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International pharmacy students' perceptions towards artificial intelligence in medicine—A multinational, multicentre cross-sectional study

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Aims: To explore international undergraduate pharmacy students' views on integrating artificial intelligence (AI) into pharmacy education and practice.

Methods: This cross-sectional institutional review board-approved multinational, multicentre study comprised an anonymous online survey of 14 multiple-choice items to assess pharmacy students' preferences for AI events in the pharmacy curriculum, the current state of AI education, and students' AI knowledge and attitudes towards using AI in the pharmacy profession, supplemented by 8 demographic queries. Subgroup analyses were performed considering sex, study year, tech-savviness, and prior AI knowledge and AI events in the curriculum using the Mann–Whitney *U*-test. Variances were reported for responses in Likert scale format.

Results: The survey gathered 387 pharmacy student opinions across 16 faculties and 12 countries. Students showed predominantly positive attitudes towards AI in medicine (58%, $n = 225$) and expressed a strong desire for more AI education (72%, $n = 276$). However, they reported limited general knowledge of AI (63%, $n = 242$) and felt inadequately prepared to use AI in their future careers (51%, $n = 197$). Male students showed more positive attitudes towards increasing efficiency through AI ($P = .011$), while tech-savvy and advanced-year students expressed heightened concerns about potential legal and ethical issues related to AI ($P < .001$/$P = .025$, respectively). Students who had AI courses as part of their studies reported better AI knowledge ($P < .001$) and felt more prepared to apply it professionally ($P < .001$).

Conclusions: Our findings underline the generally positive attitude of international pharmacy students towards AI application in medicine and highlight the necessity for a greater emphasis on AI education within pharmacy curricula.

KEYWORDS

artificial intelligence, education, international study, medicine, perception, pharmacy students

Felix Busch and Lena Hoffmann contributed equally and should be considered joint first authors.

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1 | INTRODUCTION

Artificial intelligence (AI) holds the potential to reshape healthcare, steering innovation across a multitude of disciplines and transforming traditional approaches.[1,2] Pharmacy, as a key component of the healthcare system, plays a crucial role in disease management and medication administration.[3,4] However, with the increasing integration of AI into healthcare, the role of pharmacists is expected to change significantly.[5]

AI applications in medicine not only enhance patient care quality and medical workflow efficiency but also empower healthcare professionals to analyse large datasets.[6–8] This ability is crucial for early disease detection and the development of personalized treatment plans. In the context of pharmacy, AI holds promise in the analysis and extraction of pertinent information from clinical documents, streamlining access to relevant patient data.[9] AI systems deployed in pharmacovigilance can leverage multiple data sources to monitor and detect potential adverse drug events, thus contributing to early identification and prevention of drug-related risks.[10] AI can also expedite the drug discovery and development process, utilizing machine learning models to scrutinize extensive molecular data and pinpoint therapeutic targets.[11,12] Furthermore, the application of AI-powered decision support systems can enable evidence-based recommendations for drug selection and dosage adjustments, thereby enhancing treatment outcomes and patient safety.[13]

With the growing implementation of AI applications into pharmacy practice, there is an imperative need to incorporate AI education into pharmacy curricula. Emphasizing AI education is vital not only for practical applications but also for adhering to the fundamental ethical principles of healthcare.[14–16] By fostering the ability to critically evaluate AI algorithms and identify and mitigate biases, we can better prepare pharmacy students to use AI tools responsibly and impartially.[17,18]

Despite existing studies investigating undergraduate healthcare students' perspectives towards AI in medicine, particularly among medical and dental students, there is a noticeable research gap concerning the attitudes and concerns of pharmacy students about AI integration into pharmacy education and the profession on a global scale.[19–21] However, it is critical to explore these perspectives to inform curricula and prepare future pharmacists for the increasing emergence of AI in healthcare.

This multinational, cross-sectional study aims to evaluate the perspectives of international pharmacy students on AI's role in their education and future careers, including: (i) students' tech-savviness and knowledge of informatics and AI; (ii) the current state of AI education in the pharmacy curriculum and their preferences for AI education; and (iii) students' attitudes towards AI in the pharmacy profession. The secondary objective is the stratification of pharmacy students by factors such as tech-savviness, years of study and previous AI knowledge to examine differences in perceptions among these subgroups.

2 | METHODS

Institutional review board approval for this multinational, multicentre cross-sectional study was obtained from the ethics committee of Charité – University Medicine Berlin (EA4/213/22) following the Declaration of Helsinki and its later amendments. Due to the anonymous study design, informed consent was waived.

