and development. Future research should broaden the sample population, assess respondents' knowledge of AI/ML tools, and conduct in-depth interviews with program leadership to better comprehend factors influencing attitudes toward AI/ML curriculum integration.

Introduction

The exponential progression of artificial intelligence and machine learning (AI/ML) is due to the increasing availability of massive amounts of novel data combined with equally accessible computing power[1–3]. When used in healthcare, these technologies offer an efficient method of organizing, interpreting, and applying information, resulting in improved clinical outcomes[4–6]. As AI/ML continues to evolve within the field of genetics and genomic medicine, it holds great promise in aiding users to solve complex problems and transform vast amounts of data into clinical and non-clinically actionable knowledge. By facilitating our understanding of the complex origin and progression of heritable syndromes and chronic disease, AI/ML has the potential to revolutionize healthcare[1].

Furthermore, the emergence of AI/ML has led to corresponding progress in diverse genetic counseling roles and environments, encompassing diagnostic laboratories, academic medical institutions, health maintenance organizations, as well as governmental bodies and agencies. AI/ML has played a pivotal role in the development and maintenance of essential analytical tools and models used by genetic counselors (GCs). These tools range from databases such as gnomAD and ClinVar, variant calling tools, variant interpretation and reporting tools, literature mining, classification of coding and non-coding variants tools, and annotation of genomic elements tools. Additionally, AI/ML technologies have facilitated the development of symptom trackers, phenotype-genotype correlation identification tools and chatbots for etiology identification[1,7–12].

Genetic counselors are critical members of comprehensive healthcare teams by aiding medical decision-making, providing psychosocial counseling, and offering relevant resources[13]. Genetic counselors are guided by the principle of advancing the understanding of genetic basis for disease and associated risks among the public and non-genetic professionals. The duties of GCs are centered upon practice-based core competencies outlined by the American Board of Genetic Counseling (ABGC), which include genetics expertise and analysis, interpersonal,

psychosocial and counseling skills, education, and professional development and practice.[14] The more common duties within these domains includes explaining the benefits and limitations of testing, informing risk, educating families on complex genetic diseases and syndromes, all while bearing in mind the ethical and philosophical principles of the profession[14]. The roles and responsibilities of GCs continue to expand since the profession's inception, and the rapid growth of technology has both contributed to an increase in and alleviation of responsibilities[15,16].

AI/ML has the potential to work in tandem with GCs to assist in their duties of providing patients with the best possible care. By automating repetitive tasks such as collecting medical and family history and conducting risk assessments, AI/ML technologies can free up GCs' time for the interpretation and counseling aspects of their practice. The integration of these technologies has the potential to improve patient outcomes and promote a more personalized approach to healthcare[8,17–19]. AI/ML is posed to help transform healthcare from a one-size-fits-all medical practice to data-driven individualization, allowing for more efficient and thoughtful application of expertise and better patient outcomes[20–23].

Despite the successes of AI/ML, challenges remain as we integrate these tools into genetics and genomic medicine. A key issue is the familiarity of patients and healthcare professionals with AI/ML technology that guides patient care. The possibility of receiving and relaying incorrect information if improperly trained could result in profound consequences for the institution, healthcare professional, and the patient and their family[24]. Furthermore, the integration of AI/ML technology into medical systems is inevitable, especially as we continue our pursuit of personalized medicine. Consequently, GCs bear the responsibility of learning to collaborate with these technologies and comprehending AI/ML's functions to optimize healthcare delivery, while adjusting their skills to concentrate on aspects of care that AI/ML does not support. Genetic counselors must adapt to effectively integrate these tools into their practice and cultivate a deeper understanding of AI/ML's limitations and potential biases.

The development of skills to assess available AI/ML tools, understand the limitations, and transform AI/ML produced data into patient-level decision-making should begin in genetic counseling graduate programs. Core competencies are at the center for how genetic counseling programs are structured. Current program leaders develop course work to advance these skills within the following content areas: principles of human genetics/genomics; principles of genetic counseling and clinical genetics; psychosocial; social, ethical, and legal issues; health care delivery systems and principles of public health; education; research methods; and professional development[13]. The updates and changes in technology from testing to chatbots requires an equal number of revisions to genetic counseling curricula to maintain student competency. For this reason, Program Directors (PDs) must review program content regularly to assess AI/ML integration in the curriculum as well as areas that no longer need to be as heavily emphasized due to the assistance of such technology.

A quality curriculum requires the integration of AI/ML content in an effective manner to prepare trainees with the necessary skills to gain proficiency in their role as GCs. Additionally, it is worthwhile for programs to underscore facets of genetic counseling, like psychosocial counseling, that could rise in significance as AI/ML alleviates the burden of quotidian tasks for GCs. There is currently no literature exploring the perspectives of PDs or other program leadership that participate in creating curriculum on AI/ML. This study aims to explore these gaps in knowledge through the distribution of a nationwide survey. As the result of this study, we hope to: (1) assess the attitudes of PDs and faculty leadership of AI/ML on proficiency of core competencies, (2) describe PD and faculty leadership's readiness to change the curriculum to include AI/ML content, and (3) identify perceived barriers or limitations to implementation into the curriculum.

Materials and Methods

Respondent Eligibility

Eligible respondents are individuals 18 years of age or older who are currently in an academic role that includes the responsibility to implement or participate in curriculum construction.

Survey Design

Experience and genetic counseling training program questions on AI/ML were developed by the research team to understand genetic counseling programs' attitudes toward the incorporation of AI/ML into their curriculum after a detailed literature review. Multiple-choice questions and Likert scale questions were constructed for program administration that included leadership's previous experience with AI/ML, beliefs and opinions about AI/ML, AI/MLs influence on core competencies, current and future curriculum AI/ML integration, and barriers and limitations to AI/ML being incorporated into genetic counseling programs curriculum. Open-ended questions were included to allow for general comments on genetic counseling training and AI/ML.

Survey Distribution

The anonymous online survey was hosted on the survey platform Qualtrics. The survey was distributed to the administrative leadership of genetic counseling training programs in the United States through email invitation via the Association of Genetic Counseling Program Directors (AGCPD) listserv, National Society of Genetic Counselors (NSGC) listserv, and American Board of Genetic Counseling (ABGC) listserv during November and December 2022, as well as January 2023. One email reminder was sent two weeks after the initial request via the NSGC listserv. Respondents were also asked to distribute the survey among the faculty or leadership who contributed to curriculum construction in their genetic counseling program. The

Institutional Review Board of Keck Graduate Institute (KGI) deemed this project as exempt, and survey responses were collected from November 2022 to February 2023. Descriptive statistics were used to summarize the survey responses as appropriate.

Data Cleaning

We received a total of 35 Qualtrics survey responses between November 30th, 2022, and February 15th, 2023. We performed data cleaning to identify partial, invariant, or careless respondent answers and ensure the eligibility of all respondents for the study.

