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A Survey of Medical Students' Perceptions and Satisfaction with the Educational Content of the Interactive Digital Atlas of Poisonous Plants and Fungi

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ABSTRACT

Introduction: Accurate identification and management of poisoning caused by toxic plants and fungi remain a significant challenge in medical education due to the limited availability of structured and interactive learning resources. This study aimed to develop and evaluate an interactive digital atlas of poisonous plants and fungi and to assess medical students' perceptions and satisfaction with its educational use.

Methods: This cross-sectional study was conducted during 2022–2023 at Mashhad University of Medical Sciences. Medical trainees and interns were invited to use a researcher-developed web-based atlas. Data were collected using an 18-item questionnaire designed to assess usability, visual design, and content quality. The questionnaire's face validity was evaluated qualitatively by a panel of five experts, and its content validity was assessed using the Content Validity Ratio (CVR) and Content Validity Index (CVI) based on the opinions of nine experts.

Results: A total of 107 students participated in the study. The questionnaire demonstrated acceptable content validity, with all retained items meeting the minimum CVR threshold (0.78) and overall CVI indicating good relevance, clarity, and simplicity. Participants reported generally positive perceptions of the atlas across all domains, particularly regarding content quality and visual presentation. The mean total satisfaction score indicated an acceptable level of user satisfaction. No statistically significant difference was observed between trainees and interns in the mean total satisfaction score ($P > 0.05$).

Conclusion: The interactive digital atlas was associated with positive user perceptions and acceptable satisfaction among medical trainees and interns and may serve as a useful supplementary tool in toxicology education. Further studies are needed to evaluate its impact on objective learning outcomes.

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Introduction

In recent decades, the rapid advancement of communication and information technologies has revolutionized education and medicine (1). Among these technologies, internet stands out as a global network connecting millions of computers and providing access to the World Wide Web (2). One of the newer Internet-based innovations is social networking, which allows

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users to create personal pages and share information together. Social networks are now widely used across diverse fields, including education, healthcare, business, and law (3).

Internet has become an essential tool in medical education, providing access to bibliographic, epidemiological, imaging, and other clinical resources. In higher education levels, particularly in medical education, combination of web-based learning is rapidly growing. Many institutes now utilize online platforms to enhance teaching and research, making digital learning tools a necessity (4). Faculty members use online approaches to improve teaching methods, such as blogs, which have been widely used for clinical case reporting similar to morning reports (5).

Plant poisoning still remains a critical issue in clinical toxicology, especially among children under five years. In United States, plants are responsible for approximately 5-10% of all poisoning cases (6). Multiple factors include the type and amount of plant ingested, the specific toxins involved, the route of exposure, and individual patient characteristics such as age and underlying health can determine the severity of plant poisoning (7, 8).

Teaching toxicology has faced many challenges, particularly when in person education has changed to online. The COVID-19 pandemic has further emphasized the need for digital learning tools that maintain the quality of education (9). Computer-assisted instruction (CAI) has become popular, particularly in image-based subjects like anatomy, histology, and pathology. CAI also allows participants for interactive feedback, assessment, and enhanced student engagement (10).

Accurate plant identification is vital in treating poisoning cases, in which collaboration between toxicologists, botanists, and poison control centers is crucial for accurate and quick management (11). Moreover, awareness of the local plant names can help finding the source of poisoning more easily.

The developed digital atlas was designed as a flexible and layered educational resource to assist users with different levels of knowledge and educational needs. Main content, including identification of toxic plants and fungi, recognition of clinical manifestations, and principles of initial management, was structured to address the essential learning objectives of medical trainees and interns. In addition, more detailed information-such as botanical taxonomy, morphological characteristics, traditional uses, and extended pharmacological aspects-was included as supplementary material to support advanced learners and users from related disciplines.

Although the atlas has the potential to be used by a wide range of users, including students from various health and life science fields, the present study specifically focused on evaluating its educational utility among medical trainees and interns.

