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Artificial intelligence literacy and ethical awareness among pharmacy students and associated factors: a cross-sectional study

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ABSTRACT: This study aimed to determine the levels of artificial intelligence (AI) literacy and ethics among undergraduate pharmacy students and identify key sociodemographic and educational factors. A cross-sectional online survey was conducted among 324 volunteer students at the Faculty of Pharmacy, Ege University. The questionnaire included sociodemographic items, the Artificial Intelligence Literacy Scale, and the Artificial Intelligence Ethics Scale. Descriptive and inferential statistics and multiple linear regressions were used. Male students had higher total AI literacy scores than female students (31.79 ± 5.02 vs. 30.00 ± 4.75; $p = 0.002$; Cohen's d = 0.370). Students with prior AI/programming education also had higher AI literacy scores (32.65 ± 5.22 vs. 30.35 ± 4.81; $p = 0.005$; Cohen's d = 0.473). Higher self-reported technology-use skill levels were associated with higher AI literacy. AI literacy and AI ethics were positively but weakly correlated ($r = 0.199$; 95% CI: 0.092–0.301; $p < 0.001$). In the regression model, only conscious AI use significantly predicted the AI ethics scores ($B = 0.554$; 95% CI: 0.172–0.936; $p = 0.005$). These findings suggest that AI literacy and ethics should be addressed as complementary educational outcomes in the curriculum. Integrating AI literacy with ethical reasoning, transparency, accountability, data privacy, and patient-centered decision-making may better prepare future pharmacists for responsible AI use.

KEYWORDS: Artificial intelligence literacy; artificial intelligence ethics; pharmacy students; pharmacy education; pharmacy practice; social pharmacy; digital literacy.

1. INTRODUCTION

Artificial intelligence (AI) is increasingly used in pharmacy for drug discovery, inventory management, automated and robotic dispensing, clinical prescription review, drug interaction identification, and pharmacovigilance [1-4]. Consequently, AI technologies are becoming increasingly relevant to pharmacy practices.

In healthcare, safety and reliability are fundamental requirements for AI models to be used. Therefore, pharmacists must not only operate AI-based tools but also understand their underlying logic, data requirements, limitations, and potential error sources. Equally important is the ability to critically appraise AI outputs, relate them to professional decision-making, and recognize their ethical and legal implications. Therefore, awareness of autonomy, informed consent, patient privacy, data security, justice, accountability, transparency, and algorithmic bias should be considered essential components of pharmacy education [5-7].

Artificial intelligence is expected to transform pharmacy practice and the competencies required of future pharmacists. International organizations and healthcare educators increasingly emphasize that healthcare professionals should possess both technical AI literacy and ethical awareness to ensure the safe, transparent, accountable, and patient-centered use of AI technology in healthcare. Consequently, pharmacy education programs are facing growing pressure to incorporate AI-related competencies into undergraduate curricula and prepare students for technology-enhanced health care.

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Recent studies of pharmacy students suggest that they generally view AI as potentially useful for professional practice, decision-making, error reduction, and efficiency; however, they often do not consider themselves sufficiently competent in AI knowledge, ethical awareness, or practical application. A multinational study in the MENA region also reported substantial concerns regarding patient data confidentiality, cybersecurity threats, potential job loss, legal uncertainty, and limited access to AI tools [8-10].

Although the literature has described pharmacy students' general attitudes towards AI, studies that simultaneously examine AI literacy and ethics, including their relationships and associated factors, remain limited [11-13]. This is an important gap because technical familiarity with AI does not necessarily imply ethical sensitivity in its use. Socioeconomic conditions, access to technology, formal instruction, class level, and technology-use skills may also shape students' opportunities to engage with AI and develop ethical awareness in the future. To the best of our knowledge, no previous study conducted in Türkiye has simultaneously evaluated AI literacy and ethics among pharmacy students and examined their relationship with associated sociodemographic and educational factors. Therefore, this study aimed to determine the current levels of AI literacy and ethics among undergraduate pharmacy students, examine the sociodemographic and educational factors associated with these levels, and propose strategies for improving pharmacy curricula.

2. RESULTS

Among the 324 participants, most were between 18 and 24 years of age (94.8%); 64.5% were female, and 35.5% were male. Participation was highest among fourth-(32.1%) and fifth-year (26.5%) students. Most students reported being from middle-income households (37.0%). More than half reported 4-6 hours of daily Internet/computer technology use (50.9%). Only 12.3% of the respondents had received prior formal education in computer programming or AI applications (Table 1).

Table 1. Demographic characteristics of the participants (N = 324).