Out of the original 35 respondents, all 35 consented to participate in the study. Among these, 23 (65.7%) stated that they played a role in either implementing or designing curriculum development in a Master of Science in Human Genetics and Genetic Counseling (MSGC) program, meeting the study's inclusion criteria. However, we removed eight (22.9%) from the dataset prior to analysis, as they provided no answers beyond the first page of screening questions.

We then examined all data using histograms (for numeric variables) or frequency tables (for ordinal or categorical variables) to confirm the feasibility of all responses. These analyses revealed no erroneous data. Similarly, we found no invariant responses, and the written responses to open-ended questions all appeared as good-faith efforts to provide valid answers. An examination of survey completion times showed a median response time of 9.3 minutes, with responses ranging from 3.2 to 26.2 minutes. Since all response times seemed feasible and all respondents' responses reflected good-faith efforts to answer the survey questions, we retained all 15 respondents' answers in the final dataset.

Results

I. Demographics Tables

Table 1
Demographic Characteristic of Respondents (n = 15)

Demographic	M (SD)	n (%)
Clinical Work Experience, Years	12.60 (8.90)	
Academia Work Experience, Years	7.73 (5.78)	
Time in Academic Leadership Role, Months	42.07 (25.52)	
Age of Current GC Program, Years	13.15 (15.62)	
Academic Position *		
Professor, Assistant		4 (26.7)
Professor, Associate		7 (46.7)
Professor, Level Unspecified		1 (6.7)
Course Director		1 (6.7)
Program Director, Assistant		2 (13.3)
Program Director		3 (20.0)
GC Positions Previously Held		
Academic leadership position (not including current position)		5 (33.3)
Academic position		12 (80.0)
Clinical genetic counselor - direct patient care		15 (100)
Clinical genetic counselor - indirect patient care		4 (26.7)
Diagnostic laboratory genetic counselor - direct patient care		1 (6.7)
Diagnostic laboratory genetic counselor - indirect patient care		5 (33.3)
Other [a]		3 (20.0)
Genetic Counseling Specialties		
Academic		11 (73.3)
Cancer Genetics, Adult		7 (46.7)
Cancer Genetics, Pediatrics		1 (6.7)
Prenatal		8 (53.3)
Pediatrics		11 (73.3)
Preconception/Reproductive Screening		4 (26.7)
General Adult Genetics		7 (46.7)
Laboratory-Related		4 (26.7)
Other [b]		4 (26.7)

* Multiple positions could be named, so items do not sum to 100%

Examples include: [a] researcher, advocacy organization, [b] cardiology, neurogenetics, metabolic

Respondent Demographics

Table 1 was assembled to describe the demographics of respondents who completed the survey. Among the 15 respondents, seven (46.7%) held an Associate Professor position, four (26.7%) held an Assistant Professor position, while one (6.7%) selected Course Director,

and an unspecified Professorship position. On average, respondents had spent a greater length of time in a clinical position than an academic position, with a mean of 12.60 (*SD = 8.90*) compared to 7.73 (*SD = 5.78*) years. There was a broad array of experience related to leadership positions among respondents, with the average length of time a respondent spent in their academic leadership role being 3.5 years ± 25.52. Similarly, the sample population was more often affiliated with, but not limited to, well established programs, with the average age of the respondent's affiliated genetic counseling program being 13.15 years ± 15.62.

Most respondents had previous experience as clinical GCs with direct patient care. Genetic counselors in this cohort have experience in a wide variety of specialties, as evidenced by the diverse range of selections and specialties they entered in the provided space. Respondents disclosed experience in specialties ranging from pediatric oncology to general adult; however, the most selected practices were academic (73.3%) and pediatric positions (73.3%). The least selected practices were preconception (26.7%), laboratory (26.7%), "other" (i.e., cardiology, neurogenetics, metabolic) (26.7%), and pediatric cancer genetic counseling (6.7%).

Table 2

Characteristics of AI/ML Curriculum Exposure and Integration (n = 4 - 15)

Demographic	M (SD)	n (%)
Respondents' AI/ML Exposure in Academic settings		
Course: discussed, but not focused on, AI/ML		1 (6.7)
Course: explicitly about AI/ML		0
Workshop(s): AI/ML		5 (33.3)
I have attended one or more conference presentations on AI/ML		10 (66.7)
I have worked in a GC program that offered courses on AI/ML		0
Taught Course: Discussed, but not focused on, AI/ML		1 (6.7)
I have taught a course explicitly about AI/ML		0
I have not had any exposure to AI/ML in academia		5 (33.3)
Exposed through journal articles		1 (6.7)
Respondents' AI/ML Exposure in Clinical settings		
Used AI/ML in own practice		3 (20.0)
Worked at a practice that utilized AI/ML		3 (20.0)
Trained on AI/ML programs in own practice		2 (13.3)
Requested AI/ML training in own practice		0
No exposure to AI/ML in genetic counseling role outside of academia		10 (66.7)
Other [b]		2 (13.3)
Estimated Time to Integrate AI/ML (in months)		
Programs Without AI/ML Curriculum	1.50 (2.12)	
Programs that Implemented AI/ML Curriculum	3.00 (4.24)	
Current AI/ML Integration into Curriculum *		
Across Various Classes		4 (26.7)
Into One Class, but not the Focus		0
Into One Class, Dedicated to this Topic		0
Students Trained in 1+ AI/ML Tools		4 (26.7)
Seminars Offered		1 (6.7)
Rotations Offered		0
AI/ML Expertise of Program Faculty *		
Teach Courses Dedicated to AI/ML		1 (6.7)
Teach Courses Integrating AI/ML		4 (26.7)
Teach AI/ML Workshops		1 (6.7)
Familiar with AI/ML but do not Teach It		0
Do Not Have Faculty with Expertise in AI/ML		1 (6.7)
AI/ML Barriers and Limitations **		
My program can integrate AI/ML content	4.00 (1.52)	
Cost is a barrier to our implementing AI/ML	4.43 (1.72)	
Inadequate faculty experience/expertise is a barrier	4.86 (1.86)	
AI/ML integration isn't a priority as it's not in accreditation standards	4.29 (1.38)	
Our current curriculum works well without AI/ML content	3.86 (1.57)	
AI/ML curriculum integration is not necessary; it's not integral to GCs	3.57 (1.62)	

Examples include: work at an institution that utilizes AI, work at a start-up in blended care

* Respondents could select multiple items; percentages will not sum to 100%

** Scored on a 7-point Likert scale where 1 = Strongly Disagree and 7 = Strongly Agree

[b] "Although my institution uses it I do not on a regular basis"; "So I was part of a start up [sic] company with a blended direct care/indirect care role and this is where I had most of my exposure to this- I wasn't sure which response to select above so decided to describe. This has not been a routine part of my role for the past 5 years."