Materials

Study Design

This cross-sectional study was conducted during years 2022-2023 at Mashhad University of Medical Sciences. The study was a collaborative effort among the Department of Clinical Toxicology and the Department of Pharmacology (Mashhad University of Medical Sciences), the Department of Phytomedicine (Faculty of Agriculture, Ferdowsi University of Mashhad), and the Plant Sciences Research Institute (Ferdowsi University of Mashhad). All stages of the study followed the ethical principles of the Declaration of Helsinki and were approved by the Ethics Committee of Mashhad University of Medical Sciences (IR.MUMS.REC.1400.280).

Participants

The study population consisted of medical interns and trainees of Mashhad University of Medical Sciences. No formal a priori sample size calculation was performed. Instead, all eligible medical trainees and interns who were available during the study period were invited to participate; therefore, the final sample size was determined by the accessible study population. 1A census/convenience sampling approach was used, and all eligible medical trainees and interns who were available during the study period were invited to participate. Participants who were actively studying in medicine were included in the study. Students who did not provide consent to participate were not eligible for inclusion.

Development of the Digital Atlas

An interactive digital atlas of poisonous plants and fungi was developed and published on the

website www.toxicplants.ir. The content of this website was designed as a multimedia educational tool. The content was collected using validated national and international scientific references, including peer-reviewed literature and reliable databases. An expert panel of specialists in clinical toxicology, pharmacology, and plant sciences reviewed the content to ensure scientific accuracy and educational relevance.

Overview of the Atlas Content and Educational Features

The Interactive Digital Atlas of Poisonous Plants and Fungi was developed as a web-based educational resource designed to support both clinical and scientific learning. It serves a broad audience, including general medical students, clinical toxicology fellows, students in paramedical and agricultural sciences, environmental and plant biology disciplines, as well as healthcare professionals. The atlas provides comprehensive information for each plant and fungus, compiled from credible national and international scientific sources, including peer-reviewed literature, botanical collections, institutional databases, and museums archives.

For each species, the atlas presents detailed taxonomic classification (order, genus, and species), along with visual and descriptive information regarding the morphology of key parts such as flowers, leaves, stems, roots, and seeds. It also includes data on geographical distribution and observable seasonal changes in appearance to facilitate field recognition. To enhance accessibility, local and common names are listed alongside scientific terminology.

Furthermore, the atlas explores both traditional therapeutic applications and non-therapeutic uses, offering insight into the cultural and medicinal relevance of each species. Documented pharmacological effects, supported by scientific literature, are provided when available. A distinctive educational feature of the atlas is its detailed toxicological profile for each entry, including known toxic effects, clinical manifestations of poisoning, and suggested treatment protocols. These components were carefully curated to ensure the atlas could be used as a practical reference in both educational and clinical settings.

The digital atlas was built using an interactive design approach focused on functionality, clarity, and user engagement. Its development involved domain and server setup, creation of a structured wireframe, database integration, and iterative user-interface design tailored to learner behaviour. After initial content entry and pilot testing with target student groups, the platform was refined through ongoing feedback and content expansion to enhance its educational impact.

Identification and Selection of Toxic Species

A preliminary list of poisonous plants and fungi was compiled using credible resources and scientific databases. This list was reviewed by an expert panel comprising specialists from Ferdowsi University and Mashhad University of Medical Sciences. Plants and fungi agreed upon by at least three panel members as specialist for medical education.

Questionnaire Development and Validation

Content validity of the researcher-developed questionnaire was assessed using both qualitative and quantitative approaches. Face validity was evaluated qualitatively by a panel of five experts, who reviewed the questionnaire in terms of clarity, wording, and comprehensibility, and their feedback was incorporated into the final version.

For quantitative content validity assessment, the Content Validity Ratio (CVR) and Content Validity Index (CVI) were calculated based on the opinions of nine experts. For CVR, experts rated each item as “essential,” “useful but not essential,” or “not essential,” and the values were calculated using Lawshe’s method. A minimum acceptable CVR of 0.78 was considered based on the number of experts. Items not meeting this threshold were removed.

For CVI, experts evaluated each item in terms of relevance, clarity, and simplicity using a four-point Likert scale. Items with CVI values below acceptable thresholds were revised or excluded.

Website Design and Pilot Evaluation

The website was designed using existing interactive educational platforms as conceptual models. The development process included several key steps. Initially, a suitable domain and hosting service were identified and purchased. Subsequently, a preliminary wireframe and user interface were developed, with an emphasis on

logical architecture and user accessibility. The interactive web design was then implemented, focusing on user behavior, engagement patterns, and usability principles to enhance the learning experience. After finalizing the interface and database, the website was uploaded to the server and made publicly accessible.

