Health Professions Education

Volume 10 | Issue 3 Article 15

2024

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Recommended Citation

Cruz, Jonas Preposi; Sembekova, Anara; Omirzakova, Dinara; Bolla, Srinivasa Rao; and Balay-odao, Ejercito Mangawa (2024) "Attitudes toward and readiness for medical artificial intelligence among medical and health science students," *Health Professions Education*: Vol. 10: Iss. 3, Article 15.
DOI: 10.55890/2452-3011.1296
Available at: https://hpe.researchcommons.org/journal/vol10/iss3/15

ORIGINAL RESEARCH REPORTS

Attitudes Toward and Readiness for Medical Artificial Intelligence Among Medical and Health Science Students

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Abstract

Purpose: **This study assessed general attitudes toward artificial intelligence and medical artificial intelligence readiness among medical and health sciences students and examined the factors that influence the medical artificial intelligence readiness of the students.**

Methods: **A descriptive cross-sectional quantitative online survey was conducted among medical and health sciences students. We employed the 'General Attitudes Toward Artificial Intelligence Scale' (GAAIS) to assess students' artificial intelligence attitudes and the 'Medical Artificial Intelligence Readiness of Students Scale for Medical Students' (MAIRS-MS) to measure student readiness for medical artificial intelligence.**

Results: **Nearly all students did not receive/attend any experience of artificial intelligence education from medical school (95.3%) or outside of medical school (85.0%), and most of them received information about artificial intelligence from the media (74.8%). The students reported a poor knowledge of artificial intelligence and its application in healthcare. The students demonstrated a negative to neutral general attitude towards artificial intelligence and poor overall readiness for medical artificial intelligence. Knowledge of artificial intelligence applications in healthcare care and a generally positive attitude toward artificial intelligence were associated with increased readiness for medical artificial intelligence among students.**

Conclusion: **The study findings can inform education policymakers and medical and health science professors about creating, introducing, and integrating new curricular content involving artificial intelligence in medical schools. Including medical artificial intelligence content in medical and health science curricula will increase students' readiness and improve its use for more advanced patient care.**

Keywords: Attitudes, Artificial intelligence, Health sciences, Medical artificial intelligence, Readiness

1. Introduction

Medical artificial intelligence (AI) development aims to create sophisticated technology to comprehend complex computations and perform jobs that require human knowledge. These tasks incorporate the capabilities of human intellectual processes, including rationality, sense-making, generalization, or learning from previous experience [1]. Consequently, AI is no longer an idea confined to science fiction. AI is becoming increasingly widespread in the medical domain [2,3]. Early introductions of AI to the medical community include the MYCIN system, which suggests antibiotics for infections based on the input of patient symptoms data; the causal association network

Received 27 April 2024; revised 13 August 2024; accepted 18 August 2024.
Available online 9 October 2024

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https://doi.org/10.55890/2452-3011.1296

CASNET, which was a glaucoma consultation program in 1976, and INTERNIST-I, a diagnostic service in internal medicine [4–6]. Since then, medicine and AI have evolved significantly, and today, AI not only covers simple computational tasks but exceeds humans in some segments of health assessment, diagnostic precision, outcome prediction, drug discovery, and planning preventive and interventional approaches [7,8]. In Kazakhstan, medical AI has only begun in recent years. In 2017, the "Digital Kazakhstan" national development program introduced AI into the healthcare system, which was 75% accurate in rule-based disease diagnosis using a tool based on two machine learning algorithms for disease diagnosis: a rule-based method and the decision tree algorithm [9].

Shortly, healthcare professionals can engage patients in significantly different healthcare settings compared to the present. Worldwide, Statista reports show that less than 10% of hospitals have used AI for over five years to detect diseases, perform medical imaging, and recognize drugs [10]. AI in medicine has achieved many accomplishments, such as comprehensive image analysis, increased precision of diagnosis in radiology and surgical pathology, and prediction of results in cancer patients [11,12]. For example, Kim et al. showed that an AI-trained model was better at diagnosing breast cancer on mammography than a normal radiologist, especially when it comes to cancers with mass, tumor classification, and node-negative tumors [8]. Moreover, AI has been used in healthcare to support and inform various medical procedures and serve as an alert system for patients and related personnel [7]. In addition, medical AI also has economic benefits due to its applications in management, surgical support, virtual patient care, patient support, and diagnosis [13].

However, some drawbacks hinder the integration of medical AI, such as AI algorithms that are based only on previously uploaded data, resulting in an unreliable and increasing frequency of errors, bias, and incorrect data [14]. Additionally, medical AI typically uses confidential patient data that could be sensitive. As a result, many researchers express concerns about the privacy of this data [15]. Studies have shown that cybersecurity and data privacy risks hinder technology acceptance [16–18]. Furthermore, the application of AI in clinical settings is controversial, as it may challenge commonly held values and ethical principles [19]. In addition, there are several critical issues with medical AI, including inadequate personnel training, problems with integration with existing technologies, ethical doubts, and others [20].

In the foreseeable future, healthcare professionals can interact with patients in markedly distinct healthcare settings, in contrast to the current state. Medical and health sciences education requires additional development [21]. Evidence suggests that medical students are concerned about the possibility of robot replacement [22]. Gong et al. conducted a study that revealed a substantial proportion of medical students dissuaded from pursuing a career in medical school due to the fear associated with relocation [23]. The potential influence of AI on our daily lives provokes both positive and negative perspectives. From a pessimistic AI standpoint, AI is anticipated to eventually replace humans in several areas. Furthermore, AI advocates contend that those who support the technology are more inclined to benefit from future improvements [24]. The surge in interest in educating medical students about AI underscores the extensive application of AI in clinical care, research, and education. Notable organizations, including the American Association of Medical Colleges and the Royal College of Physicians and Surgeons of Canada, have strongly advocated for the incorporation of AI training, data acquisition and security, AI ethics, and thorough evaluation and comprehension of AI applications in healthcare care [25,26].