2.1 | Survey development and design

We developed an anonymous online Google Forms survey in English language, targeting international pharmacy students to assess their tech-savviness and knowledge of informatics and AI, the current state of AI education and their preferences for AI teaching in the pharmacy curriculum, as well as their attitudes towards AI in the pharmacy profession. Questionnaire items were developed following the AMEE Guide.[22] In December 2022, a systematic literature review was conducted using the MEDLINE, Google Scholar and Scopus databases to identify original peer-reviewed publications of surveys that focus on undergraduate healthcare students' attitudes towards AI in medicine to inform the development of questionnaire items. Studies were included for review based on the following criteria: (i) the survey had to be administered in English only; (ii) the survey items were fully publicly available; (iii) the survey encompassed topics aligning with the objectives of our research; (iv) the survey was specifically designed for undergraduate students actively enrolled in healthcare degree programmes; and (v) The scope of the survey was not limited to any specific sub-discipline. Considering these criteria, 4 publications with a total of 51 items were identified, resulting in 23 items after exclusion of items not consistent with our study objectives or duplicate items.[19,21,23,24] Subsequently, the scope of remaining items was adapted to the pharmacy degree and profession, which were then reviewed by a mixed-focus group of 4 medical AI researchers and students, respectively, resulting in the exclusion of 7, merging of 2 and rephrasing of 14 items. Additionally, 2 new items were constructed to capture preferences in medical AI diagnostics with a focus on the trade-offs between AI explainability and accuracy, as well as between sensitivity and specificity. In the next step, an expert panel of 8 domain experts in medical education, AI research and biomedical statistics validated the content, excluding 1 and rephrasing 6 items, ensuring the adequacy of content domain sampling on a 5-point Likert scale if applicable, clarity and relevance with regard to the study objectives. At this stage, 8 items were added to delineate the demographic composition of the study cohort. A subsequent cognitive interview involving 10 pharmacy students served to pre-assess item clarity, comprehensibility and adequacy of the overall survey length. The feedback culminated in 2 rewordings and 1 item deletion, finalizing the instrument with 14 multiple-choice questions pertinent to the research objectives, supplemented by 8 demographic queries. Pilot testing was performed in a group of 30 pharmacy students from 2 universities (Goethe-University Frankfurt and University of Greifswald, $n = 15$ each) not included in the final participant pool and survey development process.

Pharmacy faculties and student associations were invited by email to distribute the survey among undergraduate pharmacy students via mailing lists or newsletters, using either a QR code or the direct link to the survey website. The survey was open for 2 months, from 05/2023 to 07/2023.

2.2 | Inclusion and exclusion criteria

Eligibility for inclusion required students to be at least 18 years old, actively enrolled in a pharmacy degree programme when completing the survey and proficient in English. Students who did not respond during the survey's open period or were enrolled in nonpharmacy courses were excluded from the analysis. Incomplete answers to individual questions led to exclusion from each subanalysis.

2.3 | Statistical analysis

SPSS Statistics 25 (version 28.0.1.0, IBM, Armonk, NY, USA) and R (version 4.2.1) with the *tidyverse*, *rnaturalearth* and *sf* packages were used for statistical analysis and figure designs.[25–28] Normal distribution was tested using the Kolmogorov–Smirnov test. Frequencies with percentages were reported for categorical and ordinal data. Median and interquartile ranges were reported for nonparametric continuous data. Variances were reported for responses in Likert scale format. In the pilot study group, the reliability of the items was assessed using Cronbach's α. Values >.7 were deemed indicative of acceptable internal consistency. The structure and subscales of the instrument were evaluated using explanatory factor analysis. An Eigenvalue threshold of 1 was the chosen extraction method. Items were retained if they had a factor loading of at least 0.40. The Kaiser–Meyer–Olkin measure of sampling adequacy and Bartlett's test of sphericity were employed to assess the suitability of data for structural delineation. For subgroup analysis, the study population was divided into women and men, study year (above the median current academic year of the study population *vs*. below or equal to the median), tech-savviness (above the median of the number of technical devices used per week by the study population compared to those below or equal to the median, as well as reporting having programmed code compared to those who had not), AI knowledge (rated their AI knowledge as good or expert compared to those who reported little or no knowledge) and previous curricular events on AI in the pharmacy curriculum (reported curricular events on AI in medicine of any duration compared to those who reported no curricular events). The Mann–Whitney *U*-test was used for subgroup analysis. *P*-values below 0.05 were considered significant.

3 | RESULTS

3.1 | Psychometric validation

The median age of the pilot study cohort was 24 years (interquartile range [IQR]: 21–25 years), with the majority being women (60%, $n = 18$). The median current academic year was 4 (IQR: 3–5 years) of 5 total academic years (IQR: 5–5 years). Cronbach's α demonstrated acceptable to good internal consistency among the dimensions of our scale. Acceptable internal consistency was achieved for the sections 'Tech-savviness and knowledge of informatics and AI' (α: .72) and 'Perspectives towards AI in the pharmacy profession' (α: .77). The section 'Current state of AI in the pharmacy curriculum and preferences for AI education' scored an α of .83, indicating good internal consistency. The pilot dataset yielded a Kaiser–Meyer–Olkin measure of sampling adequacy of 0.716, supporting the sample's representativeness. Bartlett's test of sphericity achieved a *P*-value <.001, endorsing the validity of our selected factor analysis approach. Factor analysis resulted in a structure comprising 14 items across 3 dimensions. These factors collectively accounted for 57% of the total variance. Item factor loadings ranged from 0.419 for the item 'As part of my studies, there are curricular events on artificial intelligence (AI) in medicine.' to 0.905 for 'What is your view on the influence of artificial intelligence (AI) on the profession of pharmacists? AI will affect the everyday life of pharmacists in a way that is…'.