Variables	Group	n	Percentage (%)
Age	18-24	307	94.8
	25-31	14	4.3
	32 and above	3	0.9
Gender	Female	209	64.5
	Male	115	35.5
Class	1st year	29	9.0
	2nd year	22	6.8
	3rd year	83	25.6
	4th year	104	32.1
	5th year	86	26.5
Monthly income level	Very low (minimum wage and below)	22	6.8
	Low (2x minimum wage)	54	16.7
	Moderate (3x minimum wage)	120	37.0
	Upper-middle (4x minimum wage)	64	19.8
	High (5 minimum wage and above)	64	19.8
Daily internet use duration	1-3 hours	22	6.8
	4-6 hours	165	50.9
	7-9 hours	109	33.6
	10-12 hours	17	5.2
	13 and above	11	3.4
Technology tools use skill level	Poor	9	2.8
	Moderate	127	39.2

Variables	Group	n	Percentage (%)
	Good	164	50.6
	Very good (advanced)	24	7.4
Formal education status	Yes	40	12.3
	No	284	87.7

Table 2 presents the internal consistency estimates of the instruments in the current sample. The AI literacy and ethics scales demonstrated acceptable-to-good reliability (Cronbach's alphas = 0.814 and 0.803, respectively).

Table 2. Reliability and descriptive estimates of the study scales.

Scale	Number of Items	Cronbach's α	Mean ± SD (95% CI)
AI competence in pharmacy	5	0.750	16.41 ± 3.22 (16.06-16.76)
Conscious AI use	4	0.638	14.23 ± 2.20 (13.98-14.47)
AI literacy total	9	0.814	30.64 ± 4.91 (30.10-31.17)
Bias	3	0.618	9.34 ± 2.25 (9.09-9.59)
Transparency	3	0.702	10.94 ± 1.80 (10.74-11.13)
Accountability	3	0.624	8.31 ± 2.16 (8.07-8.54)
Data privacy	3	0.840	8.18 ± 2.31 (7.92-8.43)
AI ethics total	12	0.803	36.76 ± 6.09 (36.09-37.42)

CI: confidence interval; SD: standard deviation.

According to the independent samples t-test, male students scored significantly higher than female students in AI competence in pharmacy, conscious use of AI, and AI literacy. The effect size was small for AI competence in pharmacy (Cohen d = 0.243), small-to-moderate for total AI literacy (Cohen d = 0.370), and moderate for conscious AI use (Cohen d = 0.471). The total AI ethics scores did not differ significantly by gender (Table 3).

Table 3. Artificial intelligence literacy and ethical awareness scores according to participants' gender.

Scale	Female Mean ± SD (n=209)	Male Mean ± SD (n=115)	t	p	Cohen's d	Mean Difference (95% CI)
AI competence in pharmacy	16.13 ± 3.10	16.91 ± 3.39	-2.094	0.037	0.243	0.78 (0.03-1.53)
Conscious AI use	13.87 ± 2.14	14.88 ± 2.16	-4.058	<0.001	0.471	1.01 (0.52-1.50)
AI literacy total	30.00 ± 4.75	31.79 ± 5.02	-3.184	0.002	0.370	1.79 (0.66-2.92)
Bias	9.22 ± 2.11	9.55 ± 2.49	-1.235	0.218	0.143	0.32 (-0.22-0.86)
Transparency	10.96 ± 1.63	10.89 ± 2.08	0.357	0.721	-0.041	-0.07 (-0.52-0.37)
Accountability	8.33 ± 2.12	8.28 ± 2.24	0.188	0.851	-0.022	-0.05 (-0.55-0.46)
Data privacy	8.20 ± 2.21	8.13 ± 2.50	0.262	0.793	-0.030	-0.07 (-0.62-0.48)
AI ethics total	36.71 ± 5.58	36.84 ± 6.94	-0.184	0.854	0.021	0.13 (-1.36-1.62)

Cohen's d is positive when male students scored higher than female students.

Students who received formal AI/programming education had significantly higher pharmacy AI competence and total AI literacy scores than those who did not. The observed effect sizes were small to moderate in magnitude. No significant differences were observed in the total AI ethics score or its sub-dimensions (Table 4).

Table 4. Artificial intelligence literacy and ethical awareness scores according to formal education status.