To evaluate the usage and overall function of the website, a pilot study was conducted involving five volunteer medical students. Their feedback on different aspects regarding navigation, visual design, and content clarity was collected and incorporated into the final version of the website.

Educational Implementation and Evaluation

The final version of the web-based atlas was introduced to medical trainees and interns during a structured training session.

Following this introduction, students were granted access to the atlas throughout the academic semester and were encouraged to use it as a supplementary educational resource alongside their regular curriculum. Use of the atlas was not restricted to a single session, allowing participants to explore its content over time and integrate it into their learning process.

At the end of the semester, participants were invited to complete a 5-point Likert-scale questionnaire designed to assess their perceptions of the atlas in terms of usability, visual design, and content quality. This timing ensured that responses were based on actual user experience rather than initial impressions.

Educational Application

The digital atlas is designed to support education across multiple disciplines, including medical and paramedical fields, clinical toxicology (general, specialist, and fellowship levels), and biological and environmental sciences. It also serves as a reference tool for staff at medical, health, and agricultural centers.

Statistical Analysis

Descriptive statistics were used to summarize the findings and were presented as frequency (percentage) for categorical variables and mean ± standard deviation for continuous variables. Prior to analysis, the content validity of the questionnaire was assessed using qualitative review as well as the Content Validity Ratio (CVR) and Content Validity Index (CVI). Differences in the distribution of item-level Likert-scale responses between trainees and interns were analyzed using Pearson's chi-square test. The mean total questionnaire score between the two groups was compared using the independent-samples t-test. A P-value < 0.05 was considered statistically significant.

Results

A total of 107 medical students participated in the study, including 76 trainees (71%) and 31 interns (29%). All participants completed the questionnaire and were included in the analysis. The questionnaire demonstrated acceptable content validity. All retained items met the minimum acceptable CVR threshold (0.78) based on Lawshe's criteria. The overall CVI also indicated good levels of relevance, clarity, and simplicity across the items, confirming the adequacy of the instrument for the intended evaluation (Table 1-2).

Table 1. Summary of content validity indices of the questionnaire

Measure	Value
Number of items	18
Number of experts (CVR/CVI)	9
Minimum acceptable CVR (Lawshe)	0.78
Range of CVR values	≥ 0.78
Overall CVI	≥ 0.79
Interpretation	Acceptable content validity

CVR: Content Validity Ratio, CVI: Content Validity Index. This table presents descriptive validity indices only and does not involve an inferential statistical test.

Table 2. Participants' responses to survey questions regarding the designed website

Question	Options	Trainee		Intern		P-value
		Participants	percentage	Participants	percentage	
1. How do you rate the ease of access to the website?	Very weak	1	1.3	0	0.0	0.946
	weak	4	5/3	1	3.2	
	average	19	25/0	9	29.0	
	good	32	42/1	13	41.9	
	Very good	20	26/3	8	25.8	