General Characteristics of AI/ML Integration and Exposure

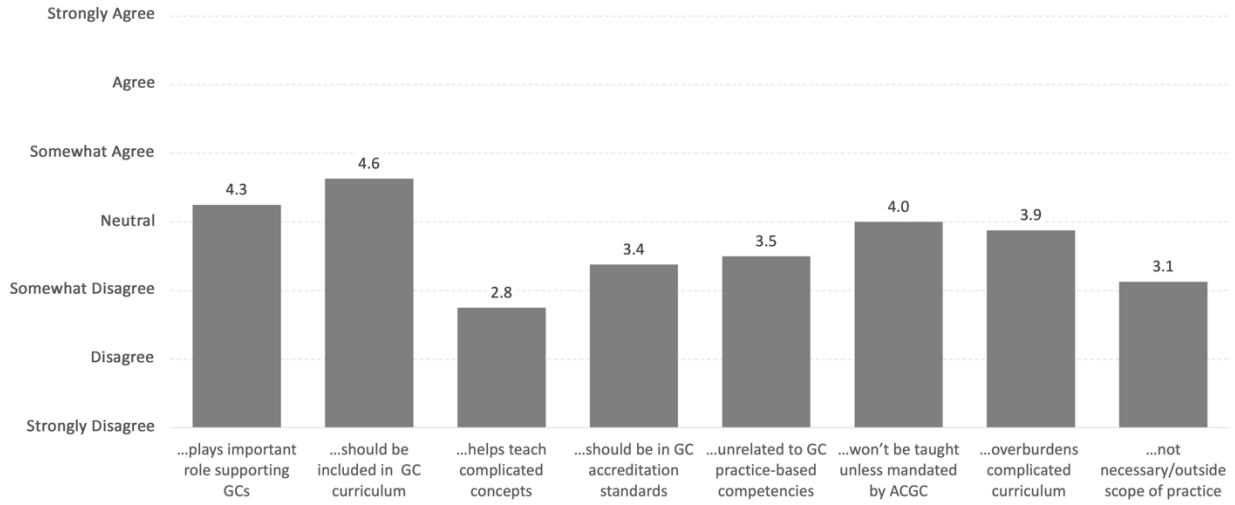
Respondents were asked several additional questions to better understand their perspectives on expectations and experiences integrating AI/ML curriculum into their genetic counseling programs (see Table 2). When asked about exposure to AI/ML in academic settings, 66.7% of respondents identified conference presentations as the most common source of their awareness, while 33.3% cited workshops as the second most frequent mode of exposure. Of the respondents, 33.3% had not had any exposure to AI/ML in academia. None of the respondents had taken a course that focused on AI/ML, and one respondent (6.7%) had attended a course that had discussed but not focused on AI/ML. Most respondents (66.7%) had no exposure to AI/ML outside of academia. Otherwise, respondents' exposure to AI/ML in a clinical setting ranged from teaching AI/ML to working in a setting that utilized it at an equivalent frequency.

Interestingly, the anticipated duration for incorporating AI/ML into a curriculum was estimated to be half the actual time it took (M = 1.5 months), compared to the reported integration time AI/ML content (M = 3.0 months). Respondents affiliated with a program that has an AI/ML curriculum reported that integration took place across various classes (26.7%), and the program provided training on one or more AI/ML tools for students (26.7%). Only one of the 15 respondents was affiliated with a program that offered an AI/ML seminar. Relatedly, the majority of programs (26.7%) had faculty teach courses which integrated AI/ML content in comparison to those that solely focus on AI/ML content (6.7%). Among the options related to faculty expertise chosen by respondents, all indicated some degree of familiarity with AI/ML, except for one respondent (6.7%) who revealed that their program lacked faculty with AI/ML expertise.

We assessed attitudes towards barriers and limitations to AI/ML curriculum integration using a seven-point Likert scale. Respondents demonstrated neutral attitudes (*M = 3.57-4.86*) towards all suggested barriers and limitations in the survey. Despite the overall neutral responses, some respondents somewhat disagreed with the statement "AI/ML curriculum integration is not necessary" (*M = 3.57*). Likewise, when inquired about the potential barrier of inadequate faculty expertise for AI/ML curriculum integration, some respondents somewhat agreed with the statement (*M = 4.86*).

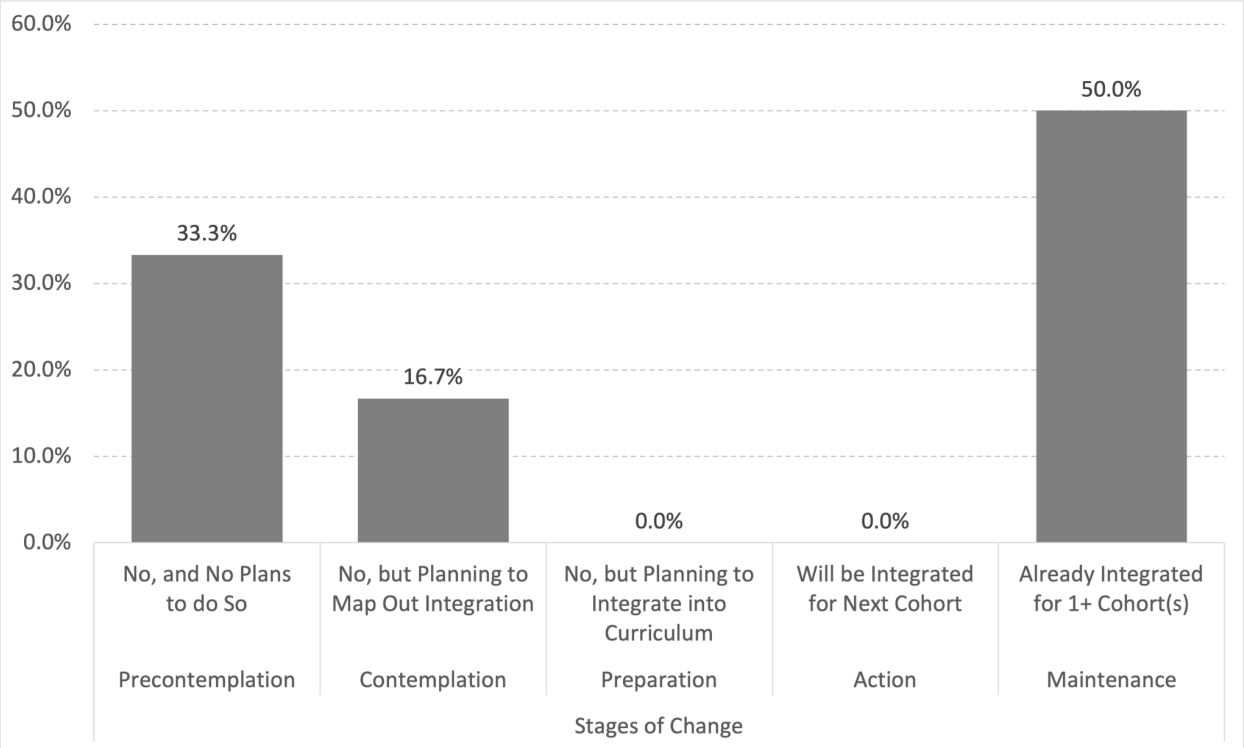
II. Univariate Analyses

Figure 1
"AI/ML…" (n = 8)