To foster innovation, it is crucial that medical and health sciences students, representing the future of the health industry, have robust scientific concepts that facilitate the advancement of healthcare technology [27]. To effectively implement and filter AI-based judgments, clinicians and health informatics specialists who design AI applications must fully understand the fundamental ideas of the technology [28]. In healthcare, AI can lead to unexpected results and inaccurate assumptions based on algorithms, methods used, and data sources [29].

Despite increasing interest in recent discoveries, medical and health sciences education remains behind extraordinary advances in AI [30]. The integration of AI training into undergraduate medical and health sciences education has progressed slowly despite multiple requests for action [31]. Sarwar et al. conducted a study in 54 countries and found that 75% of the respondents shared enthusiasm about introducing AI in pathology and expressed a generally positive attitude [32]. In the United Kingdom, 89% of medical students believe that AI is essential in the healthcare system; therefore, AI education should be part of medical education [33]. In Canada, about 70–80% of students were confident in AI's abilities for objective tasks that do not require human skills [34]. In Korea, approximately 83.4% believed that AI would be

helpful in medicine and agreed that AI would be the most effective in diagnosing diseases [35]. Ahmed et al. also conducted a study in Pakistan, which revealed that 68.8% of medical students had a general AI understanding, and about 57–65% of respondents acknowledged the functional and practical impact of AI in various areas of medicine [36]. An informal interview conducted with some medical students in one of the higher medical education institutions in Kazakhstan shows that the primary factors contributing to the unsuccessful implementation of AI were a lack of adequate knowledge and awareness about the technology, a lack of enthusiasm for the subject matter, inadequate training provisions, and the absence of AI courses in the Education in medical and health sciences education curriculum. Similarly, Pakistan's primary obstacle that hinders the implementation of AI among university students is a lack of knowledge or awareness [36].

Research has shown that undergraduate medical students with limited exposure to AI are susceptible to experiencing anxiety, which subsequently influences their career choices. Therefore, examining the opinions of the general public and the knowledge of medical students may be beneficial in identifying areas where curriculum designers should focus on making decisions, including AI education [37]. Integrating AI into the healthcare sector requires the involvement of several industrial players, including medical experts from multiple disciplines. This results from reassessing the numerous functions that healthcare professionals perform in contemporary medicine. Collecting data from diverse healthcare students is crucial to gathering information effectively [14]. With the increasing prominence of AI in the healthcare sector, medical students must dedicate more time to studying and receiving AI-focused training.

Concerns of undergraduate medical students about the decreased opportunities to interact with AI impact their choices regarding future employment [23,33]. Since AI has been used in various ways in healthcare, its impact has been recognized in the last decade. Medical AI has made great strides in the healthcare industry, revolutionizing the way doctors and healthcare professionals diagnose and treat diseases.

Several studies were conducted to understand medical students' knowledge and perceptions regarding the integration of medical AI into practice. The General Attitudes Towards Artificial Intelligence Scale (GAAIS) is a standard tool to evaluate general and students' perceptions of medical AI. According to Schepman and Rodway, the GAAIS shows mixed views on AI, with people holding mixed opinions on big data applications and those involving human judgment [38]. In the UK and USA, Cultural context, age, and gender differences significantly influence future perspectives on AI as a potential threat or benefit for humanity [39]. Similarly, a study conducted in a multicountry (US, UK, Germany, and Switzerland) shows that trustworthiness, risks, and usage shape public perceptions of AI, with proponents recognizing its transformative potential and those assessing its threats [40]. In Korea, the tool was validated, and it shows that the attitude toward accepting technology indicates its discriminant validity, and male students' positive attitude score was significantly higher than that of the female students, satisfying the known-groups validity [41].

Researchers and medical professionals around the world have recognized the potential of medical AI. However, its acceptance among medical students needs to be clarified. It is critical to analyze the readiness and attitude of future healthcare professionals to integrate AI before the process has begun. Consequently, by conducting a study on the general attitudes and readiness for medical AI among medical and health sciences, students can be useful to pinpoint problem areas and obtaining crucial information to guide decisions about incorporating AI into undergraduate education in medical and health sciences education.

1.1. Purpose

This study assessed general attitudes towards AI and medical AI readiness among medical and health sciences students in Kazakhstan. The study also examined the relationship between AI attitudes and readiness and factors that influence the medical AI readiness of students in Kazakhstan.

2. Method

2.1. Design

This descriptive and cross-sectional quantitative study was implemented in higher medical education institution.

2.2. Setting and samples

The survey was conducted at a higher medical education institution in Astana, Kazakhstan, which offers several medical and health sciences programs ranging from undergraduate to doctoral level. In addition to the Doctor of Medicine program, the

school offers the following undergraduate health sciences programs: Bachelor of Medical Sciences, Bachelor of Science in Nursing, and Bachelor of Nursing (BN). The higher medical education institution also offers master's programs in molecular medicine, public health, pharmacology and toxicology, and sports medicine and rehabilitation. The medical school has Ph.D. in Biomedical Sciences and Global Health. Finally, the school offers various residency programs for medical doctors.

