

RESEARCH

Open Access



Shaping future practices: German-speaking medical and dental students' perceptions of artificial intelligence in healthcare

Sebastian Fitzek^{1*} and Kyung-Eun Anna Choi^{1,2}

Abstract

Background The growing use of artificial intelligence (AI) in healthcare necessitates understanding the perspectives of future practitioners. This study investigated the perceptions of German-speaking medical and dental students regarding the role of artificial intelligence (AI) in their future practices.

Methods A 28-item survey adapted from the AI in Healthcare Education Questionnaire (AIHEQ) and the Medical Student's Attitude Toward AI in Medicine (MSATAIM) scale was administered to students in Austria, Germany, and Switzerland from April to July 2023. Participants were recruited through targeted advertisements on Facebook and Instagram and were required to be proficient in German and enrolled in medical or dental programs. The data analysis included descriptive statistics, correlations, t tests, and thematic analysis of the open-ended responses.

Results Of the 409 valid responses (mean age = 23.13 years), only 18.2% of the participants reported receiving formal training in AI. Significant positive correlations were found between self-reported tech-savviness and AI familiarity ($r=0.67$) and between confidence in finding reliable AI information and positive attitudes toward AI ($r=0.72$). While no significant difference in AI familiarity was found between medical and dental students, dental students exhibited slightly more positive attitudes toward the integration of AI into their future practices.

Conclusion This study underscores the need for comprehensive AI education in medical and dental curricula to address knowledge gaps and prepare future healthcare professionals for the ethical and effective integration of AI in practice.

Keywords Artificial intelligence, Healthcare, Medical education, Survey, Perceptions, Digital literacy, Students

Introduction

Artificial intelligence (AI) is rapidly transforming healthcare, with promising applications developing in several specialties, such as radiology, pathology, dermatology, and dentistry [29]. The challenges imposed by

artificial intelligence require significant adaptation in medical education to ensure readiness [2]. The ability of AI to enhance the accuracy of medical imaging, streamline surgical procedures, and improve diagnostic capabilities demonstrates its potential to significantly improve patient care [4, 10]. AI's potential in medicine is vast and varied [15].

However, the effective integration of AI into clinical practice requires more than technological innovation alone. Healthcare professionals who are prepared, knowledgeable, and receptive to the potential of AI are also needed. Recent research underscores the

*Correspondence:

Sebastian Fitzek
sebastian.fitzek@dp-uni.ac.at

¹ Health Services Research, Faculty of Medicine/Dentistry, Danube Private University, Steiner Landstraße 124, Krems-Stein 3500, Austria

² Center for Health Services Research, Brandenburg Medical School, Seebad 82/83, 15562 Rüdersdorf b. Berlin, Neuruppin, Germany



© The Author(s) 2024. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

importance of integrating AI education into undergraduate medical and dental curricula to equip future physicians and dentists with the knowledge and skills necessary to work effectively in a healthcare environment that is increasingly reliant on AI [24, 30].

Although researchers widely acknowledge the importance of AI literacy in healthcare [11, 22], the educational needs and perspectives of medical and dental students regarding AI, particularly within different regional and cultural contexts, have not been fully explored. Comprehensive AI policy education frameworks are essential for university teaching and learning [7]. AI deployment in healthcare faces numerous challenges that need to be addressed [13]. Culture and language can influence how individuals perceive and interact with new technologies, making it crucial to adapt educational approaches to meet the diverse needs of learners in various settings. Moreover, the variation in teaching and learning approaches across medical and dental education programs necessitates individualized AI curricula that address regional variations in challenges and opportunities [12].

To address this gap, we focused our research on the perceptions of, knowledge about, and training experiences with AI among German-speaking medical and dental students in Austria, Germany, and Switzerland. These countries share a common language and cultural heritage while also having distinct healthcare systems and educational approaches. By examining perspectives on AI within this specific context, we aim to inform the development of tailored educational interventions and policy recommendations that effectively address the unique challenges and opportunities faced by these countries. Trends indicate a growing need for AI literacy in medical curricula [16].

We drew upon established learning theories, such as constructivism and social learning theory, to guide our investigation. Constructivism emphasizes the active role learners play in constructing their knowledge, while social learning theory underscores the importance of social interaction and observation in the learning process. These theories suggest that AI education should be learner-centered, interactive, and relevant to the specific context of medical practice [9, 18].