3.2 | Descriptive data of the study population

Figure 1 visually represents the number of participants and geographical distribution on transnational maps. Please refer to Appendix S1 to view the number of universities and student associations contacted per country, corresponding response rates, final participants list and any free-field comments.

A total of 489 pharmacy faculties and student associations from 77 countries worldwide were invited to participate, resulting in 387 participants from 16 faculties (overall response rate: 3%) in 12 countries (median response rate per country: 0%, range: 0–100%) who responded to the survey. Most participants studied in European countries (71%, $n = 274$), particularly in Germany (33%, $n = 126$), England (13%, $n = 50$) and Albania (11%, $n = 42$), followed by the United Arab Emirates (26%, $n = 102$), Mexico (2%, $n = 6$) and the USA (1%, $n = 5$). The median age of the participants was 21 years (IQR: 20 to 22 years), and the majority of them were women (70%, $n = 272$). The median current academic year was 3 (IQR: 2 to 4 years) of 5 total academic years (IQR: 4–5 years). Most students had no curricular events on AI in medicine (70%, $n = 270$).

Table 1 presents the study population's descriptive data alongside the responses to questions related to technological savviness and the integration of AI education within the pharmacy curriculum. Figure 2 graphically represents the students' preferences for what aspects of AI they wish to learn about in their pharmacy studies.

3.3 | Views on AI in the pharmacy profession and curriculum

The survey results of all questions on attitudes towards the pharmacy degree, AI in medicine and healthcare, AI in the pharmacy profession and AI education and knowledge can be found in Table 2.

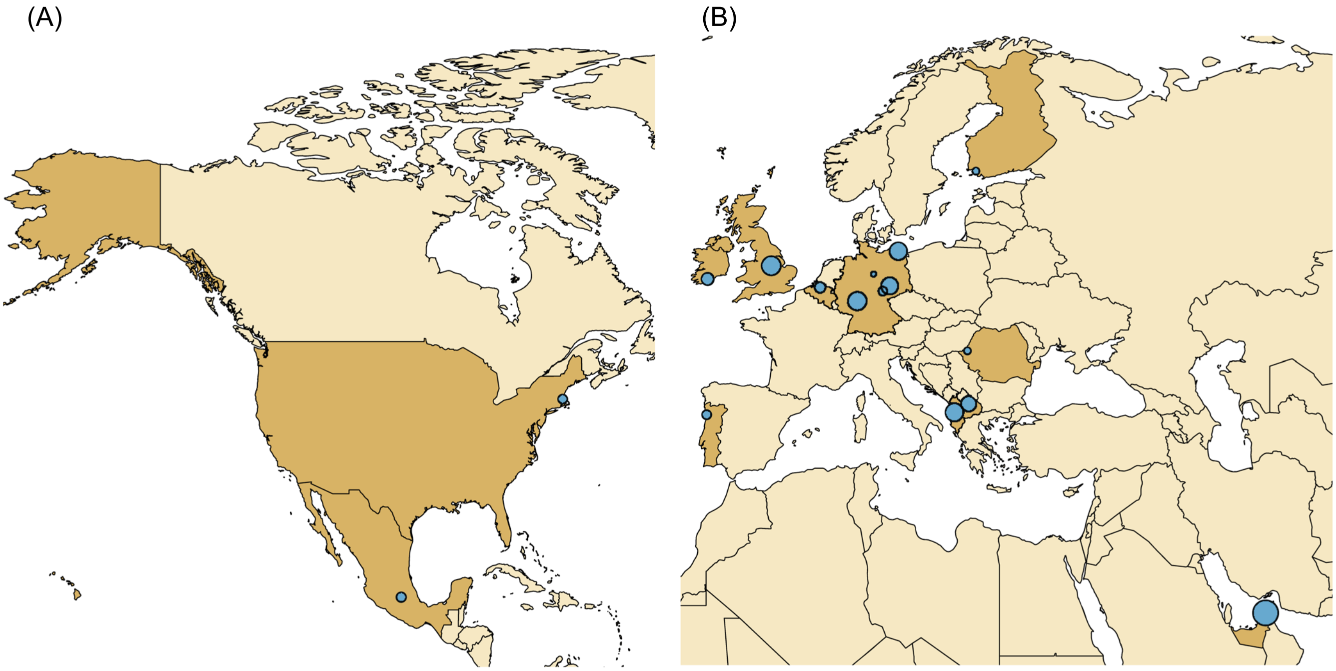

FIGURE 1 Maps showing the geographical distribution of participating pharmacy student faculties (blue dots) in relation to the number of respondents per location: (A) participants in North and Central America; (B) participants in Europe and Asia.