The convenience sampling technique was implemented for sample selection. The inclusion criteria were (1) enrolled in any program in this higher medical school in the Spring Semester of 2023, (2) at least 18 years of age, (3) can understand English, and (4) have access to the Internet. Students on academic leave and those who could not understand English (e.g., BN students) were excluded from the study. Students who did not have access to the Internet were also excluded due to the data collection method. We calculate the sample size through G*Power version 3.1 (priori power analysis). The sample size required based on the analysis was 102 to detect a hypothesized moderate effect size ($R^2 = 0.15$) in a multiple linear regression with ten predictor variables. The statistical power was 80.0% and the alpha was 0.05. A total of 155 medical students consented to participate in the study. However, 28 respondents did not answer any survey questions, leaving 127 viable samples for the study (a completion rate of 81.9%).

2.3. Instruments

An online questionnaire (Survey Monkey) was used to collect data. We used the English language since the students are proficient in this language, and English is the language of instruction at the university. The online questionnaire is comprised of two main parts. Part 1 contained the demographic data questions and two scales: the 'General Attitudes Toward Artificial Intelligence Scale' (GAAIS) and the 'Medical Artificial Intelligence Readiness Scale for Medical Students' (MAIRS-MS). The second part has four open-ended questions on the student's perceptions of how AI can be incorporated into medical education, the student's opinion on the benefits and drawbacks of using AI in healthcare, the students' vision of healthcare's future considering the development and integration of AI, and the student's opinion about the changes in healthcare workers' roles due to AI. The results of the second part of the survey were published in a previous article [42]. This article reports on the data collected in the first part of the survey. The characteristics of the respondents collected in this study include the respondents' age, sex, program enrolled, average time spent on self-study per day, and the latest GPA. AI-related information was also collected, including attendance to any educational experience on AI at NUSOM and outside NUSOM, primary sources of information on AI, recent experience of using AI (related and not related to academic work), and self-assess knowledge about AI in general, and its application to healthcare care (0–100 scale).

The 'General Attitudes Toward Artificial Intelligence Scale' (GAAIS) assessed students' attitudes toward AI, developed in 2022 by Schepman and Rodway (see Appendix A) [43]. GAAIS has 20 items that measure the "general positive attitudes" (12 items; GPA-AI) and "general negative attitudes" (8 items; GNA-AI) toward AI. The GPA-AI reflected personal and societal usage, while the GNA-AI reflected concerns. The scale developers generated positive and negative attitude statements from the literature [38]. GAAIS asks students to rate each of the items using a 5-point Likert scale (1 "Strongly disagree" to 5 "Strongly agree"). The items in the negative attitudes subscales were reverse-coded before calculating the mean. Mean scores for GPA-AI and GNA-AI with possible scores range from 1 to 5. A higher mean score suggests more positive attitudes toward AI. Schepman and Rodway established the validity and reliability of the tool [43]. Validity was supported by convergent and discriminant validity, exploratory factor analysis (EFA), and confirmatory factor analysis (CFA) [43]. The EFA revealed a two-factor solution that accounts for an overall variance of 41.6%. The CFA supported a good model fit for the two factors with the following indices. RMSEA = 0.0573, TLI = 0.94, and the model test $\chi^2 = 182$, df = 151, p = 0.046 [43]. The GPA-AI had an internal consistency reliability alpha of 0.88, while the GNA-AI had 0.82 [43]. In the current sample, the computed Cronbach alpha of GPA-AI and GNA-AI was 0.86 and 0.91, respectively.

We used the 'Medical Artificial Intelligence Readiness Scale for Medical Students' (MAIRS-MS) to assess student readiness for medical AI [7]. The MAIRS-MS is a 22-item scale with 5-point Likert scale options (1 "Strongly disagree" to 5 "Strongly agree"). MAIRS-MS has four dimensions, which measure the respondents' readiness for AI in terms of "cognitive factor" (8 items), "ability factor" (8 items), "vision factor" (3 items) and "ethics factor" (3 items). The subscale 'cognitive factor' is one's cognitive readiness in medical AI applications terminologies and AI application and data science logic. The "ability factor" is the ability of an individual to choose the right medical AI

application and combine it with his/her professional knowledge. The "vision factor" is the ability of an individual to "explain limitations, strengths, and weaknesses of medical AI". This factor also includes the ability to anticipate and recognize opportunities and threats related to medical AI. The 'ethic factor' encompasses compliance with the ethical and legal aspects of using AI in healthcare [7]. The scale was scored by calculating the mean for overall readiness and its factors, which could range from 1 to 5. Higher mean scores imply a greater readiness of students for medical AI. The construct validity of the tool was supported by EFA and CFA, which explains the four-factor solution of the scale. The EFA supported the four-factor solution of the scale with an overall explained variance of 50.9%. The CFA revealed the following indices of good fit: $\chi 2/df = 3.81$, RMSEA = 0.094, SRMR = 0.057, CFI = 0.938, and NNFI (TLI) = 0.928. The MAIRS-MS had an acceptable internal consistency with an alpha value of 0.87. These indicate that MAIRS-MS is a valid and reliable tool [7]. In the current sample, Cronbach's alphas were: 'Cognitive factor' = 0.88, 'Ability factor' = 0.90, 'Vision factor' = 0.90, 'Ethic factor' = 0.89, and overall MAIRS-MS = 0.96.

2.4. Data collection

Data collection was performed from 30 March to 5 May 2023. We sent the recruitment email to the higher medical school Academic Unit, which is responsible for sending the email to the students through the students' group email. The recruitment email contained the survey link. The students responded to the survey at their convenient time and place. Respondents had the option of avoiding any question they were uncomfortable answering. The responses were automatically saved on the online survey server and downloaded and saved on the PI's computer. The higher medical school Academic Unit sent a weekly reminder to students to ensure an adequate sample.