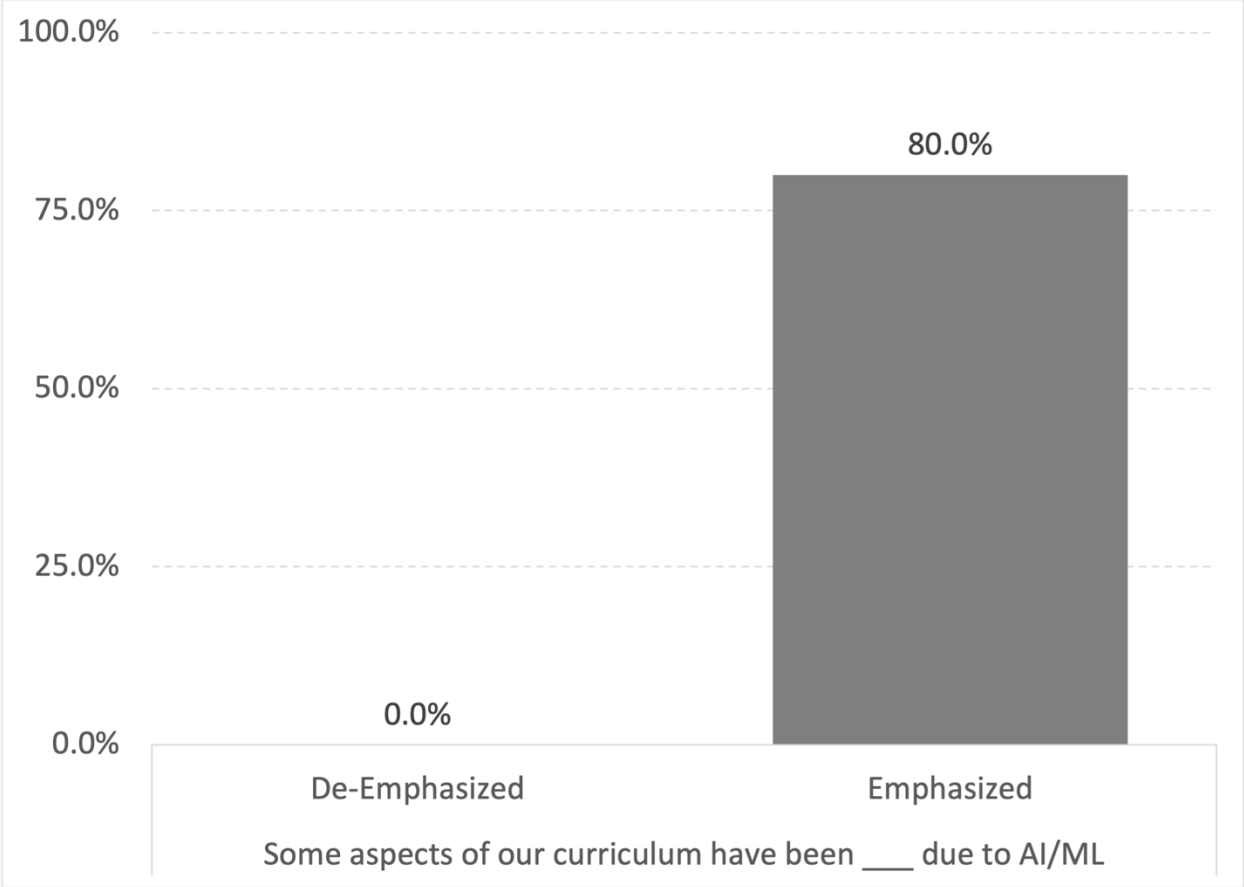
We assessed respondents' attitudes towards AI/ML by asking them to indicate their agreement with eight questions (see Figure 1). Numerous respondents somewhat agreed with incorporating AI/ML into genetic counseling curricula (*M = 4.6*); however, they disagreed with the idea that AI/ML aids in teaching complex concepts (*M = 2.8*). Respondents disagreed with including AI/ML in genetic counseling accreditation standards (*M = 3.4*) but, conversely, believed it to be a necessary component of genetic counseling's scope of practice (*M = 3.1*). All other options exhibited similar levels of neutral agreement among respondents (*M = 3.5-4.3*), encompassing statements that investigated AI/ML's role in supporting GCs in clinics, achieving practice-based competencies, and its perceived significance and impact on the curriculum.

Figure 2
"Have you considered integrating instruction about the use of AI/ML in the field of genetic counseling into your curriculum?" (n = 6)



To evaluate the readiness of respondents' affiliated programs for AI/ML curriculum integration, a single item was employed measuring the stages of change: Precontemplation, Contemplation, Action, and Maintenance (see Figure 2). Figure 2 demonstrates that 50% of the respondents indicated their affiliated program had already incorporated AI/ML material into their curriculum, while 33.3% had no intentions to include such material. Although none of the respondents were in the stages of contemplation or action of AI/ML into their curriculum, 16.7% were in the precontemplation stage.