Most of the students had a rather positive attitude (61%, $n = 237$) towards their pharmacy studies, which was similar to the general attitude towards the use of AI in medicine (58%, $n = 225$). The majority reported little general knowledge of AI (63%, $n = 242$), displaying the lowest variance among all responses; however, considering that responses were given on a 4-point Likert-scale ($\sigma^2 = 0.313$). Notably, a high percentage (rather/completely agree: 72%, $n = 276$) agreed that they would like to have more teaching on AI as part of their studies. By contrast, around half of the participants felt they were not sufficiently prepared to work with AI in their future profession as a pharmacist (rather/completely disagree: 51%, $n = 197$), displaying the highest variance of responses among the study population ($\sigma^2 = 1.518$). A large proportion saw the influence of AI on the everyday life of pharmacists as positive (rather/extremely positive: 68%, $n = 261$), and 260 participants (67%) rated the availability of AI software as a second opinion on medical issues as rather or extremely positive. In particular, 237 participants (61%) considered working with AI as a pharmacist as necessary to stay competitive. The highest proportion of positive attitudes towards AI in healthcare was recorded for improving the efficiency of healthcare processes through AI in the next 10 years, with 324 respondents (84%) indicating a rather or extremely positive influence. However, more than half of the respondents (58%, $n = 225$) rather or completely agreed that AI use in medicine would increasingly lead to legal and ethical conflicts.

When considering AI's decision-making ability in medicine (see Figure 3), most students (80%, $n = 310$) favoured explainable AI over a higher accuracy (20%, $n = 76$) as well as a higher sensitivity (59%, $n = 229$) rather than a higher specificity (27%, $n = 105$) or equal sensitivity and specificity (14%, $n = 52$).

3.4 | Comparison of subgroups

P-values of the subgroup analyses, including all significant differences, are shown in Table 2. The full data for each subgroup analysis can be found in Appendix S1. Men showed significantly higher positive attitudes towards the impact of AI on the efficiency of healthcare processes within the next 10 years ($P = .011$) and towards the availability of AI as a second opinion on medical issues ($P = .046$) compared to women respondents. The comparison of years of study also showed significantly higher positive attitudes towards AI improving the efficiency of healthcare processes among respondents who have exceeded the median study year ($P = .016$). However, respondents who exceeded the median study year were also more concerned that AI would increasingly lead to legal and ethical conflicts ($P < .001$). The latter was also expressed by tech-savvy students who exceeded the median technical devices used per week ($P = .025$). Students who have already coded ($P = .023$) or reported higher general knowledge of AI ($P < .001$) felt significantly better prepared to work with AI in their future profession as pharmacists. In addition, students who have programmed code had a significantly higher positive attitude towards their pharmacy studies ($P = .027$) and towards the use of AI in medicine in general ($P < .001$), were more likely to respond that working with AI as a pharmacist is necessary to stay competitive ($P = .004$), indicated that they would like more teaching on AI in their studies ($P = .005$) and felt significantly better prepared to use AI in their future profession ($P < .001$). However, students who have programmed code also expressed greater concerns about the increasing legal and ethical conflicts of using AI in medicine ($P = .008$). Of note, students who reported taking courses on AI in medicine of any

TABLE 1 Descriptive data of the study population and results of the questions about tech-savviness, the current state of artificial intelligence (AI) events in the pharmacy curriculum and topic preferences for AI teaching in the pharmacy curriculum.

Item	Value
Sex (*n* = 387)	*n* (%)
Women	272 (70.3)
Men	109 (28.2)
Diverse	2 (0.5)
Prefer not to disclose	4 (1.0)
Age (*n* = 387)	Years, median (IQR) 21 (20–22)
Current academic year (*n* = 355)	Years, median (IQR) 3 (2–4) *n* (%)
≤3 academic years	231 (65.1)
>3 academic years	124 (34.9)
Total academic years (*n* = 383)	Years, median (IQR) 5 (4–5)
Tech-savviness	
Which of these technical devices do you use at least once a week? (*n* = 387)	*n*, median (IQR) 3 (2–3) *n* (%)
Smartphone	358 (92.5)
PC/laptop	325 (84.0)
Game console (e.g., PlayStation, Switch)	43 (11.1)
Tablet (e.g., iPad)	144 (37.2)
E-reader	24 (6.2)
Smartwatch	103 (26.6)
None	1 (0.3)
Have you already programmed code? (*n* = 386)	*n* (%)
Yes	52 (13.5)
C	3 (0.8)
C++	13 (3.4)
C#	1 (0.3)
CSS	3 (0.8)
Dart	1 (0.3)
Delphi	2 (0.5)
HTML	6 (1.6)
Java	12 (3.1)
JavaScript	4 (1.0)
Lazarus	1 (0.3)
Python	19 (4.9)
R	1 (0.3)
SQL	1 (0.3)
TeX	1 (0.3)
No	334 (86.5)
AI teaching in the pharmacy curriculum	
As part of my studies, there are curricular events on AI in medicine. (*n* = 387)	*n* (%)
No	270 (69.8)
Yes; 1–5 h in total	68 (17.6)
Yes; >5–10 h in total	20 (5.2)

(Continues)

TABLE 1 (Continued)

Item	Value
Yes; >10–20 h in total	10 (2.6)
Yes; >20 h in total	19 (4.9)
What would you like to learn about AI as part of your pharmacy curriculum? ($n = 387$)	n (%)
Theory and background (e.g., mathematical basics)	118 (30.5)
Practical skills (e.g., learning programming languages; solving medical problems with AI)	245 (63.3)
History and development	52 (13.4)
Legal and ethical aspects	196 (50.7)
Future perspectives of AI in medicine	272 (70.3)
No preference	19 (4.9)
None	8 (2.1)

Abbreviation: IQR, interquartile range.