2.5. Statistical analysis

The data was inspected and cleaned before analysis. The characteristics of the students and the information related to AI were descriptively analyzed by calculating the means, standard deviations, frequencies, and percentages. The main variables of the study (general attitudes toward AI and medical AI readiness) were treated using means, standard deviations and ranges. Associations between students' general attitudes towards AI and medical AI readiness were examined using 'Pearson's product–moment correlations'. A 'multiple linear regression analysis' was conducted to examine the influence of student characteristics, AI-related information, and general attitudes toward AI on the medical AI readiness of students. In the regression model, the readiness for medical AI of students was the dependent variable, while the age, sex, program, average self-study hours per day, experience of AI education outside of the higher medical school, self-reported knowledge about AI in general, and AI applications in healthcare, and positive and negative attitudes towards AI. Dummy codes were generated for the predictor variable 'program' before they were used in the regression model. Statistical significance was at a p-value less than 0.05. We utilize SPSS version 22.0 for all analyses.

2.6. Ethical consideration

The higher medical education institutions approved the study protocol (submission number 679/17022023). The study adhered strictly to the study protocol, the ethics committee policy, and the ethical principles in human subject studies. The dean of the higher medical school approved the conduct of the study and the distribution of the online survey to the students. The email and online informed consent for the recruitment provided relevant information about the study, such as the objective of the study, the procedures, the expected participation of the respondents, the potential risks and benefits, the voluntary nature of the survey, and the contact information of the ethics committee and the principal investigator (PI). It was specified in the online consent form that if respondents have questions or clarifications about the study, they could contact the study PI and the ethics committee. Respondents were asked to click "I agree" in the electronic informed consent if they wanted to participate, leading them to an online survey. Those who did not want to participate were asked to click "I disagree," which directed them to the disqualification page. The online survey was not set to force respondents to provide an answer; therefore, respondents can skip a question if they were not comfortable answering it. Respondents could also leave the survey at any time. The online survey did not collect any identifying information about the respondents. Therefore, there was no way to identify the respondents or to match the data with a specific respondent. Throughout data collection, the collected data was protected. The data was saved in the PI's password-protected computer and analyzed aggregately.

3. Results

3.1. Characteristics of the respondents and information related to AI

Table 1 contains the characteristics of the respondents and information related to AI. As indicated, the average age of the respondents was 22.98 years ($SD = 3.55$, range = 18.00–34.00). Most of the respondents were women (77.2%) and in a baccalaureate program (52.0%). The students spent an average of 4.06 h ($SD = 1.69$) per day of self-study, which ranged from 1 h to 12 h. Among the 97 students who provided their latest GPA, the average GPA was 3.25 ($SD = 0.53$, range = 1.67–4.00).

Regarding AI-related information, nearly all students did not receive/attended any AI education experience from NUSOM (95.3%) or outside of NUSOM (85.0%). Most of the students received information about AI from communication media (ie TV, Youtube, Twitter, Google) (74.8%), while the rest get their information about AI from family and friends (13.4%) and other sources, such as online forums (5.5%), peer-reviewed articles (2.4%), professors/doctors (3.1%), or books (0.8%). More than half of the students recently used AI technology in their academic work (51.2%) and in activities/tasks that are not related to schoolwork (68.5%). Students reported poor knowledge of AI in general and AI application in healthcare, with mean scores of 45.16 ($SD = 20.12$) and 32.65 ($SD = 22.70$), respectively, in the range of 0.00–100.00.

3.2. Attitudes towards artificial intelligence

The results of the descriptive analyzes on GAAIS are summarized in Table 2. The overall mean on the GPA-AI and GNA-AI subscales was 2.95 ($SD = 0.70$) and 3.02 ($SD = 0.76$), indicating an overall negative to neutral general attitude toward AI.

The means of the item for GPA-AI ranged from 2.63 ($SD = 0.99$) for the item 'An artificially intelligent agent would be better than an employee in many routine jobs" to 3.83 ($SD = 1.33$) for the item "I am impressed by what Artificial Intelligence can do'. Furthermore, the items 'Artificial intelligence is exciting' ($M = 3.13$, $SD = 1.29$), 'Artificial

Table 1. Characteristics of the students and their information related to artificial intelligence (n = 127).

Characteristics	n	%	Mean (SD)	Range
Age			22.98 (3.55)	18.00–34.00
Gender				
Male	29	22.8		
Female	98	77.2		
Program				
Baccalaureate (Nursing and Biomedical sciences)	66	52.0		
Doctor of Medicine	37	29.1		
Graduate (Master's and Ph.D.)	24	18.9		
Average self-study hours/day			4.06 (1.69)	1.00–12.00
Latest Grade Point Average (n = 97)			3.25 (0.53)	1.67–4.00
AI-related information				
Received/attended any education experience on AI from medical school				
No	121	95.3		
Yes	6	4.7		
Received/attended any education experience on AI outside medical school				
No	108	85.0		
Yes	19	15.0		
The main source of AI information				
Media (television, YouTube, Twitter)	95	74.8		
Online forums	7	5.5		
Peer-reviewed articles	3	2.4		
Professors/doctors	4	3.1		
Books	1	0.8		
Family and Friends	17	13.4		
Recent use of AI technology in any schoolwork				
No	62	48.8		
Yes	65	51.2		
Recent use of AI technology in activities/tasks unrelated to schoolwork				
No	40	31.5		
Yes	87	68.5		
Knowledge about AI in general			45.16 (20.12)	0.00–100.00
Knowledge about AI applications in healthcare			32.65 (22.70)	0.00–100.0

Note. a Self-reported on a scale of 0–100.

Table 2. General attitudes towards artificial intelligence among students (n = 127).