Our overarching research question is as follows: What are the perceptions of German-speaking medical and dental students regarding the integration of AI into their future professional practices? Through this inquiry, we aim to:

1. The gaps in AI literacy among medical and dental students were identified.
2. To develop evidence-based educational strategies that align with established learning theories.
3. The preparedness of future healthcare professionals for the ethical and effective utilization of AI in their careers should be enhanced.

Materials and methods

Study design and participants

A cross-sectional survey was conducted from April to July 2023 among medical and dental students in Germany, Austria, and Switzerland. Participants were recruited through targeted advertisements on Facebook and Instagram, focusing on individuals within the specified age range, geographic locations, and fields of study. The eligibility criteria included current enrollment in a medical or dental program and proficiency in the German language.

Survey instrument

The survey instrument was adapted from a prior study by Bisdas et al. [5], incorporating elements from the AI in Healthcare Education Questionnaire (AIHEQ, [20]) and the Medical Student's Attitude Toward AI in Medicine (MSATAIM) scale [23]. The survey contained 28 items covering sociodemographic data, understanding of AI principles, AI in medical education, and attitudes toward AI. The survey was translated into German by a bilingual expert and refined through cognitive interviews with native German-speaking medical students. Improving the quality of web surveys is critical for accurate data collection [14]. Content validity was assessed by a panel of experts in artificial intelligence and medical education, with feedback quantified using the content validity ratio (CVR) and content validity index (CVI) metrics. The instrument's internal consistency (reliability) was assessed using Cronbach's alpha ($\alpha = 0.807$).

Data collection

The survey was administered online using Google Forms. Before starting, participants provided electronic consent and confirmed their eligibility (age over 18 and current enrollment in a medical or dental program). Anonymity was ensured throughout the data collection process.

Statistical analysis

We used G*Power to conduct an a priori power analysis, determining the required sample size to detect a medium effect size ($f^2 = 0.15$) for multiple linear

regression with three predictors (tech-savviness, AI familiarity, and confidence in finding reliable AI information), given a power of 0.80 and an alpha level of 0.05. This effect size was chosen based on both a preliminary assessment of our data and the literature in the field of AI and medical education ([5] reported an effect size of 0.14 for a similar analysis [20], observed a range of effect sizes from 0.10 to 0.18 in their study). Data normality was assessed using the Shapiro–Wilk test and Q–Q plots, informing the selection of appropriate parametric or nonparametric tests. Descriptive statistics (means, ranges, standard deviations), t tests, correlations (Pearson’s *r*), and multiple linear regression analyses were performed using Python 3.10. Analyses focused on examining relationships between variables, including differences in AI perspectives between students with and without formal AI training, and evaluating predictors of attitudes toward AI.

Qualitative data analysis

The open-ended responses were analyzed via thematic analysis. Initial open coding extracted keywords and concepts, which were then grouped into themes and subthemes based on recurring patterns and relationships. Multiple researchers independently reviewed the data to ensure intercoder reliability, with any discrepancies resolved through discussion and consensus. Atlas.ti software (version 8) was used to facilitate the coding process.

Ethics approval

The study received ethical approval from the Ethics Committee of Danube Private University.

Results

Demographic characteristics

The study participants were primarily young adults (mean age = 23.13 years, SD = 4.27), with a balanced gender distribution (49.6% men, 45.5% women, 2.9% nonbinary, and 2.0% unspecified). Most were medical (57.0%) or dental (43.0%) students enrolled in various stages of their education, providing diverse perspectives on AI. The majority were in the preclinical/bachelor stage (59.2%), followed by those in the clinical/master stage (33.0%), and a smaller proportion were pursuing a doctorate/Ph.D. (7.8%). Geographically, most respondents were from Germany (45.5%), followed by Austria (34.7%) and Switzerland (19.8%).

Familiarity with AI applications and tech savviness

A significant proportion of respondents (52.3%) reported no familiarity with AI applications, while only a small percentage (4.4%) indicated being very familiar. Self-assessed tech savviness varied considerably, with no significant association found between tech affinity and familiarity with AI applications in medicine. Cluster analysis identified three distinct groups based on tech-savviness and AI familiarity: basic users, intermediate users, and proficient users (Fig. 1).