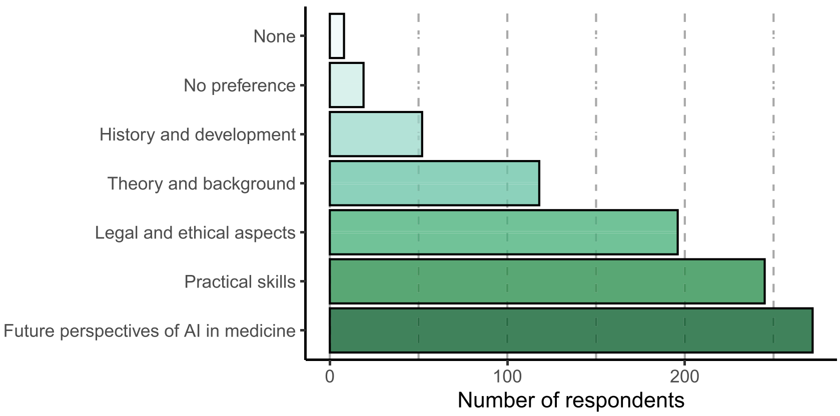

FIGURE 2 Bar chart illustrating pharmacy students' preferences for artificial intelligence (AI) teaching within the pharmacy curriculum: none ($n = 8$, 2%), no preference ($n = 19$, 5%), history and development ($n = 52$, 13%), theory and background ($n = 118$, 30%), legal and ethical aspects ($n = 196$, 51%), practical skills ($n = 245$, 63%) and future perspectives of AI in medicine ($n = 272$, 70%).

duration reported significantly higher general knowledge of AI ($P < .001$) and felt better prepared to work with AI in their future profession as pharmacists ($P < .001$) than those who had not.

4 | DISCUSSION

This study presents the first comprehensive multinational, multicentre survey on international pharmacy students' perspectives towards the integration of AI into pharmacy education and practice. Most respondents reflected a positive attitude towards the use of AI in medicine, despite their self-reported lack of comprehensive AI knowledge, and expressed a keen interest in AI education within their degree. Furthermore, the majority of students recognized the potential impact of AI on pharmacists' daily operations positively, viewing it as an enhancer of healthcare process efficiency. By contrast, around half of the respondents felt ill-prepared to work with AI in their future profession and voiced concerns regarding emerging ethical and legal issues. Notably, students who reported having AI courses as part of their curriculum had subjectively greater overall AI knowledge and felt better equipped to use AI in future pharmacy practice than their peers.

The recognized deficiency in AI knowledge among healthcare professionals is a global phenomenon.[29–33] As an example, a study by Scheetz *et al.* involving dermatologists, radiologists and ophthalmologists from Australia and New Zealand demonstrated that 53% ($n = 342$ out of $n = 632$) of the respondents considered their AI knowledge as average or poor.[29] This concurs with a separate survey by Polesie *et al.*, which showed that only 19% ($n = 135$ out of $n = 718$) of pathologists surveyed among 91 countries reported a good knowledge of AI.[30] Our findings mirror these results, revealing a substantial knowledge deficit about AI among pharmacy students. However, this lack of knowledge is not exclusive to pharmacy students, as other studies have shown that 50–69% of medical students also indicate a limited understanding of AI.[20,21,34]

Our data also indicate that the majority of pharmacy students would like more AI teaching as part of their degree while also reporting that they did not have any AI curricular events. These findings are analogous to a 2023 study conducted by Syed *et al.*, where 80% ($n = 136$ out of $n = 157$) of senior pharmacy students in Saudi Arabia disclosed that they had not received any formal AI training.[35] However, it is crucial to consider the variations in pharmaceutical curriculum systems and geographical and socioeconomic contexts when comparing these results. For instance, in our study, a significant majority of participants were studying in European countries. These differing backgrounds may influence exposure to and understanding of AI in the respective educational systems. However, the preference for AI

TABLE 2 Survey results of the questions on perceptions towards the pharmacy degree, artificial intelligence (AI) in medicine and healthcare, AI in the pharmacy profession and AI education and knowledge, and *P*-values for subgroup comparison.