Variable	Range		Mean	SD
Positive general attitudes towards AI	2.00	5.00	2.95	0.70
For routine transactions, I would rather interact with an artificially intelligent system than with a human.	1.00	5.00	2.86	1.11
Artificial Intelligence can provide new economic opportunities for this country.	2.00	5.00	3.16	1.24
Artificially intelligent systems can help people feel happier.	1.00	5.00	2.80	0.95
I am impressed by what Artificial Intelligence can do.	2.00	5.00	3.83	1.33
I am interested in using artificially intelligent systems in my daily life.	1.00	5.00	2.83	1.07
Artificial Intelligence can have positive impacts on people's wellbeing.	1.00	5.00	2.79	1.04
Artificial Intelligence is exciting.	1.00	5.00	3.13	1.29
An artificially intelligent agent would be better than an employee in many routine jobs.	1.00	5.00	2.63	0.99
There are many beneficial applications of Artificial Intelligence.	2.00	5.00	3.22	1.25
Artificially intelligent systems can perform better than humans.	1.00	5.00	2.64	0.81
Much of society will benefit from a future full of Artificial Intelligence	1.00	5.00	2.71	1.02
I would like to use Artificial Intelligence in my own job.	1.00	5.00	2.81	0.99
Negative general attitudes towards AI	1.38	4.63	3.02	0.76
Organizations use Artificial Intelligence unethically.	1.00	5.00	2.97	0.71
I think artificially intelligent systems make many errors.	1.00	5.00	2.89	0.86
I find Artificial Intelligence sinister.	1.00	5.00	3.06	0.93
Artificial Intelligence might take control of people.	1.00	5.00	3.08	1.08
I think Artificial Intelligence is dangerous.	1.00	5.00	3.04	0.98
I shiver with discomfort when I think about future uses of artificial intelligence.	1.00	5.00	3.05	1.08
People like me will suffer if Artificial Intelligence is used more and more.	1.00	5.00	3.06	1.09
Artificial Intelligence is used to spy on people	1.00	5.00	2.98	1.00

intelligence can provide new economic opportunities for this country' ($M = 3.16$, $SD = 1.24$), and 'There are many beneficial applications of artificial intelligence' ($M = 3.22$, $SD = 1.25$) received means slightly above the midpoint. The remaining items on this subscale received means below 3.00. For GNA-AI, the elements ranged from 2.89 ($SD = 0.86$), "I think artificially intelligent systems make many errors", to 3.08 ($SD = 1.08$), "Artificial intelligence could take control of people," indicating the neutrality of students in their attitudes toward AI.

3.3. Medical artificial intelligence readiness among students

Table 3 reflects the results of the descriptive analysis on the students' medical AI readiness of students. The overall mean on the scale was 2.64 ($SD = 0.68$), implying that the students are generally not ready for medical AI. All the items on the scale were rated poorly by the students (means ≤ 3.00), with item means ranging from 2.46 ($SD = 0.79$) for the item "I can organize workflows compatible with AI' to 3.00 ($SD = 1.17$) for the item 'I find it valuable to use AI for education, service and research purposes'. In comparing the four dimensions of medical AI readiness, the students rated the dimension 'Ability' ($M = 2.72$, $SD = 0.75$) as the highest dimension, followed by 'Ethics' ($M = 2.70$, $SD = 0.89$), then 'Vision' ($M = 2.67$, $SD = 0.88$). The dimension 'Cognition' ($M = 2.52$, $SD = 0.65$) received the lowest mean among the four dimensions.

3.4. Correlation between the students' attitudes towards artificial intelligence and their medical artificial intelligence readiness

Pearson's product–moment correlation tested the relationship between the two variables. As indicated in Table 4, GPA-AI had a moderate positive correlation with the dimensions 'Cognition' ($r = 0.43$, $p < 0.001$), 'Vision' ($r = 0.49$, $p < 0.001$), and 'Ethics' ($r = 0.43$, $p < 0.001$). Furthermore, the 'Positive general AI attitudes' exhibited a strong positive association with 'Ability' ($r = 0.51$, $p < 0.001$) and overall medical AI readiness ($r = 0.52$, $p < 0.001$). The analyzes did not reveal a statistically significant relationship between GNA AI and medical AI readiness of the students ($p > 0.05$).

3.5. Factors associated with the medical artificial intelligence readiness

The regression model was statistically significant ($F_{10,\ 126} = 26.58$, $p < 0.001$), explaining approximately 30.7% ($R^2 = 0.362$, Adjusted $R^2 = 0.307$) of the variance in the students' medical AI readiness of students. In Table 5, only "Positive general attitudes toward AI" and self-reported knowledge about AI applications in healthcare were identified as significant factors influencing the students' medical AI readiness of students. A point increase in self-reported knowledge of AI applications in healthcare was associated with a 0.01 point increase ($p = 0.006$, 95% CI = 0.00, 0.02) in the mean score of general readiness of medical AI.

Table 3. Medical readiness for artificial intelligence among students (n = 127).