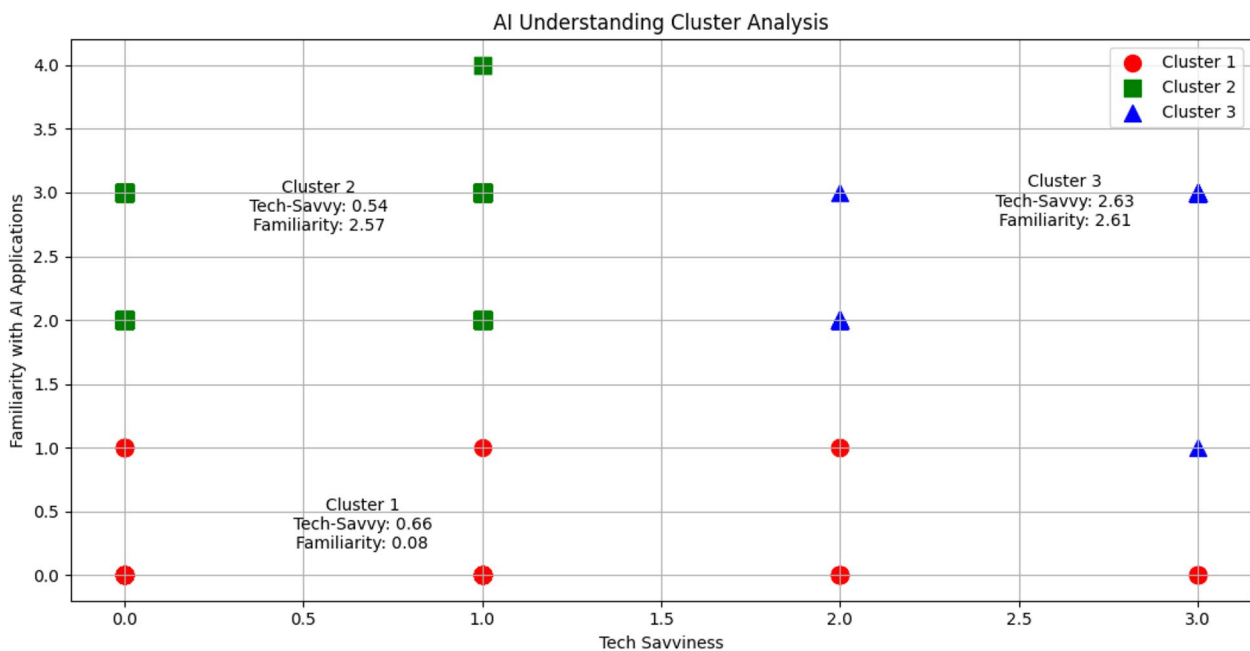


Fig. 1 Cluster analysis of tech savviness and AI familiarity

AI understanding by gender and age

Analysis of AI understanding by gender (Figure A18) revealed a diverse range of comprehension across all gender identities, with no one group demonstrating significantly greater familiarity with AI. Age was associated with AI understanding, with younger participants generally reporting lower levels of AI comprehension than older participants (Fig. 2). There was no significant difference in AI understanding between medical and dental students across age groups or gender identities (Fig. 3).

Attitudes toward AI

Table 1 summarizes respondents' views on the adoption of AI in healthcare, assessed on a scale from 0 to 5, where higher scores indicate greater agreement.

The respondents strongly agreed that AI has the potential to revolutionize healthcare and improve medical care. Opinions were divided on whether AI would replace all doctors, with some expressing concerns. While fear of AI development was not widespread, a minority expressed strong concerns. Excitement about AI's potential to advance medical practice was prevalent, and there was strong support for incorporating AI into medical education.

Correlation analysis

Correlation analysis revealed significant positive associations between attitudes favoring AI's potential to revolutionize medicine and the belief that AI will improve

medical practices ($r = 0.61$). Conversely, negative correlations emerged between positive attitudes toward AI and the belief that AI could replace human doctors.

Comparison between medical and dental students

No significant difference was found in AI familiarity between medical (mean = 2.76, SD = 0.89) and dental students (mean = 2.85, SD = 0.85; $p = 0.123$). However, dental students demonstrated slightly more positive attitudes toward AI's potential to revolutionize medicine (medical students: mean = 4.72, SD = 0.68; dental students: mean = 4.81, SD = 0.65; $p = 0.032$). This suggests that dental students might perceive AI as having more direct or immediate applications in their field, potentially due to the increasing use of AI in diagnostic and treatment planning tools specific to dentistry.