Scale	Yes Mean ± SD (n=40)	No Mean ± SD (n=284)	t	p	Cohen's d	Mean Difference (95% CI)
AI competence in pharmacy	17.95 ± 3.23	16.19 ± 3.16	3.277	0.001	0.553	1.76 (0.66-2.85)
Conscious AI use	14.70 ± 2.41	14.16 ± 2.16	1.460	0.145	0.247	0.54 (-0.27-1.35)
AI literacy total	32.65 ± 5.22	30.35 ± 4.81	2.799	0.005	0.473	2.30 (0.54-4.05)
Bias	9.07 ± 2.49	9.38 ± 2.22	-0.792	0.429	-0.134	-0.30 (-1.14-0.53)
Transparency	10.75 ± 2.13	10.96 ± 1.75	-0.695	0.488	-0.117	-0.21 (-0.92-0.50)
Accountability	8.18 ± 2.52	8.33 ± 2.11	-0.418	0.676	-0.071	-0.15 (-0.99-0.69)
Data privacy	7.95 ± 2.80	8.21 ± 2.24	-0.659	0.510	-0.111	-0.26 (-1.19-0.67)
AI ethics total	35.95 ± 7.71	36.87 ± 5.83	-0.898	0.370	-0.152	-0.92 (-3.47-1.63)

Cohen's d is positive when students with formal education scored higher than those without formal education.

Kruskal-Wallis H tests showed no statistically significant differences in total AI literacy or total AI ethics according to age group, class level, monthly income, or daily internet use. The technology-use skill level was significantly associated with total AI literacy, with a small-to-moderate effect size (eta squared = 0.101), but not with total AI ethics (Table 5).

Table 5. Kruskal-Wallis summary for total AI literacy and total AI ethics scores.

Variable	Outcome Variable	H Statistic	df	p	η^2H
Age group	AI literacy total	3.271	2	0.195	0.004
Age group	AI ethics total	0.890	2	0.641	<0.001
Class	AI literacy total	6.435	4	0.169	0.008
Class	AI ethics total	0.490	4	0.974	<0.001
Monthly income	AI literacy total	3.755	4	0.440	<0.001
Monthly income	AI ethics total	6.070	4	0.194	0.006
Daily internet use	AI literacy total	2.994	4	0.559	<0.001
Daily internet use	AI ethics total	4.845	4	0.304	0.003
Technology-use skill	AI literacy total	35.292	3	<0.001	0.101
Technology-use skill	AI ethics total	1.850	3	0.604	<0.001

η^2H = Eta squared effect size based on the Kruskal-Wallis H statistic.

When the technology-use skill level was examined in more detail, AI competence in pharmacy, conscious AI use, and total AI literacy increased with higher self-reported technology-use skill categories. The highest mean scores were observed among students who described their technology-use skills as very good (Table 6).

Table 6. Technology-use skill level and selected artificial intelligence outcomes.

Outcome Variable	Poor (n=9) Mean ± SD	Moderate (n=127) Mean ± SD	Good (n=164) Mean ± SD	Very Good (n=24) Mean ± SD	H Statistic	p	η^2H
AI competence in pharmacy	13.56 ± 3.21	15.82 ± 2.99	16.62 ± 3.14	19.21 ± 3.12	26.119	<0.001	0.072
Conscious AI use	12.78 ± 2.59	13.50 ± 2.07	14.60 ± 1.94	16.04 ± 2.69	37.881	<0.001	0.109
AI literacy total	26.33 ± 5.22	29.31 ± 4.53	31.22 ± 4.53	35.25 ± 5.51	35.292	<0.001	0.101
AI ethics total	38.44 ± 4.39	36.81 ± 5.67	36.75 ± 6.10	35.92 ± 8.48	1.850	0.604	0.000

Values are mean ± SD.

Pearson's correlation analysis showed a weak, positive, and statistically significant correlation between total AI literacy and total AI ethics scores ($r = 0.199$; 95% CI: 0.092-0.301; $p < 0.001$). This indicates that AI literacy and ethics are related but are distinct constructs.

The confidence intervals and effect sizes are presented in Table 7.

Table 7. Correlations between artificial intelligence literacy and ethics.

Variable 1	Variable 2	Pearson r	95% CI	p
AI literacy total	AI ethics total	0.199	0.092-0.301	<0.001
AI competence in pharmacy	AI ethics total	0.155	0.046-0.259	0.005
Conscious AI use	AI ethics total	0.218	0.112-0.320	<0.001
AI literacy total	Bias	0.133	0.024-0.238	0.017
AI literacy total	Transparency	0.136	0.028-0.242	0.014
AI literacy total	Accountability	0.110	0.001-0.217	0.048
AI literacy total	Data privacy	0.186	0.078-0.289	<0.001

Pearson correlation analysis. CI: confidence interval.