Variable	Range		Mean	SD
Cognition	1.13	5.00	2.52	0.65
I can define the basic concepts of data science	1.00	5.00	2.51	0.92
I can define the basic concepts of statistics	1.00	5.00	2.63	0.95
I can explain how AI systems are trained	1.00	5.00	2.48	0.86
I can define the basic concepts and terminology of AI	1.00	5.00	2.47	0.79
I can properly analyze the data obtained by AI in healthcare.	1.00	5.00	2.47	0.84
I can differentiate the functions and features of AI-related tools and applications.	1.00	5.00	2.50	0.82
I can organize workflows compatible with AI.	1.00	5.00	2.46	0.79
I can express the importance of data collection, analysis, evaluation, and safety; for the development of AI in healthcare.	1.00	5.00	2.61	1.02
Ability	1.25	5.00	2.72	0.75
I can use AI-based information combined with my professional knowledge.	1.00	5.00	2.69	0.97
I can use AI technologies effectively and efficiently in the delivery of healthcare.	1.00	5.00	2.62	0.96
I can use artificial intelligence applications according to its purpose.	1.00	5.00	2.58	1.00
I can access, evaluate, use, share and create new knowledge using information and communication technologies.	1.00	5.00	2.72	1.05
I can explain how AI applications offer a solution to which problem in healthcare.	1.00	5.00	2.61	0.85
I find it valuable to use AI for education, service, and research purposes.	1.00	5.00	3.00	1.17
I can explain the AI applications used in healthcare services to the patient.	1.00	5.00	2.72	0.93
I can choose the proper AI application for the problem encountered in healthcare.	1.00	5.00	2.77	0.88
Vision	1.00	5.00	2.67	0.88
I can explain the limitations of AI technology.	1.00	5.00	2.65	1.00
I can explain the strengths and weaknesses of AI technology.	1.00	5.00	2.69	0.93
I can foresee the opportunities and threats that AI technology can create.	1.00	5.00	2.68	0.95
Ethics	1.33	5.00	2.70	0.89
I can use health data in accordance with legal and ethical norms.	1.00	5.00	2.74	0.99
I can conduct under ethical principles while using AI technologies.	1.00	5.00	2.69	0.95
I can follow legal regulations regarding the use of AI technologies in healthcare.	1.00	5.00	2.68	1.01
Medical Artificial Intelligence overall readiness	1.27	4.86	2.64	0.68

Similarly, a point increase in the "Positive general attitudes towards AI' was associated with a 0.54 point increase ($p < 0.001$, 95% CI = 0.39, 0.70) in the mean score of general readiness for medical AI. This finding indicates that being knowledgeable about AI applications in healthcare care and having a generally positive attitude towards AI were associated with increased readiness for medical AI among students at NUSOM.

4. Discussion

Our study focused on assessing general attitudes toward AI in general and readiness for medical AI among health science students in Kazakhstan. Moreover, we studied the link between AI attitudes and readiness, including factors influencing the students' medical AI readiness of students.

Table 4. Association between general attitudes toward Artificial Intelligence and readiness for medical Artificial Intelligence among students (n = 127).

Variables	Positive general AI attitudes		Negative general AI attitudes	
	r	*p*	*r*	*p*
Cognition	0.43	<0.001***	−0.03	0.779
Ability	0.51	<0.001***	−0.01	0.932
Vision	0.49	<0.001***	0.06	0.519
Ethics	0.43	<0.001***	0.02	0.748
Medical AI overall readiness	0.52	<0.001***	0.00	0.964

Note. ***Significant at the 0.01 level.

AI is tightly woven into the field of medicine. In this study, medical students reported low knowledge about medical AI and its application in healthcare. These findings are similar to previous studies conducted in other countries [36,41,44]. According to a previous study conducted in Northern India, most of the medical students (79.6%) reported having low knowledge of medical AI applications [45]. This lack of knowledge is concerning, as AI has the capacity to transform diagnostics, planning treatment, and caring for patients. The reason for the low familiarity with AI is mainly due to the absence of AI in educational programs [36,46,47]. To close this gap, it is essential that medical instructors put emphasis on educating about AI in the curriculum. By integrating AI concepts, uses, and ethical issues into medical education, future healthcare students can be more equipped to use the advantages of AI in clinical settings. The need for deeper knowledge was illustrated by Saudi Arabian researchers, in which 55.8% of their study participants stated that they should seriously consider implementing lectures, seminars, and curricular courses

Table 5. Factors associated with Student's medical artificial intelligence readiness (n = 127).

Predictors	β	SE-*b*	Beta	*t*	*p*	95% Confidence Interval	
Age	0.03	0.02	0.16	1.31	0.192	−0.02	0.08
Gender	0.08	0.13	0.05	0.66	0.508	−0.17	0.33
Program (Reference group: Baccalaureate)							
Doctor of Medicine	−0.23	0.16	−0.15	−1.39	0.166	−0.55	0.10
Graduate (Master's and Ph.D.)	−0.18	0.21	−0.10	−0.87	0.389	−0.59	0.23
Average self-study hours per day	0.03	0.03	0.06	0.81	0.419	−0.04	0.09
Received/attended any education experience on AI outside NUSOM	0.14	0.15	−0.08	−0.97	0.333	−0.44	0.15
Knowledge about AI in general	0.00	0.00	−0.09	−0.85	0.396	−0.01	0.00
Knowledge about AI applications in healthcare	0.01	0.00	0.30	2.78	0.006[a]	0.00	0.02
Positive general attitudes	0.54	0.08	0.56	7.14	<0.001***	0.39	0.70
Negative general attitudes	−0.04	0.07	−0.04	−0.53	0.594	−0.17	0.10

Note. The dependent variable was the overall readiness for medical artificial intelligence of the students. β is the unstandardized coefficients; SE-b is the standard error.
$R^2 = 0.362$, Adjusted $R^2 = 0.307$.
[a] Significant at the 0.01 level.

to gain more knowledge about AI applications [48]. The study's findings agree with previous researchers regarding the importance of adding AI in medical education, given the knowledge gap among students and the need for medical AI advancement.

Interestingly, students became familiar with AI mainly through social networks, while a smaller proportion said that they became familiar through family and friends. This finding resonates with the findings of Khanagar et al. [48] Current findings showed that most respondents had not yet attended any educational sessions on medical AI in- and out-of-campus. Although school does not provide education on AI applications, 51.2% of respondents have used AI for their schoolwork, and approximately 70% have used AI for other purposes. Assumingly, the cause is the increasing popularity of the ChatGPT platform.