Qualitative data from open-ended questions

Qualitative analysis of the open-ended responses identified three key themes:

1. Need for foundational AI instruction
2. Desire to integrate AI into existing curricula
3. Concerns about the potential dehumanization of care

These findings underscore the need for a balanced approach to AI adoption in medical education that incorporates both technical skills and ethical considerations.

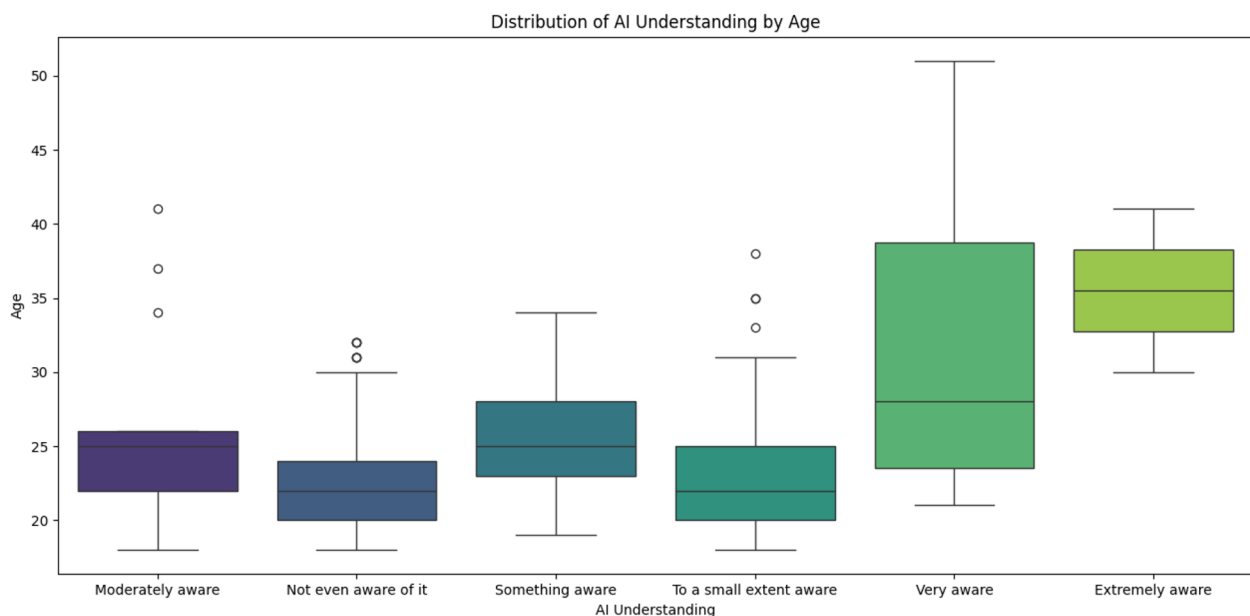
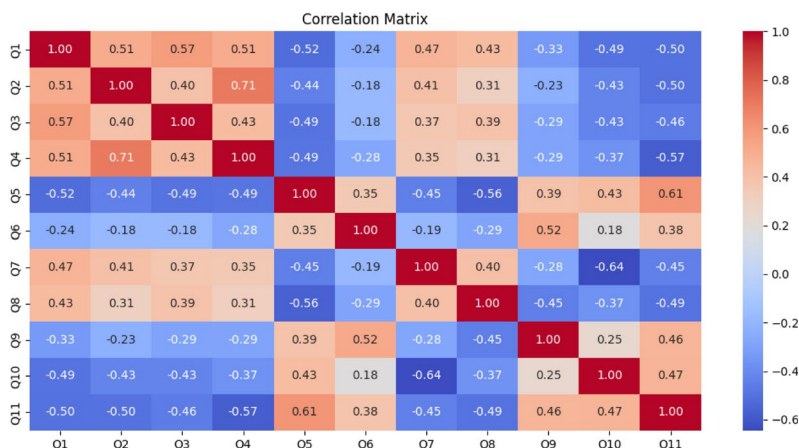


Fig. 2 How AI understanding varies with age



Legend:

- Q1. To what extent do you consider yourself tech-savvy?
- Q2. Artificial intelligence (AI) is a collective term for various technologies (e.g., machine learning). Do you have a basic understanding of these technologies?
- Q3. AI has various applications in medicine (e.g., AI-assisted robotic surgery). How familiar are you with these applications?
- Q4. How much do you trust their ability to find trustworthy information about AI in medicine/dentistry?
- Q5. I consider AI in medicine as a partner and not as a competitor.
- Q6. Artificial intelligence will revolutionize medicine/dentistry.
- Q7. All doctors will be replaced in the foreseeable future.
- Q8. These developments scare me.
- Q9. These developments make medicine seem more exciting to me.
- Q10. AI will never make the human doctor dispensable.
- Q11. AI should be part of medical/dental education.

Fig. 3 Correlation matrix for technological proficiency levels and familiarity with AI applications. Legend: Q1. To what extent do you consider yourself tech-savvy? Q2. Artificial intelligence (AI) is a collective term for various technologies (e.g., machine learning). Do you have a basic understanding of these technologies? Q3. AI has various applications in medicine (e.g., AI-assisted robotic surgery). How familiar are you with these applications? Q4. How much do you trust their ability to find trustworthy information about AI in medicine/dentistry? Q5. I consider AI in medicine as a partner and not as a competitor. Q6. Artificial intelligence will revolutionize medicine/dentistry. Q7. All doctors will be replaced in the foreseeable future. Q8. These developments scare me. Q9. These developments make medicine seem more exciting to me. Q10. AI will never make the human doctor dispensable. Q11. AI should be part of medical/dental education

Table 1 Attitudes toward AI

Variable	Mean	SD	Min	25th Pctl	Median	75th Pctl	Max
AI revolutionizing medicine/dentistry	4.76	0.67	1	5	5	5	5
All doctors being replaced in the future	2.14	1.13	1	1	3	3	5
Fear of AI developments	1.76	1.31	1	1	1	3	5
Excitement about AI developments	4.64	0.82	1	5	5	5	5
AI making doctors dispensable	3.73	1.13	1	3	3	5	5
AI improving medicine	4.74	0.67	3	5	5	5	5
AI as part of medical education	4.17	1.04	1	3	5	5	5

Discussion

This study investigated German-speaking medical and dental students’ attitudes and perceptions toward AI, revealing a diverse range of understanding. Our findings underscore the urgent need for customized AI

educational approaches within medical and dental programs to address variability in knowledge and technical proficiency. AI familiarity and attitudes varied significantly across educational stages, with tech-savviness increasing as students progressed in their studies

($F=54.93$, $p<0.0001$). AI systems can predict patient deterioration in emergency settings [25]. This highlights the necessity of adaptable educational strategies throughout medical training.

Despite a generally positive sentiment toward AI, a significant gap in formal AI education exists, with only 18.2% of students receiving structured training. This underscores the need for comprehensive AI curricula, as advocated in previous research [5, 23]. Primary care will see significant changes due to AI integration [6]. A significant positive correlation ($r=0.72$) was found between students' confidence in sourcing reliable AI information and their favorable attitudes toward AI. This strong association suggests that enhancing technological competence and providing accessible, trustworthy AI resources could be pivotal in fostering more receptive attitudes toward AI in medical practice [8].

Our findings align with global discussions on AI education in medical fields, confirming the need for specific policies and ethical instructional design. AI educational programs using AI can significantly impact learning outcomes [17]. Similar to observations in Canada, the UK, and the US, our study identifies prevalent gaps in formal AI instruction, highlighting a common international challenge in integrating AI into medical education [3, 21, 26]. These findings hold particular significance in the German-speaking European context, enriching our understanding of medical student AI perceptions and contributing to the broader discourse on AI in medical informatics.

The significant positive correlation between confidence in sourcing reliable AI information and favorable attitudes toward AI suggests that both knowledge and the quality and accessibility of information are crucial. The emerging field of mobile health integrates AI technologies [27]. An ethical instructional design should ensure equitable access to AI knowledge, address potential biases in AI algorithms, and teach critical appraisal skills for AI information. Practical implementations include incorporating case studies on AI ethics, providing resources on bias in AI, and ensuring diverse representations in AI training materials. AI's role in democracy and healthcare is critical [19].