Item	Completely disagree/ extremely negative/ great deterioration *n* (%)	Rather disagree/rather negative/moderate deterioration *n* (%)	Neutral/no effect *n* (%)	Rather agree/rather positive/moderate improvement *n* (%)	Completely agree/ extremely positive/great improvement *n* (%)
Attitude towards pharmacy studies					
What is your current general attitude towards your pharmacy studies? ($n = 387$)	1 (0.3)	21 (5.4)	96 (24.8)	237 (61.2)	32 (8.3)
AI in medicine and healthcare					
What is your general attitude towards the application of AI in medicine? ($n = 386$)	6 (1.6)	31 (8.0)	91 (23.6)	225 (58.3)	33 (8.6)
How do you estimate the effect of AI on the efficiency of healthcare processes in the next 10 years? ($n = 386$)	11 (2.9)	27 (7.0)	24 (6.2)	221 (57.3)	103 (26.7)
The use of AI in medicine will increasingly lead to legal and ethical conflicts. ($n = 386$)	15 (3.9)	61 (15.8)	85 (22.0)	125 (32.4)	100 (25.9)
AI in the pharmacy profession					
What is your view on the influence of AI on the profession of pharmacists? AI will affect the everyday life of pharmacists in a way that is … ($n = 386$)	3 (0.8)	33 (8.6)	89 (23.1)	216 (56.0)	45 (11.7)
How would you rate AI software being available to pharmacists as a second opinion on medical issues? ($n = 386$)	10 (2.6)	27 (7.0)	89 (23.1)	188 (48.7)	72 (18.7)
I think working with AI as a pharmacist is necessary to stay competitive. ($n = 386$)	11 (2.9)	46 (11.9)	92 (23.8)	173 (44.8)	64 (16.6)
AI education and knowledge level					
I would like to have more teaching on AI in medicine as part of my studies. ($n = 386$)	7 (1.8)	24 (6.2)	79 (20.5)	187 (48.5)	89 (23.1)
With my current knowledge, I feel sufficiently prepared to work with AI in my future profession as a pharmacist. ($n = 386$)	61 (15.8)	136 (35.2)	82 (21.2)	64 (16.6)	43 (11.1)

(Continues)

TABLE 2 (Continued)

Item	Completely disagree/ extremely negative/ great deterioration *n* (%)	Rather disagree/rather negative/moderate deterioration *n* (%)	Neutral/no effect *n* (%)	Rather agree/rather positive/moderate improvement *n* (%)	Completely agree/ extremely positive/great improvement *n* (%)
How would you rate your general knowledge of AI? (*n* = 387)	**No knowledge (never heard of AI)**	**Little knowledge (e.g., documentary seen on TV)**	**Good knowledge (e.g., read several journal articles on AI)**	**Expert (e.g., involved in AI research/development)**	
	10 (2.6)	242 (62.5)	128 (33.1)	7 (1.8)	-

The Mann–Whitney *U*-test was used to compare the subgroups. Significant *P*-values of <.05 are marked in bold. Full data for each subgroup analysis can be found in Appendix S1.

[a]Significant *P*-values in this column display higher Likert scale scores by male respondents.

[b]Study year compares pharmacy students exceeding the median current academic year of 3 years of the study population *vs.* those below or equal to the median. Significant *P*-values in this column display higher Likert scale scores by respondents exceeding the median current academic year.

[c]Compares pharmacy students exceeding the median number of 3 technical devices used per week of the study population *vs.* those below or equal to the median. A significant *P*-value in this column displays a higher Likert scale score by respondents exceeding the median devices used per week.

[d]Compares pharmacy students who have already programmed code *vs.* those who have not. A significant *P*-value in this column displays a higher Likert scale score by respondents who have already programmed code.

[e]Compares pharmacy students who rated their AI knowledge as good or expert *vs.* those who indicated little or no knowledge. Significant *P*-values in this column display higher Likert scale scores by respondents who rated their AI knowledge as good or expert.

[f]Compares pharmacy students who reported curricular events on AI in medicine of any duration *vs.* those who indicated no curricular events. Significant *P*-values in this column display higher Likert scale scores by respondents who reported curricular events on AI in medicine.

TABLE 2 (Continued)

Item	Variance	*P*-value *Women vs. Men*[a]	*P*-value *Study year*[b]	*P*-value *Tech-savviness*	*P*-value *AI knowledge*[e]	*P*-value *AI in pharmacy curriculum*[f]
Attitude towards pharmacy studies						
What is your current general attitude towards your pharmacy studies? (*n* = 387)	0.492	.353	.299	.674[c]/.467[d]	**.027**	.567
AI in medicine and healthcare						
What is your general attitude towards the application of AI in medicine? (*n* = 386)	0.655	.058	.747	.782[c]/.116[d]	**<.001**	.293
How do you estimate the effect of AI on the efficiency of healthcare processes in the next 10 years? (*n* = 386)	0.865	**.011**	**.016**	.179[c]/.133[d]	.086	.297
The use of AI in medicine will increasingly lead to legal and ethical conflicts. (*n* = 386)	1.306	.601	**<.001**	**.025**[c]/.360[d]	**.008**	.185
AI in the pharmacy profession						
What is your view on the influence of AI on the profession of pharmacists? AI will affect the everyday life of pharmacists in a way that is ... (*n* = 386)	0.664	.074	.541	.710[c]/.318[d]	.085	.564
How would you rate AI software being available to pharmacists as a second opinion on medical issues? (*n* = 386)	0.862	**.046**	.983	.881[c]/.917[d]	.198	.529

TABLE 2 (Continued)

Item	Variance	*P*-value *Women vs. Men*[a]	*P*-value *Study year*[b]	*P*-value *Tech-savviness*	*P*-value *AI knowledge*[e]	*P*-value *AI in pharmacy curriculum*[f]
I think working with AI as a pharmacist is necessary to stay competitive. ($n = 386$)	0.980	.260	.342	.828[c]/.731[d]	**.004**	.137
AI education and knowledge level						
I would like to have more teaching on AI in medicine as part of my studies. ($n = 386$)	0.824	.515	.216	.104[c]/.393[d]	**.005**	.243
With my current knowledge, I feel sufficiently prepared to work with AI in my future profession as a pharmacist. ($n = 386$)	1.518	.322	.081	.716[c]/**.023**[d]	**<.001**	**<.001**
How would you rate your general knowledge of AI? ($n = 387$)	0.313	.210	.595	.807[c]/.620[d]	-	**<.001**

The Mann–Whitney *U*-test was used to compare the subgroups. Significant *P*-values of <.05 are marked in bold. Full data for each subgroup analysis can be found in Appendix S1.