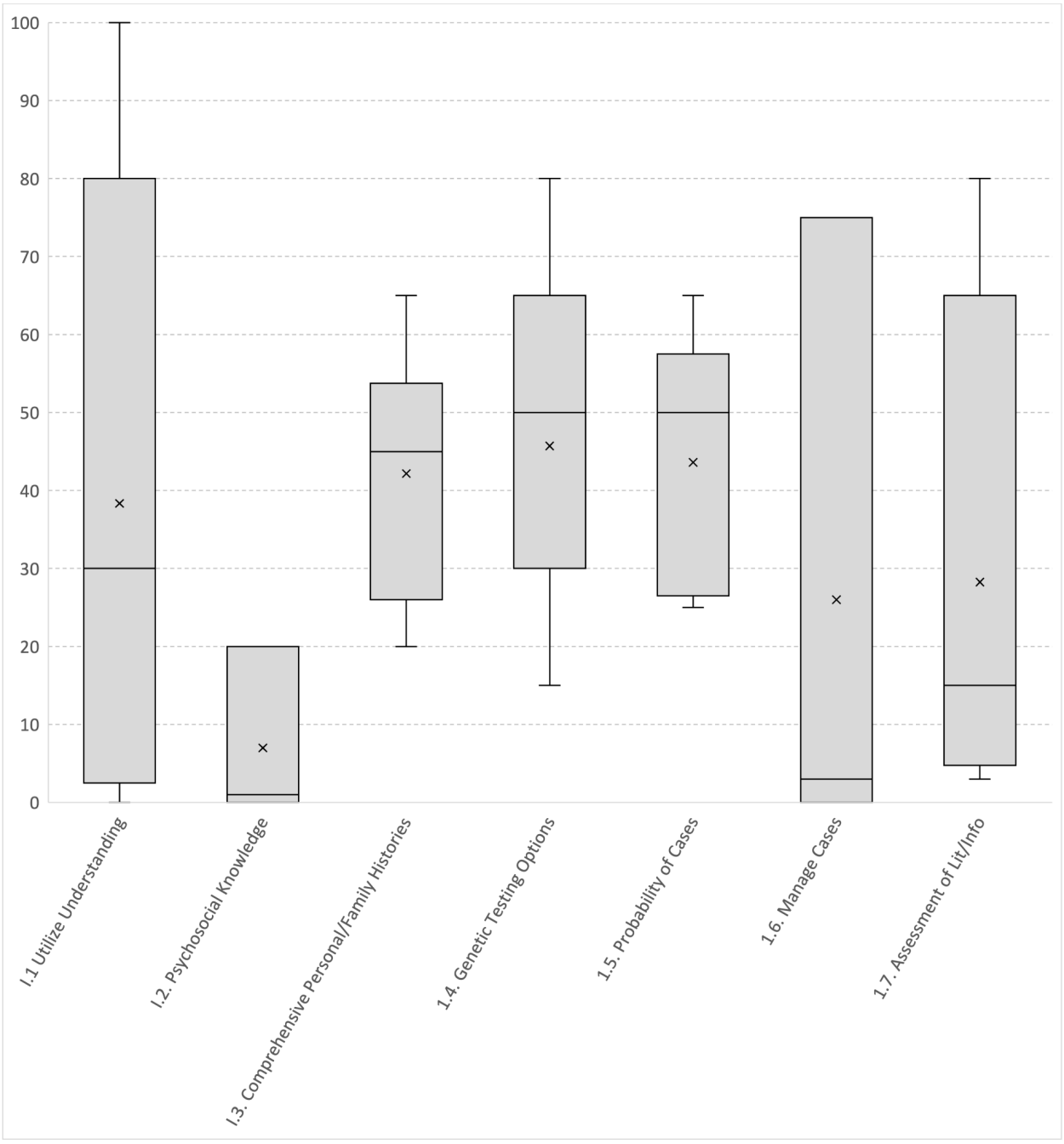
Figure 3
Impact of AI/ML Tools' Availability on Curriculum (n = 5)



We asked respondents a pair of questions concerning whether AI/ML had led to changes in their curriculum (see Figure 3). As illustrated in Figure 3, none of the respondents reported AI/ML causing any curriculum topics to be de-emphasized. Moreover, they did not provide any explanations in the space available for why they believed AI/ML had not led to the de-emphasis of curriculum topics.

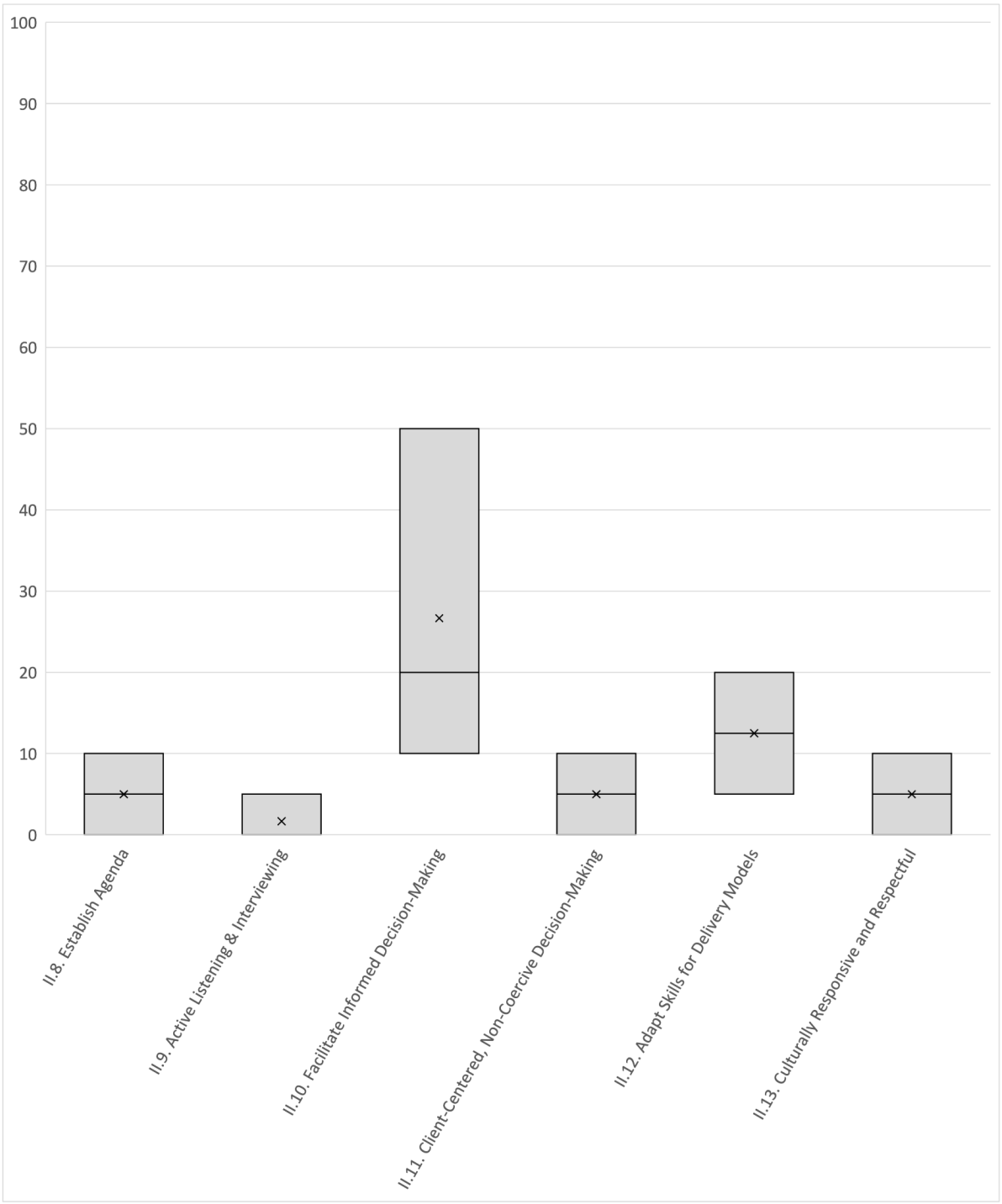
In contrast, 80.0% of respondents reported that AI/ML had caused an increased emphasis on one or more topics in their curriculum. Open-ended responses from these respondents elaborated that their curriculum now places more emphasis on clinical decision support, variant interpretation aspects, and ethical issues related to AI/ML usage.

Figure 4A
To what degree has each Domain I competency been enhanced by AI/ML tools?