Our findings revealed significant variations in AI understanding across gender categories, aligning with other studies (e.g., [28]) and challenging assumptions about gender disparities in technological proficiency within the medical field. This emphasizes the need for gender-inclusive AI education policies to create a workforce that is both inclusive and prepared for AI, ensuring that individuals across all demographics have fair access to AI knowledge and skills.

Furthermore, our study adds a new dimension by exploring the specific context of German-speaking medical and dental students. While previous research has focused primarily on other regions, our findings highlight that the need for comprehensive AI education is a global phenomenon, emphasizing the importance of tailoring AI education to specific cultural and linguistic contexts.

Potential limitations in our study design should be acknowledged, particularly regarding the potential for selection bias introduced by recruiting participants through social media platforms. This approach may have led to an overrepresentation of tech-savvy individuals, affecting the generalizability of our findings, as those who were more comfortable with technology might have been more likely to participate in the survey. Although we assessed participants' self-reported technology use in the survey, this might not fully capture the nuances of technological proficiency. Therefore, the findings may not be completely generalizable to the broader population of German-speaking medical and dental students. Future studies should consider using a more diverse range of recruitment methods to enhance representativeness.

Additionally, although we took measures to mitigate common method bias (e.g., careful formulation of survey questions, ensuring participant anonymity, and employing a mixed-methods approach), the use of a single survey instrument for data collection may have introduced some bias. However, Harman's single-factor test did not suggest that common method bias was a major concern in this study.

Efforts were made to address nonresponse bias by keeping the survey short and engaging and by sending follow-up reminders to maximize participation. We compared the demographic characteristics of our sample (e.g., age, sex, year of study) with available data on the broader population of German-speaking medical and dental students to assess representativeness. However, despite these efforts, the potential for bias remains, and future research should aim to verify these findings in more diverse and representative samples.

Limitations and future directions

This study has limitations. The cross-sectional design and self-reported data may not fully capture evolving attitudes toward AI or provide a comprehensive assessment of AI knowledge. Additionally, the sampling method may introduce selection bias. Future research should prioritize longitudinal studies and objective measures, such as assessments of AI knowledge or skills using standardized tests or simulations, to track changes in AI perceptions and education needs over time.

Conclusion

This study provides compelling evidence for significant variations in AI familiarity and attitudes among German-speaking medical and dental students, underscoring the urgent need for comprehensive and adaptable AI education programs tailored to different educational stages and cultural contexts. Medical school curricula must adapt to the digital age [31]. Enhancing technological competence and providing access to reliable AI information are crucial for fostering more receptive attitudes toward AI in healthcare.

The study's findings challenge assumptions about gender disparities in technological proficiency and emphasize the need for inclusive AI education policies. By addressing the identified gaps and implementing inclusive, comprehensive AI education programs, we can empower future healthcare professionals to confidently and ethically navigate the AI-driven landscape of modern medicine, ultimately leading to improved patient care and a more equitable healthcare system.

Abbreviations

AI	Artificial intelligence
DL	Deep learning
ML	Machine learning
SD	Standard deviation
NAN	No answer

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12909-024-05826-z>.

Supplementary Material 1.

Acknowledgements

We extend our appreciation to all the medical and dental students who took the time to participate in our survey. Their insightful contributions have enriched this study. We express our appreciation to Danube Private University (DPU, Krems) for their support in facilitating the distribution of our survey. We also thank our colleagues at MIAAI for providing fruitful comments in a team meeting regarding our survey.

Authors' contributions

S.F. and A.C. conceived the study and designed the survey. S.F. conducted the survey, performed the statistical analyses, and drafted the initial manuscript. A.C. supervised the project and provided critical revisions on the manuscript. All authors interpreted the data, reviewed the manuscript, and approved the final version. In this statement, the initials refer to: S.F. - Sebastian Fitzek. A.C. - Anna Choi.

Funding

The research was performed by internal university resources of the Danube Private University. The two authors had a full role in the conceptualization, design, data collection, analysis, decision to publish, or preparation of the manuscript.

Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available because the data are anonymous and voluntary survey responses. However, they are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

This online survey study involved voluntary participation in an anonymous survey, with no intervention or collection of personally identifiable data. Due to the nature of the study, the need for formal ethics approval was waived by Prof. Dr. Frank, Chair and Board Member of the Ethics Committee at Danube Private University, Krems, Austria. This decision, as communicated by Univ.-Prof. Mag. Dr. Wilhelm Frank, MLS, Ph.D, was based on institutional policy and adheres to the standards set by the Austrian Federal Hospitals and Health Clinics Act (KaKuG) and the Austrian Universities Act 2002 (UG), aligning with international ethical guidelines for noninterventional studies.

To ensure adherence to ethical online research practices, as outlined in the literature (e.g., [1]), participants were requested to accept the study terms and conditions before accessing the survey. This procedure was implemented to obtain informed consent from all participants for their involvement in this noninterventional, anonymous format. Participation in the study was voluntary, with no compensation or incentives provided.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Received: 23 August 2023 Accepted: 26 July 2024

Published online: 06 August 2024

References

1. Azer SA. Social media channels in health care research and rising ethical issues. *AMA J Ethics*. 2017;19(11):1061–9. <https://doi.org/10.1001/journalofethics.2017.19.11.peer1-1711>.
2. Azer SA, Guerrero APS. The challenges imposed by artificial intelligence: are we ready in medical education? *BMC Med Educ*. 2023;23:680. <https://doi.org/10.1186/s12909-023-04660-z>.
3. Banerjee M, Chiew D, Patel KT, et al. The impact of artificial intelligence on clinical education: perceptions of postgraduate trainee doctors in London (UK) and recommendations for trainers. *BMC Med Educ*. 2021;21(1):429. <https://doi.org/10.1186/s12909-021-02870-x>.
4. Bi WL, Hosny A, Schabath MB, et al. Artificial intelligence in cancer imaging: clinical challenges and applications. *CA Cancer J Clin*. 2019;69(2):127–57. <https://doi.org/10.3322/caac.21552>.
5. Bisdas S, et al. Multinational survey on the attitudes of medical students toward artificial intelligence in radiology. *Eur Radiol*. 2021;31:4365–74. <https://doi.org/10.3389/fpubh.2021.795284>.
6. Blease C, Kaptchuk TJ, Bernstein MH, et al. Artificial intelligence and the future of primary care: exploratory qualitative study of UK general practitioners' views. *J Med Internet Res*. 2019;21(3): e12802. <https://doi.org/10.2196/12802>.
7. Chan CKY. A comprehensive AI policy education framework for university teaching and learning. *Int J Educ Technol High Educ*. 2023;20(1):1–25. <https://doi.org/10.1186/s41239-023-00408-3>.
8. Civaner MM, Uncu Y, Bulut F, Chalil EG, Tatli A. Artificial intelligence in medical education: a cross-sectional needs assessment. *BMC Med Educ*. 2022;22(1):772. <https://doi.org/10.1186/s12909-022-03852-3>.
9. Cook DA, Triola MM. Virtual patients: a critical literature review and proposed next steps. *Med Educ*. 2009;43(4):303–11.
10. Davenport T, Kalakota R. The potential for artificial intelligence in healthcare. *Future Healthc J*. 2019;6(2):94–8. <https://doi.org/10.7861/futurehosp.6-2-94>.
11. Dumić-Čule I, Orešković T, Brkljačić B, Kujundžić Tiljak M, Orešković S. The importance of introducing artificial intelligence to the medical curriculum—assessing practitioners' perspectives. *Croat Med J*. 2020;61(5):457–64.
12. Ellaway RH, Topps D, Hoskins S, Graves L. Leading curriculum change in medical education: a complexity perspective. *Med Educ*. 2020;54(2):99–107.