[a]Significant *P*-values in this column display higher Likert scale scores by male respondents.

[b]Study year compares pharmacy students exceeding the median current academic year of 3 years of the study population *vs.* those below or equal to the median. Significant *P*-values in this column display higher Likert scale scores by respondents exceeding the median current academic year.

[c]Compares pharmacy students exceeding the median number of 3 technical devices used per week of the study population *vs.* those below or equal to the median. A significant *P*-value in this column displays a higher Likert scale score by respondents exceeding the median devices used per week.

[d]Compares pharmacy students who have already programmed code *vs.* those who have not. A significant *P*-value in this column displays a higher Likert scale score by respondents who have already programmed code.

[e]Compares pharmacy students who rated their AI knowledge as good or expert *vs.* those who indicated little or no knowledge. Significant *P*-values in this column display higher Likert scale scores by respondents who rated their AI knowledge as good or expert.

[f]Compares pharmacy students who reported curricular events on AI in medicine of any duration *vs.* those who indicated no curricular events. Significant *P*-values in this column display higher Likert scale scores by respondents who reported curricular events on AI in medicine.

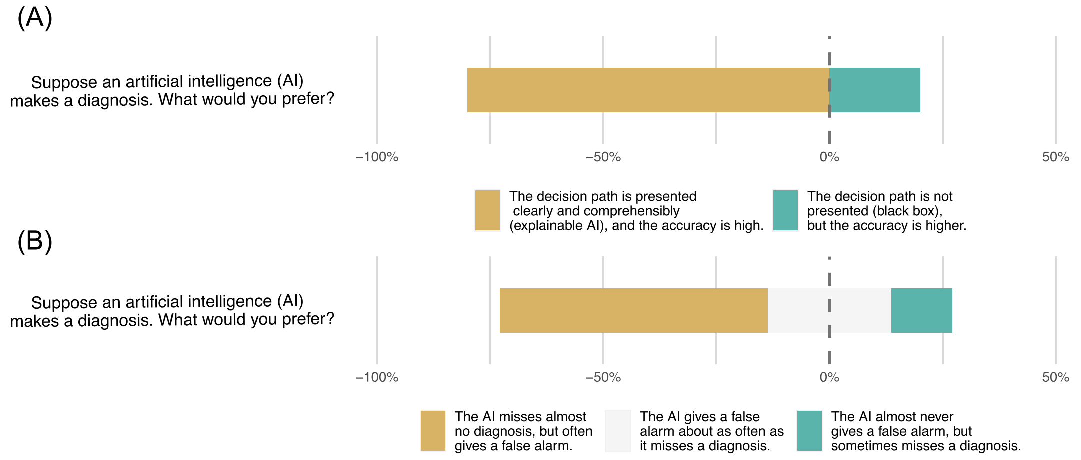

FIGURE 3 Gantt diagrams depicting pharmacy students' preferences in artificial intelligence (AI) diagnostics: (A) AI explainability ($n = 310$, 80%) *vs.* higher accuracy ($n = 76$, 20%) and (B) higher sensitivity ($n = 229$, 59%) *vs.* higher specificity ($n = 105$, 27%) or equal sensitivity and specificity ($n = 52$, 13%).

education observed in the present study is also in line with prior studies among medical and dental students, where 71–85% of the respondents indicated a positive attitude towards AI teaching.[19–21,36–38] Of particular interest, a comprehensive 2021 study by Bisdas *et al.* showed the highest agreement towards the implementation of AI education, with 85% ($n = 2683$ of $n = 3133$) of medical and dental students from 63 countries expressing support for AI teaching, underscoring the widespread demand for including AI-related content in different healthcare curricula.[19]

We found a predominantly positive attitude of pharmacy students towards AI's use in healthcare. This is similar to findings from studies that investigated attitudes towards the impact of AI in healthcare among pharmacy students in Saudi Arabia and others involving medical and dental students, with 69–90% of the participants indicating positive attitudes, suggesting a shared optimism about AI's potential impact across different healthcare fields.[19,23,24,35,39] Moreover, our results show that most pharmacy students view AI's influence on a pharmacist's daily life positively and favour AI software for second opinions on medical issues. This aligns with previous studies among physicians and medical students, which reported positive views ranging from 62 to 83% on AI's diagnostic accuracy and treatment capabilities.[40–42]