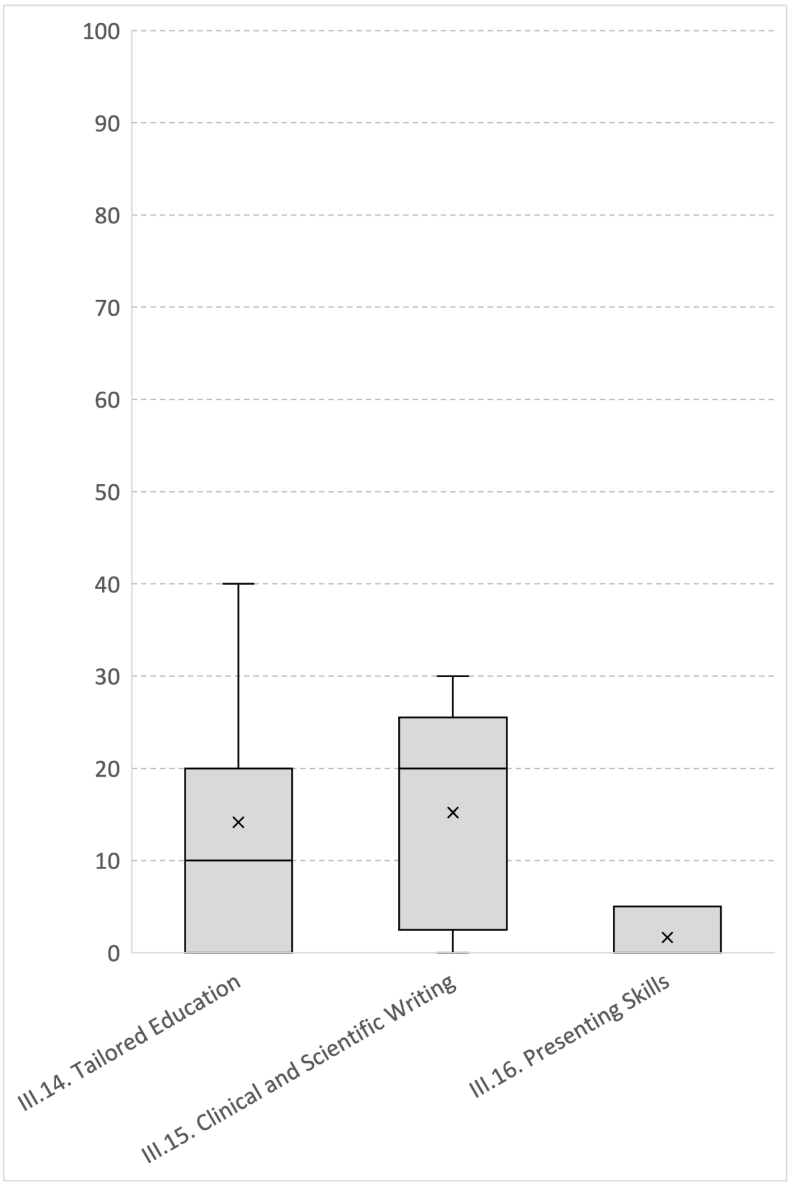
Note: please see below for complete description of ACGC Domain I: Genetics Expertise and Analysis components
I.1. Demonstrate and utilize a depth and breadth of understanding and knowledge of genetics and genomics core concepts and principles.
I.2. Integrate knowledge of psychosocial aspects of conditions with a genetic component to promote client well-being.
I.3. Construct relevant, targeted and comprehensive personal and family histories and pedigrees.
I.4. Identify, assess, facilitate, and integrate genetic testing options in genetic counseling practice.
I.5. Assess individuals' and their relatives' probability of conditions with a genetic component or carrier status based on their pedigree, test result(s), and other pertinent information.
I.6. Demonstrate the skills necessary to successfully manage a genetic counseling case.
I.7. Critically assess genetic/genomic, medical and social science literature and information.

Figure 4B
To what degree has each Domain II competency been enhanced by AI/ML tools?



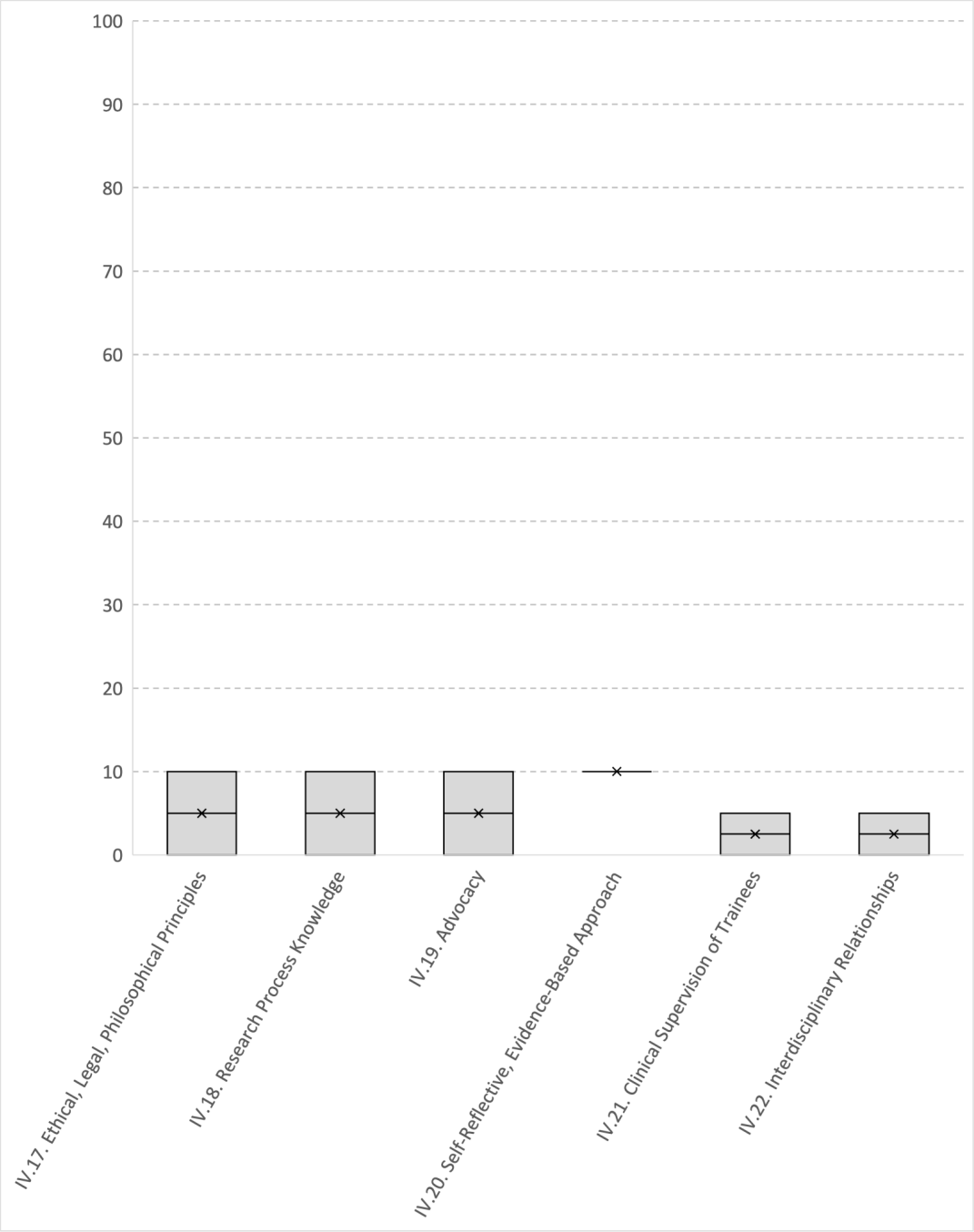
Note: please see below for a complete description of ACGC Domain II: Interpersonal, Psychosocial and Counseling Skills components
II.8. Establish a mutually agreed upon genetic counseling agenda with the client.
II.9. Employ active listening and interviewing skills to identify, assess, and empathically respond to stated and emerging concerns.
II.10. Use a range of genetic counseling skills and models to facilitate informed decision-making and adaptation to genetic risks or conditions.
II.11. Promote client-centered, informed, noncoercive and value-based decision-making.
II.12. Understand how to adapt genetic counseling skills for varied service delivery models.
II.13. Apply genetic counseling skills in a culturally responsive and respectful manner to all clients.