13. Esmailzadeh P. Challenges and strategies for wide-scale artificial intelligence (AI) deployment in healthcare practices: a perspective for healthcare organizations. *Artif Intell Med*. 2024;151: 102861. <https://doi.org/10.1016/j.artmed.2024.102861>.
14. Eysenbach G. Improving the quality of web surveys: the checklist for reporting results of internet e-surveys (CHERRIES). *J Med Internet Res*. 2004;6(3): e34. <https://doi.org/10.2196/jmir.6.3.e34>.
15. Hamet P, Tremblay J. Artificial intelligence in medicine. *Metabolism*. 2017;69:536–40.
16. Han ER, Yeo S, Kim MJ, Lee YH, Park KH, Roh H. Medical education trends for future physicians in the era of advanced technology and artificial intelligence: an integrative review. *BMC Med Educ*. 2019;19:460. <https://doi.org/10.1186/s12909-019-1891-5>.
17. Han JW, Park J, Lee H. Analysis of the effect of an artificial intelligence chatbot educational program on non-face-to-face classes: a quasi-experimental study. *BMC Med Educ*. 2022;22:830. <https://doi.org/10.1186/s12909-022-03898-3>.
18. Issenberg SB, McGaghie WC, Petrusa ER, Gordon DL, Scalese RJ. Features and uses of high-fidelity medical simulations that lead to effective learning: a BEME systematic review. *Med Teach*. 2005;27(1):10–28.
19. Jungherr A. Artificial intelligence and democracy: a conceptual framework. *Soc Med Soc*. 2023;9(3):20563051231186350. <https://doi.org/10.1177/20563051231186353>.
20. Karaca O, Çalışkan SA, Demir K. Medical artificial intelligence readiness scale for medical students (MAIRS-MS) – development, validity and reliability study. *BMC Med Educ*. 2021;21(1):112. <https://doi.org/10.1186/s12909-021-02546-6>.
21. Liu DS, Sawyer J, Luna A, Aoun J, Wang J, Boachie L, Halabi S, Joe B. Perceptions of US medical students on artificial intelligence in medicine: mixed methods survey study. *JMIR Med Educ*. 2022;8(4): e38325. <https://doi.org/10.2196/38325>.
22. Longoni C, Morewedge CK. AI Can Outperform Doctors. So Why Don't Patients Trust It? *Harv Bus Rev*. 2019. <https://hbr.org/2019/10/ai-can-outperform-doctors-so-why-dont-patients-trust-it>.
23. Pinto dos Santos D, Giese D, Brodehl S, et al. Medical students' attitude toward artificial intelligence: a multicenter survey. *Eur Radiol*. 2019;29:1640–6. <https://doi.org/10.1007/s00330-018-5601-1>.
24. Pucchio A, Rathagirişnan R, Caton N, Gariscsak PJ, Del Papa J, Nabhen JJ, et al. Exploration of exposure to artificial intelligence in undergraduate medical education: a Canadian cross-sectional mixed-methods study. *BMC Med Educ*. 2022;22:815. <https://doi.org/10.1186/s12909-022-03602-5>.
25. Shamout FE, Shen Y, Wu N, et al. An artificial intelligence system for predicting the deterioration of COVID-19 patients in emergency departments. *npj Digit Med*. 2021;4:1–8. <https://doi.org/10.1038/s41746-021-00398-0>.
26. Sit C, Srinivasan R, Amlani A, Muthuswamy K, Azam A, Monzon L, Poon DS. Attitudes and perceptions of UK medical students toward artificial intelligence and radiology: a multicenter survey. *Insights Imaging*. 2020;11:14. <https://doi.org/10.1186/s13244-019-0830-7>.
27. Steinhubl SR, Muse ED, Topol EJ. The emerging field of mobile health. *Sci Transl Med*. 2015;7:283rv3. <https://doi.org/10.1126/scitranslmed.aaa3487>.
28. Teng M, Singla R, Yau O, Lamoureux D, Gupta A, Hu Z, Hu R, Aissioui A, Eaton S, Hamm C, Hu S, Kelly D, MacMillan KM, Malik S, Mazzoli V, Teng YW, Laricheva M, Jarus T, Field TS. Health care students' perspectives on artificial intelligence: countrywide survey in Canada. *JMIR Med Educ*. 2022;8: e33390. <https://doi.org/10.2196/33390>.
29. Topol EJ. High-performance medicine: the convergence of human and artificial intelligence. *Nat Med*. 2019;25:44–56. <https://doi.org/10.1038/s41591-018-0300-7>.
30. Wartman SA, Combs CD. Medical education must move from the information age to the age of artificial intelligence. *Acad Med*. 2018;93(8):1107–9. <https://doi.org/10.1097/ACM.0000000000002044>.
31. Zainal H, Xin X, Thumboo J. Medical school curriculum in the digital age: perspectives of clinical educators and teachers. *BMC Med Educ*. 2022;22:428. <https://doi.org/10.1186/s12909-022-03454-z>.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.