Despite these positive views, around half of the pharmacy students in our study felt inadequately prepared to work with AI in their future profession while reporting concerns about increasing legal and ethical issues related to AI usage in medicine. Similar findings were observed for medical students: for instance, Sit *et al.* found that 90% ($n = 434$ out of $n = 484$) of medical students in the UK felt unprepared to work with AI upon completion of their degree.[21] Similarly, Mehta *et al.* noted that a vast majority (95%, $n = 275$ out of $n = 288$) of Canadian medical students surveyed believe AI would introduce new ethical and social challenges.[37] By comparison, a smaller proportion of pharmacy students in our study expressed feelings of inadequate preparation to work with AI or raised concerns about the increased ethical and legal issues associated with AI use. This may suggest that pharmacy students are less apprehensive about the role of AI in their future careers. Regardless, the collective findings underscore the necessity of integrating AI training into pharmacy and healthcare curricula to better equip healthcare students to use AI in their future professions. Moreover, they emphasize the importance of ongoing ethical discussions and policy and regulatory developments to ensure the responsible and ethical implementation of AI in healthcare.[14,15] These considerations are crucial across all medical subspecialties, where professionals are tasked with ensuring patient safety, confidentiality and adherence to biomedical ethical standards.

In terms of subgroup comparison, we could show that male respondents have significantly higher positive attitudes towards AI's potential impact on healthcare efficiency and the availability of AI for second opinions on medical issues. These findings are consistent with a study by Pinto dos Santos *et al.* among 263 medical students from 3 German universities, where male respondents were more confident about the benefits of AI and less fearful of AI technologies ($P < .001$, respectively).[20] Pinto dos Santos *et al.* also observed similar patterns among participants classified as tech-savvy ($P < .001$), further solidifying the role of technological proficiency in shaping attitudes towards AI. Furthermore, Bisdas *et al.* noted a higher propensity towards AI education in the curriculum among tech-savvy medical and dental students ($P < .001$), suggesting that technological literacy could potentially influence students' attitudes towards AI education.[19] Interestingly, our study did not uncover a significant relationship between the level of tech-savviness and the participants' understanding or perception of AI. This warrants a cautious interpretation of these results, given the varying definitions of tech-savviness across different studies. In our study, we objectively classified participants as tech-savvy if they used more than the median number of 3 technical devices per week or had prior coding experience. In contrast, studies by Pinto dos Santos *et al.* and Bisdas *et al.* considered respondents as tech-savvy if they self-identified as such.[19,20] This discrepancy in classification necessitates a nuanced understanding of the influence of tech-savviness on AI-related attitudes and knowledge.

Finally, our study revealed a strong preference among students for AI explainability. This inclination aligns with the escalating acknowledgement of explainable AI's importance in healthcare and underscores the need for developers to focus on creating AI systems that are not just accurate but also transparent in their decision-making processes. In this context, transparency and interpretability are key to building trust and acceptance among healthcare professionals.[43,44]

While this study offers valuable insights, it does have certain limitations. Firstly, the cross-sectional design of the study captures a specific point in time and does not allow for the determination of causality between variables. Future studies might consider adopting longitudinal or qualitative designs to provide more depth and continuity of information. Secondly, the study sample includes participants from 16 faculties across 12 countries. Despite efforts to achieve a diverse representation of geographical and socioeconomic contexts, the results may not fully generalize to all pharmacy students, particularly non-English speakers and students in countries without participating institutions. In addition, the voluntary survey participation, the digital format and the disparate sizes of student populations at participating universities contributed to an imbalance in country representation. Moreover, due to a lack of data on the population of pharmacy students at each institution, we could not determine response rates in relation to the absolute student population. The study may also suffer from selection bias, as those with a strong interest in AI might have been more likely to participate, leading to potentially skewed results. Consequently, extrapolating these findings to broader or different populations should be done with caution. Finally, this study was primarily focused on the perspective of pharmacy students. This approach could potentially overlook valuable insights from other key stakeholders in the pharmacy field, such as faculty members, practising pharmacists and patients. Future research should aim to incorporate these additional perspectives to gain a more holistic understanding of attitudes towards AI in pharmacy practice and education.

In conclusion, this initial cross-sectional analysis provides valuable insights into pharmacy students' views towards AI in medicine, highlighting several factors that may influence these attitudes. Despite the focus on pharmacy students, the consistency of our findings with those from studies involving clinicians and medical and dental students suggests a shared understanding among healthcare professionals and students about the importance of AI in healthcare and its integration into healthcare education. These findings could be instrumental in shaping educational strategies that foster positive attitudes towards AI, potentially facilitating the adoption and effective use of AI in pharmacy practice. Nonetheless, additional research is needed to validate these findings and investigate the underlying causal mechanisms of the observed associations.

AUTHOR CONTRIBUTIONS

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CONFLICT OF INTEREST STATEMENT

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DATA AVAILABILITY STATEMENT

All anonymous data generated and analysed in this manuscript, including survey questions and responses, are openly available at: Busch F, Hoffmann L, Truhn D, *et al*. Dataset: International Pharmacy Students' Perceptions Towards Artificial Intelligence in Medicine - A Multinational, Multicentre Cross-Sectional Study. *figshare*. 2023. doi:10.6084/m9.figshare.23713248.v1.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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