Multiple linear regression was performed to examine the effects of the AI literacy subdimensions on total AI ethics. The model was statistically significant ($F(2,321) = 8.105$, $p < 0.001$) and explained a small proportion of the variance in AI ethics scores ($R^2 = 0.048$; adjusted $R^2 = 0.042$). Among the predictors, only conscious AI use showed a significant positive association with total AI ethics ($B = 0.554$; 95% CI: 0.172-0.936; $p = 0.005$). (Table 8).

Table 8. Multiple linear regression analysis predicting the total artificial intelligence ethics score.

Predictor	B	SE	Standardized β	t	p	95% CI for B	VIF
Constant	27.993	2.213		12.649	<0.001	23.639-32.347	
AI competence in pharmacy	0.054	0.133	0.028	0.404	0.686	-0.207-0.314	1.659
Conscious AI use	0.554	0.194	0.200	2.855	0.005	0.172-0.936	1.659

Dependent variable: Total AI Ethics Score. Model statistics: $F(2,321) = 8.105$; $p < 0.001$; $R^2 = 0.048$; adjusted $R^2 = 0.042$; Durbin-Watson = 1.791.

3. DISCUSSION

This study investigated AI literacy, AI ethics, and their associated factors among undergraduate pharmacy students in Türkiye. The findings indicate that AI literacy and ethics are measurable and related constructs; however, their relationship is weak and should not be overstated. This supports the perspective that technical knowledge and ethical awareness should be addressed as complementary, yet distinct, educational outcomes [15].

Male students achieved significantly higher AI literacy scores than female students, whereas AI ethics scores did not differ significantly by gender. The effect size for total AI literacy was small to moderate, indicating some practical relevance but not a substantial gender-based difference in AI literacy. These results may reflect differences in confidence, prior exposure, or self-reported technology engagement, rather than inherent ability [16,17].

The technology-use skill level was a clear correlate of AI literacy. Students who rated their technology-use skills as very good obtained higher scores for AI competence, conscious AI use, and AI literacy. The effect size for the total AI literacy was small to moderate. In contrast, the technology-use skill level was not significantly associated with the total AI ethics score. This suggests that greater technical familiarity does not necessarily result in stronger ethical awareness [18-20].

Formal AI or programming education was associated with higher AI competence and total AI literacy scores, supporting the value of structured educational exposure to AI in pharmacy education. However, formal education was not associated with higher AI ethics score. This indicates that technically oriented instruction alone may be insufficient unless ethical reasoning, data privacy, accountability, transparency, bias, and patient-centered decision-making are explicitly incorporated into the curriculum [21,22].

The weak but statistically significant correlation between total AI literacy and total AI ethics ($r = 0.199$) indicates a limited positive relationship between the two. These findings require careful interpretation. While AI literacy may contribute to ethical awareness, ethical perspectives are also influenced by broader factors such as professional values, moral reasoning, institutional culture, prior experiences, and perceived responsibilities in patient-care settings.

The regression model accounted for only a small proportion of the variance in the AI ethics scores (adjusted $R^2 = 0.042$). This limited explanatory power is expected, given that AI ethics is a multi-dimensional construct. The model included only AI literacy subdimensions; therefore, unmeasured factors such as ethical sensitivity, professional identity, prior exposure to AI-related ethical dilemmas, curriculum content, personal values, and institutional climate may explain the additional variance in the data. Future research should employ broader explanatory frameworks and longitudinal designs [22,23].

No significant differences were observed in total AI ethics literacy by monthly income level. Although socioeconomic conditions can affect access to digital resources and learning opportunities, this sample may have been relatively homogeneous in terms of student status and the educational environment. Similarly, no significant differences were found by class level, suggesting that AI-related content has not yet been systematically differentiated across pharmacy curricula [23,24]. These findings have important implications for pharmacy education. Although AI applications are increasingly being discussed in healthcare, AI literacy and ethics have not been systematically integrated into most undergraduate pharmacy curricula. Therefore, the present study provides baseline evidence to guide curriculum developers, academic leaders, and policymakers in designing educational strategies to prepare future pharmacists for AI-supported healthcare environments [13,23].

This study has several strengths, including the simultaneous assessment of AI literacy and ethics, reporting of reliability estimates within the current sample, inclusion of effect sizes and confidence intervals, and evaluation of both sociodemographic and educational factors [25,26]. However, this study has certain limitations. The cross-sectional design precludes causal inference, the single-center setting limits generalizability, and self-reported data may be subject to response and social desirability biases. Additionally, the age distribution was highly concentrated in the 18-24 group, limiting comparisons across age groups and restricting generalization to older students or practicing pharmacists [27-30]. The use of self-reported measures may not accurately reflect actual AI competencies or ethical decision-making behaviors in real-world settings.