The findings of this study indicated that students mainly express negativity and neutrality toward AI applications in health care. The overall mean score of GPA-AI is lower than a similar study conducted in the US [49]. A previous study conducted in 94 countries, with developed countries comprising the bulk of the respondents, revealed that more than 85% of the participants demonstrated a positive general attitude toward AI and highlighted the importance of AI in clinical practice [50]. This could be linked to that of developed countries where students who use AI more in their education, consequently, are more knowledgeable in this aspect. Our study revealed that the positive attitude of the NUSOM students towards AI was slightly below the midpoint, indicating negative attitudes. However, respondents agreed that they were impressed by what AI could do and the benefits AI could bring to the country's economy. On the other hand, the mean score of GNA-AI was 3.02, which is slightly higher than positive attitudes. These findings are consistent with another study by Gong et al., which examined why medical students are anxious about AI applications [23]. This study demonstrated that students are anxious because of the "displacement" view, which states that demand for the healthcare workforce (i.e., radiologists) will decrease due to improved efficiency with AI. Potential reasons for negative and neutral attitudes toward AI could be related to concerns of students about errors AI would make, fear of being controlled by AI, and unethical use of AI by organizations. Again, such concerns stem from the lack of expertise in medical AI and the absence of AI in the educational program of the school. However, these reasons need to be explored further in future studies.

The study also examined the readiness of medical students for medical AI. Students' scores on the medical AI readiness scale were generally low. Although, students acknowledged AI as a practical application in education, service, and research. Of the four dimensions, 'AI ability' had the highest score, indicating that students have the potential to use medical AI effectively. The second dimension was "Ethics," which showed whether students could adhere to ethical and legal regulations related to AI applications. The dimension 'Vision' reflects the students' knowledge of AI's limitations, strengths and weaknesses. However, the results revealed the lowest mean score of 2.52 in the "Cognition" dimension, raising concern about the students' lack of knowledge about medical AI. These findings can be explained by previous results that reveal a need for more education and practice of medical AI among the students surveyed. Similarly, a study in Turkey using the same scale revealed that medical AI readiness among medical students is moderate, which was higher than our findings [51]. However,

those who responded also commented that medical AI could have a risk associated with incorrect use and expressed concern about their lack of knowledge. Therefore, they still recommended including AI education in their curriculum [50]. In our case, the NUSOM students expressed a poor readiness for medical AI, and this problem could be further explored, leaving room for development. Future healthcare professionals must be adequately prepared for AI, as unpreparedness could have serious implications. It is inevitable that AI is forcing a transformation in the medical field that will significantly impact medical practice and service delivery. Consequently, there will be a demand for new AI-related skills and knowledge among future healthcare workers as their professional roles evolve, while unpreparedness could lead to missed benefits from the most vital technological advances [7]. Based on the findings, there is an opportunity to incorporate AI into education programs so students will obtain more knowledge and competence, thus ensuring students' readiness for medical AI.

The study also examined the association between attitudes and the student's readiness for medical AI. The key finding revealed that positive attitudes toward AI were correlated with the general readiness for medical AI and its four dimensions. This result indicates that students with higher positive attitudes are more likely to be ready for the medical application of AI. Surprisingly, there was no significant association between negative attitudes and readiness for medical AI. The findings signify that positive attitudes lead to higher readiness for medical AI, while negative attitudes may not impact AI readiness. These findings are consistent with the results of the research by Rojaz-Mendez et al., stating that good attitudes are excellent predictors of the adoption and application of better technologies-related products and services [52]. As noted earlier, the reason for good attitudes is higher awareness of AI. Several studies confirmed that a high level of awareness of AI correlates with the readiness to accept AI applications in medicine [22,33,34]. Sungur et al. also revealed that the medical AI readiness score was higher in those with a high level of knowledge about AI applications and optimistically perceived AI [49]. Therefore, students must be taught and become aware of medical AI to have positive attitudes and increase readiness. The findings of the regression analysis supported the influence of AI knowledge and positive attitudes on student readiness. Students who are educated more about medical AI exhibit positive attitudes toward AI and will be more prepared. Educational institutions can further explore this finding to implement AI-teaching courses in their curricula effectively.

4.1. Limitations of the study

First, there may be self-selection bias due to voluntary participation in the survey. Students who are more familiar with AI and interested in this topic are more likely to participate in this survey. Second, since the survey is self-reported, it can lead to a social desirability bias: Respondents may respond according to social expectations instead of their own experience and attitudes. Third, the study used convenience sampling for sampling selection, which contributed to the potential generalizability of the findings. Fourth, since this research sampled only NUSOM students, this group of students may not be representative of all medical and health science students in Kazakhstan. Therefore, the findings may not be representative of the attitudes and readiness of various health sciences students in the country. This can also have an implication on the limitation of the transferability of the findings to other medical schools in the country. However, the setting was adequately described to improve the external validity of the study findings. Fourth, the survey used only two evaluation tools and may only capture some factors that affect attitudes and readiness. Fifth, the cross-sectional design of the study inhibits the evaluation of the attitudes and readiness of AI of students over time. In this study, no educational interventions to improve students and attitudes were also implemented and tested. Therefore, future studies should consider the use of a longitudinal design to capture the changes in study variables over time and attempt to develop educational interventions to address attitudes and readiness of health science students toward AI. Sixth, cultural factors that may influence student attitudes and readiness were not included as variables in the study. Future studies may consider exploring these variables as potential predictors of student attitudes and readiness. Finally, there may be some degree of information bias considering that most students received information about AI from the media, which does not always reflect accurate and comprehensive information about AI. This factor may have influenced the attitudes of the students towards AI. However, the study contributes to the limited literature on medical AI among medical students and health-related students in Kazakhstan.