Figure 4C
To what degree has each Domain III competency been enhanced by AI/ML tools?



Note: please see below for a complete description of ACGC Domain III: Education components
III.14. Effectively educate clients about a wide range of genetics and genomics information based on their needs, their characteristics and the circumstances of the encounter.
III.15. Write concise and understandable clinical and scientific information for audiences of varying educational backgrounds.
III.16. Effectively give a presentation on genetics, genomics and genetic counseling issues.

Figure 4D
To what degree has each Domain IV competency been enhanced by AI/ML tools?



Note: please see below for a complete description of ACGC Domain IV: Professional Development & Practice components
IV.17. Act in accordance with the ethical, legal and philosophical principles and values of the genetic counseling profession and the policies of one's institution or organization.
IV.18. Demonstrate understanding of the research process.
IV.19. Advocate for individuals, families, communities and the genetic counseling profession.
IV.20. Demonstrate a self-reflective, evidenced-based and current approach to genetic counseling practice.
IV.21. Understand the methods, roles and responsibilities of the process of clinical supervision of trainees.
IV.22. Establish and maintain professional interdisciplinary relationships in both team and one-on-one settings, and recognize one's role in the larger healthcare system.

Respondents were surveyed about the perceived degree of enhancement to Accreditation Council for Genetic Counseling's (ACGC) Practice-Based Competencies for GCs by AI/ML. The battery of 3-7 questions for each competency was scored on a 100-point scale, with higher scores indicating greater agreement with AI/ML enhancement. The box and whisker plots in Figures 4A-D depict the distribution of responses across the four ACGC domains.

In Domain I: Genetics Expertise and Analysis (Figure 4A), respondents showed the greatest varying degrees of agreement for competencies related to genetics and genomics core concepts and principles, case management, and critical assessment of literature. Conversely, respondents were more aligned in their perception of AI/ML enhancement for competencies related to psychosocial aspects of a case, personal and family history ascertainment, testing options, and probability of conditions. Case management, critical assessment of literature, and genetics and genomics comprehension were perceived as the least enhanced by AI/ML, while construction of pedigrees and personal family histories, identification, assessment, and facilitation of genetic testing options, and probability of conditions based on pertinent information were perceived as having been most impacted by AI/ML enhancement. Notably, psychosocial aspects of a case were perceived as being the least enhanced by AI/ML tools, which highlights the importance of human expertise in these areas.

In Domain II: Interpersonal, Psychosocial, and Counseling Skills, respondents showed a notable level of agreement across competencies, as depicted in Figure 4B. Predictably, respondents perceived AI/ML as having the least level of enhancement within a domain focused on the soft skills of genetic counseling. However, facilitating decision-making using skills and models had the highest median score for AI/ML enhancement among all competencies in this domain. Additionally, respondents showed a greater degree of agreement that AI/ML tools enhanced the development and maintenance of skills related to service delivery models compared to the other competencies within Domain II.

Figure 4C illustrates the distribution of responses among the competencies within Domain III: Education. The results showed variation in agreement among the competencies, with the tailoring of genetics and genomics education to clients receiving least consistent agreement among respondents than other competencies. Respondents consistently reported that AI/ML tools enhanced the writing of clinical and scientific information more than tailored education. The competency related to presenting on genetics and genomics was perceived as the least enhanced by AI/ML tools within this domain.

Domain IV: Professional Development & Practice elicited the least number of responses among all the domains, resulting in reduced variability and consistent medians and means across competencies as displayed in Figure 4D. Among the competencies listed, ethical, legal, and philosophical principles, knowledge of the research process, and advocacy had the least degree of agreement from respondents when asked about AI/ML enhancement, while clinical supervision of trainees and interdisciplinary relationships showed a greater degree of agreement. Notably, the self-reflective, evidence-based approach competency had the the most consistent degree of agreement among all competencies in Domain IV. Interestingly, respondents assigned a higher score for AI/ML enhancement of the self-reflective, evidence-based approach competency. Ethical, legal, and philosophical principles, knowledge of the research process, and advocacy competencies also showed higher scores for AI/ML enhancement than the other competencies, though to a lesser extent than the self-reflective, evidence-based approach competency. Clinical supervision of trainees and interdisciplinary relationships reported the lowest medians and means of all competencies within Domain IV.

III. Hypothesis Tests

RQ 4: Is there an association between how long MSGC programs have existed and their faculty members' perceptions of barriers/limitations related to AI/ML?

Table 6
Correlation: GC Program Age x Perceived AI/ML Barriers and Limitations (n = 6 - 7)

Barrier/Limitations *	GC Program Age
My program is currently capable of integrating AI/ML content into our curriculum	.25
Cost is a barrier to implementing AI/ML into our curriculum	.05
Inadequate faculty experience/expertise is a barrier to implementing AI/ML into our curriculum	-.13
Standards for accreditation do not require AI/ML integration and is therefore not a priority	.18
Our current curriculum works well for the needs of our students and does not need to be updated to include AI/ML content	-.17
AI/ML curriculum integration is not necessary since it is not an integral aspect of a GCs role	.48

* Scored on a 7-point Likert scale where 1 = Strongly Disagree and 7 = Strongly Agree

To investigate the potential association between the number of years that genetic counseling programs have existed and faculty members' perceptions of barriers and limitations related to AI/ML, we conducted a series of Pearson correlations (see Table 6). Although Table 6 shows no statistically significant correlations, it reveals the strongest correlation between program age and the belief that AI/ML is not an essential aspect of a GC's role. Respondents affiliated with programs established for a longer duration more frequently agreed with the statement that AI/ML curriculum integration is unnecessary, as it is not an integral aspect of a GC's role.