Future educational initiatives should extend beyond technical training to include structured learning experiences on algorithmic bias, accountability, transparency, patient privacy, legal responsibility, and ethical decision-making. An integrated educational approach may foster the development of competent and ethically responsible professionals.

4. CONCLUSION

This study demonstrated that AI literacy and ethics are related but distinct constructs for pharmacy students. While AI literacy was associated with gender, technology-use skills, and formal AI-related education, ethical awareness appeared to be influenced by factors beyond technical competence. The findings suggest that improving AI literacy may contribute to ethical awareness; however, ethical competence requires a dedicated educational focus on the subject. Pharmacy curricula should integrate AI literacy, ethical reasoning, accountability, transparency, awareness of bias, data privacy, and patient-centered professional judgment to prepare future pharmacists for responsible AI technology use.

5. MATERIALS AND METHODS

5.1. Study design

This study employed a cross-sectional, descriptive, and analytical design.

5.2. Study population

The study population consisted of 733 students enrolled in the Faculty of Pharmacy at Ege University during the fall semester of the 2025-2026 academic year.

5.3. Sample and eligibility criteria

A census-based, voluntary-participation approach was employed to reach the entire student population of the university. Students who did not provide consent and/or who submitted incomplete responses were excluded. Because the population size was finite, a census-based approach was adopted to reach the entire accessible population. The minimum required sample size was calculated as 253 using the Cochran formula with finite population correction, based on a 95% confidence level and a 5% margin of error. The final sample included 324 students, corresponding to 44.2% of the target population of the study.

5.4. Data collection tools

Data were collected using a 29-item questionnaire divided into three sections: The first section included seven demographic and control variables: age, gender, class level, monthly family income, daily Internet/computer technology use, self-reported technology-use skill level, and prior formal education related to computer programming or AI applications.

The second section comprised the Artificial Intelligence Literacy Scale, a five-point Likert-type instrument. In the current analysis, the scale included two sub-dimensions: AI competence and conscious AI use. Higher scores indicate greater AI literacy. The internal consistency in the current sample was acceptable to good: Cronbach's alpha was 0.750 for AI competence in pharmacy, 0.638 for conscious AI use, and 0.814 for the total AI literacy score.

The third section includes the Artificial Intelligence Ethics Scale, a 12-item, five-point Likert-type scale developed by Bayram [14]. The scale comprises four sub-dimensions: bias, transparency, accountability, and data privacy. Higher scores indicate greater awareness of AI ethics. To enhance transparency and reproducibility, the data collection questionnaire (Supplement-1) and the Artificial Intelligence Literacy/Ethics Scales were added as supplementary materials (Supplements 2 and 3).

In the current sample, Cronbach's alpha was 0.803 for the total scale, and the subdimension alpha values ranged from 0.618 to 0.840. Although the alpha coefficients for the bias and accountability subdimensions were slightly below 0.70, values above 0.60 are considered acceptable for exploratory studies and for scales with a limited number of items [31]. The study questionnaire and instruments used for data collection are provided in the Supplementary Material.

5.5. Statistical analysis

Statistical analyses were performed using IBM SPSS Statistics (version 27.0). The distributional properties of continuous variables and scale scores were assessed using the Kolmogorov-Smirnov test, skewness, and kurtosis tests. Although the Kolmogorov-Smirnov tests were significant for all scale dimensions ($p < 0.001$), this result alone was insufficient to reject the assumption of normality, given the relatively large sample size. Skewness ranged from -0.843 to 1.410, and kurtosis ranged from -0.229 to 1.739, indicating that scale scores were generally close enough to a normal distribution for parametric analyses when group sizes were adequate.

Categorical variables were summarized using frequency and percentage. Scale scores were reported as means, standard deviations (SDs), and 95% confidence intervals (CIs). Independent-samples t-tests were used for variables with two groups, and Cohen's d with 95% confidence intervals was reported as the effect size. Kruskal-Wallis H tests were used for variables with three or more groups; eta squared, based on the H statistic, was reported to indicate the effect size. Pearson correlation coefficients with 95% confidence intervals were calculated to evaluate the association between AI literacy and ethical considerations. Multiple linear regression was used to examine the predictors of the total AI ethics score. The regression coefficients were reported with standard errors, standardized beta coefficients, p-values, variance inflation factors, and 95% confidence intervals. Statistical significance was set at $p < 0.05$.

5.6. Ethical approval

Ethics approval for this study was obtained from the Ege University Scientific Research and Publication Ethics Committee for Health Sciences (date: 23.12.2025; Protocol no.3157). All participants were informed of the objectives of the study and agreed to participate voluntarily by accepting the informed consent form included in the online questionnaire.

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