5. Conclusions

The study assessed the general attitudes toward AI and medical AI readiness of health science students in Kazakhstan, and several conclusions can be drawn from the findings. First, health sciences

students generally have negative to neutral attitudes toward AI. Second, students can be evaluated as generally not prepared for medical AI. Third, students with a positive attitude and broader knowledge of AI are more likely to be prepared for AI's practical introduction and application in the medical field.

6. Recommendations

The study's findings can inform and encourage education policymakers and professors in medical and health science programs to create, introduce, and integrate new curriculums involving AI in medical schools. Specific areas in general attitudes and medical AI readiness where students were negatively related in this study should be considered when preparing educational interventions geared toward enhancing the attitudes and readiness of health sciences students to medical AI. Additionally, students who reported having a more positive outlook on machine learning have been shown to be more ready to use AI in their practice, and thus healthcare organizations should promote the benefits of its implementation for its adoption in the field. Furthermore, the country's government, medical education institutions, and healthcare organizations should consider students' concerns about AI when developing ethical regulations.

The results of the investigation also have implications for the research. The findings can be used as the basis for future research studies in Kazakhstan. Medical AI should be focused on and included in the research priorities of healthcare institutions and medical universities across the country to advance this field. For future research, a larger sample is recommended to ensure generalizability of the findings. In addition, a qualitative approach can be used to complement the quantitative data. Through qualitative inquiry, one can deeply explore the different reasons for the AI attitudes and readiness of students that could not be examined using the quantitative methods. This could give a richer discussion of the different factors that influence students' AI attitudes and readiness. It would broaden the perspective on the factors that may have influenced the findings that quantitative data cannot capture. Different data collection methods, such as interviews, case studies, or scenario-based assessments, can be used for the same reasons. In addition, investigating external factors that may influence students' perceptions (media, personal experience, cultural differences) can provide an in-depth understanding of the issue. Since this research recorded students' attitudes and readiness at only one point in their medical training, future research may conduct a longitudinal study to follow medical students on every step of their professional development and record changes throughout the process.

Ethical approval

The study protocol was approved by "Nazarbayev University Institutional Research Ethics Committee" (submission number 679/17022023).

Other disclosure

None.

Conflict of interest

All authors declare no financial or non-financial competing interests.

Appendix A.

The General Attitudes towards Artificial Intelligence Scale.

Response options:
1 = Strongly disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly agree.

Statement	1	2	3	4	5
For routine transactions, I would rather interact with an artificially intelligent system than with a human.					
Artificial Intelligence can provide new economic opportunities for this country.					
Organizations use Artificial Intelligence unethically.					
Artificially intelligent systems can help people feel happier.					
I am impressed by what Artificial Intelligence can do.					
I think artificially intelligent systems make many errors.					
I am interested in using artificially intelligent systems in my daily life.					
I find Artificial Intelligence sinister.					
Artificial Intelligence might take control of people.					
I think Artificial Intelligence is dangerous.					
Artificial Intelligence can have positive impacts on people's wellbeing.					
Artificial Intelligence is exciting.					
An artificially intelligent agent would be better than an employee in many routine jobs.					
There are many beneficial applications of Artificial Intelligence.					
I shiver with discomfort when I think about future uses of Artificial Intelligence.					
Artificially intelligent systems can perform better than humans.					
Much of society will benefit from a future full of Artificial Intelligence					
I would like to use Artificial Intelligence in my own job.					
People like me will suffer if Artificial Intelligence is used more and more.					
Artificial Intelligence is used to spy on people.					

Medical Artificial Intelligence Readiness Scale for Medical Students.

Response options:
1 = Strongly disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly agree.

Statement	1	2	3	4	5
I can define the basic concepts of data science.					
I can define the basic concepts of statistics.					
I can explain how AI systems are trained.					
I can define the basic concepts and terminology of AI.					
I can properly analyze the data obtained by AI in healthcare.					
I can differentiate the functions and features of AI related tools and applications.					
I can organize workflows compatible with AI.					
I can express the importance of data collection, analysis, evaluation and safety; for the development of AI in healthcare.					
I can harness AI-based information combined with my professional knowledge.					
I can use AI technologies effectively and efficiently in healthcare delivery.					
I can use artificial intelligence applications in accordance with its purpose.					
I can access, evaluate, use, share and create new knowledge using information and communication technologies.					
I can explain how AI applications offer a solution to which problem in healthcare.					
I find valuable to use AI for education, service and research purposes.					
I can explain the AI applications used in healthcare services to the patient.					
I can choose proper AI application for the problem encountered in healthcare.					
I can explain the limitations of AI technology.					
I can explain the strengths and weaknesses of AI technology.					
I can foresee the opportunities and threats that AI technology can create.					
I can use health data in accordance with legal and ethical norms.					
I can conduct under ethical principles while using AI technologies.					
I can follow legal regulations regarding the use of AI technologies in healthcare.					

Open Ended Question

1. How do you think artificial intelligence can be incorporated into medical education to enhance students' learning experiences and prepare them for future roles in the healthcare system?

Answer:

2. In your opinion, what are some potential benefits and drawbacks of using artificial intelligence in the healthcare system?

Answer:

3. How do you envision the future of healthcare with the continued development and integration of artificial intelligence?

Answer:

4. In your opinion, what changes might we see in the roles of healthcare professionals, the delivery of care, and the overall healthcare landscape in relation to artificial intelligence?

Answer:

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