Discussion

The survey respondents, a diverse group of experienced GCs from clinical and academic settings, had an average of 12.60 years of clinical experience. The most common specialties were academic and pediatric, while preconception and laboratory genetic counseling were the least reported, suggesting a need to explore the impact of AI/ML on these areas of genetic counseling to better understand its scope. Regardless, the diverse backgrounds of the respondents provide valuable context for interpreting their views on the impact of AI/ML on Practice-Based Competencies and curriculum integration.

The respondents' varied backgrounds and specialties may have shaped their perceptions of AI/ML's impact on competencies, as different specialties have differing degrees of AI/ML exposure. For instance, those with more academic and research experience may have more positive perceptions of AI/ML's impact on competencies related to genetics and genomics comprehension due to exposure limited to presentations and workshops. Conversely, respondents with more direct patient care experience may have a more nuanced understanding of the limitations and challenges of AI/ML in genetic counseling, leading to hesitations regarding feasible integration into curricula. The diversity of experience and specialties represented emphasizes the importance of individual expertise in understanding the potential impact of AI/ML on genetic counseling and its integration into curricula.

Most respondents had limited exposure to AI/ML in academic and clinical settings, with conference presentations being the most common source of awareness, which may indicate a need for increased access to AI/ML education and resources. Interestingly, respondents affiliated with programs that had integrated AI/ML into their curriculum reported that integration took twice as long as estimated by those who had not yet integrated AI/ML into their curriculum, suggesting that more planning and preparation than anticipated may be necessary for successful integration.

Despite the limited exposure to AI/ML, respondents demonstrated neutral attitudes towards potential barriers and limitations to AI/ML curriculum integration. However, some respondents somewhat disagreed with the statement that AI/ML curriculum integration is not necessary, indicating the potential growth of AI/ML's presence in future curricula. Additionally, some respondents somewhat agreed with the potential barrier of inadequate faculty expertise for AI/ML curriculum integration, highlighting the need for training and professional development opportunities for faculty members.

Respondents had varied attitudes towards incorporating AI/ML material into their curriculum. While numerous respondents indicated they somewhat agreed with the idea of incorporating AI/ML into genetic counseling curricula, others were less convinced that AI/ML aids in teaching complex concepts. Interestingly, respondents somewhat disagreed with the idea of including AI/ML in genetic counseling accreditation standards, but skewed toward it being a necessary component of genetic counseling's scope of practice. This may indicate a disparate understanding of current AI/ML tools and their role in the profession. The majority of other options explored in the study showed similar levels of neutral agreement among respondents, indicating that further investigation is needed to better understand GCs' attitudes towards AI/ML's role in supporting their work and achieving practice-based competencies.

Although there was a low response rate, these findings suggest the potential of a fragmented understanding of AI/ML tools utilized across the genetic counseling profession, emphasizing the need for greater familiarity with such tools to better anticipate the needs of students in genetic counseling programs. Our survey revealed that a third of those who participated had no intention of integrating AI/ML into their curriculum, despite respondents indicating to some degree that AI/ML is a necessary component of a GC's scope of practice. In contrast, half of the respondents reported their affiliated program had already incorporated AI/ML material into their curriculum. These results are unsurprising, given that AI/ML is a still emerging tool used in the genetic counseling practice. It is worth mentioning that none of the

respondents were in the contemplation or action phases for integrating AI/ML into genetic counseling education. This indicates that a significant amount of effort is still required to comprehend the potential advantages and obstacles of incorporating AI/ML into this field. Additionally, it suggests that the resources that once facilitated the successful integration of AI/ML into curricula may no longer be accessible.

This study found that respondents did not perceive availability of AI/ML tools to cause the de-emphasis of any topics in genetic counseling curricula. Instead, a significant majority reported an increased emphasis on one or more topics, particularly clinical decision support, variant interpretation, and AI/ML-related ethical issues. These findings imply that the scope of genetic counseling practice is expanding rather than being redefined, highlighting the need for genetic counseling faculty to consider the logistics of incorporating AI/ML into an already crowded curriculum to properly prepare students.

Respondents perceived varying degrees of AI/ML impact on different genetic counseling practice competencies. Domain I (Genetics Expertise and Analysis) was seen as the most enhanced by AI/ML tools, particularly in constructing pedigrees and personal family histories, assessing genetic testing options, and estimating the probability of conditions based on pertinent information. In contrast, competencies in Domain II (Interpersonal Psychosocial and Counseling skills), Domain III (Education), and Domain IV (Professional Development & Practice) were perceived as marginally enhanced by AI/ML tools, with the least impact on psychosocial aspects of genetic counseling practice.

These results highlight the importance of evaluating AI/ML's potential impact on specific competencies within genetic counseling practice. The perceived enhancement of certain competencies suggest that AI/ML tools can provide support in areas of data management and analysis, allowing GCs to better focus on the interpretation of results and counseling aspects of their practice. However, the perceived limited impact on psychosocial aspects of a case highlights the importance of maintaining human expertise and empathy in these areas.

Furthermore, these findings may guide future genetic counseling curricula development by focusing on competencies not augmented by AI, including emotional intelligence cultivation, communication skill refinement, and promotion of critical thinking and ethical deliberation.

If these results reflect the broader population, the correlation between program age and the belief that AI/ML is not essential to a GC's role raises questions about the factors that influence institutional culture and values. Established programs' attitudes aligning with traditional GC practices suggest a need for more comprehensive conversations about genetic counseling's evolving scope of practice. While newer programs may have less overall experience in academic or clinical instruction, they offer fresh perspectives and amenability to novel ideas. These findings underscore the importance of addressing resistance to change and the role of institutional values in the integration of emerging technologies like AI/ML into genetic counseling curricula. Ultimately, a deeper understanding of the factors that contribute to these attitudes may facilitate more effective AI/ML integration.

Limitations and Future Directions

This study's low response rate limits statistical power and generalizability. Consequently, planned hypothesis tests were not conducted, including the relationship between academic position and perceptions of AI/ML's impact on practice-based competencies, beliefs about AI/ML's impact on competencies, and the perceived impact of AI/ML on competencies and whether it was taught in the respondent's program. Additionally, the expansive nature of AI/ML tools and the emerging field itself may have contributed to a sample population potentially unaware of the tools they use being AI/ML-driven. Future research should include items to test respondents' knowledge of available AI/ML tools in the genetic counseling field, and consider expanding the eligibility criteria to include all faculty, as they can advocate for the integration of AI/ML into curricula even if they are not directly involved in constructing curricula. Moreover,

future research could benefit from conducting in-depth interviews with program leadership to further elucidate and expand upon these findings.

Conclusion

This study investigated the attitudes of leadership in genetic counseling programs towards integrating AI/ML into their curricula and the impact on practice-based competencies. Responses indicated a spectrum of beliefs, revealing a lack of consensus on the emerging technology, and a potential resistance to change. Overall, our results suggest that while AI/ML curriculum integration is still in its nascent stages in genetic counseling programs, there is interest and potential for further exploration of integration and development of AI/ML expertise. Future studies may provide insights into successful approaches for integrating AI/ML into genetic counseling education and professional development.

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