2. How do you evaluate the website's design space and its visual effects?	Very weak	1	1.3	0	0.0	0.903
	weak	4	5.3	2	6.5	
	average	19	25.0	6	19.4	
	good	29	38.2	14	45.2	
	Very good	23	30.3	9	29.0	
3. In your opinion, how well does the website's URL match its content and title?	Very weak	1	1.3	0	0.0	0.768
	weak	5	6.6	2	6.5	
	average	21	27.6	10	32.3	
	good	21	27.6	11	35.5	
	Very good	28	36.8	8	25.8	
4. How do you assess the currency of the website's information?	Very weak	1	1.3	0	0.0	0.609
	weak	4	5.3	0	0.0	
	average	20	26.3	11	35.5	
	good	28	36.8	11	35.5	
	Very good	23	30.3	9	29.0	
5. If you have used the website's search feature, how would you rate its quality?	Very weak	3	3.9	0	0.0	0.406
	weak	5	6.6	0	0.0	
	average	23	30.3	10	32.3	
	good	24	31.6	13	41.9	
	Very good	21	27.6	8	25.8	
6. What is your opinion about the comprehensiveness of the website's information in the poisonous plants section?	Very weak	2	2.6	0	0.0	0.609
	weak	6	7.9	1	3.2	
	average	19	25.0	11	35.5	
	good	24	31.6	8	25.8	
	Very good	25	32.9	11	35.5	
7. What is your opinion about the comprehensiveness of the website's information in the poisonous fungi section?	Very weak	2	2.6	0	0.0	0.150
	weak	4	5.3	0	0.0	
	average	24	31.6	9	29.0	
	good	20	26.3	15	48.4	
	Very good	26	34.2	7	22.6	
8. What is your assessment of the quality of the images in the poisonous fungi section?	Very weak	1	1.3	0	0.0	0.889
	weak	2	2.6	1	3.2	
	average	18	23.7	9	29.0	
	good	27	35.5	12	38.7	
	Very good	28	36.8	9	29.0	
9. How do you assess the adequacy of the images to the content in the poisonous fungi section?	Very weak	1	1.3	0	0.0	0.139
	weak	5	6.6	2	6.5	
	average	15	19.7	12	38.7	
	good	23	30.3	11	35.5	
	Very good	32	42.1	6	19.4	
10. How do you assess the quality of the images in the poisonous plants section?	Very weak	1	1.3	0	0.0	0.445
	weak	8	10.5	1	3.2	
	average	22	28.9	8	25.8	
	good	27	35.5	10	32.3	
	Very good	18	23.7	12	38.7	
11. How do you assess the adequacy of the images to the content in the poisonous plants section?	Very weak	1	1.3	1	3.2	0.835
	weak	2	2.6	1	3.2	
	average	17	22.4	8	25.8	
	good	31	40.8	14	45.2	
	Very good	25	32.9	7	22.6	
12. How would you rate the quantity of information on the site in the poisonous plants section?	Very weak	2	2.6	0	0.0	0.778
	weak	5	6.6	2	6.5	
	average	23	30.3	7	22.6	
	good	19	25.0	10	32.3	
	Very good	27	35.5	12	38.7	
13. How do you rate the quantity of images on the website in the poisonous plants section?	Very weak	2	2.6	0	0.0	0.480
	weak	2	2.6	3	9.7	
	average	18	23.7	7	22.6	
	good	22	28.9	10	32.3	
	Very good	32	42.1	11	35.5	
14. How would you rate the quantity of information on	Very weak	2	2.6	0	0.0	0.381
	weak	6	7.9	0	0.0	

the website in the poisonous fungi section?	average	16	21.1	8	25.8	
	good	32	42.1	12	38.7	
	Very good	20	26.3	11	35.5	
15. How would you rate the quantity of images on the website in the poisonous fungi section?	Very weak	1	1.3	0	0.0	0.828
	weak	3	3.9	2	6.5	
	average	21	27.6	11	35.5	
	good	21	27.6	8	25.8	
	Very good	30	39.5	10	32.3	
16. Overall, how satisfied are you with the content of the poisonous plants section?	Very weak	1	1.3	0	0.0	0.366
	weak	8	10.5	1	3.2	
	average	26	34.2	7	22.6	
	good	24	31.6	13	41.9	
	Very good	17	22.4	10	32.3	
17. Overall, how satisfied are you with the content of the poisonous fungi section?	Very weak	1	1.3	0	0.0	0.815
	weak	2	2.6	1	3.2	
	average	15	19.7	9	29.0	
	good	35	46.1	12	38.7	
	Very good	23	30.3	9	29.0	
18. Considering all aspects, how would you rate the overall quality of the site?	Very weak	1	1.3	1	3.2	0.916
	weak	4	5.3	2	6.5	
	average	21	27.6	7	22.6	
	good	27	35.3	10	32.3	
	Very good	23	30.3	11	35.5	

Values are presented as n (%). P-values were calculated using Pearson's chi-square test.

Overall, the digital atlas received favorable evaluations from participants. Sixty-six percent of respondents rated the overall quality of the website as good or very good, while 26.2% rated it as average and fewer than 8% reported poor or very poor satisfaction. The mean total questionnaire score was 70.22 ± 12.61, with scores ranging from 18 to 90.

Participants reported positive perceptions across multiple domains of the website. The visual design and layout were rated as good or very good by 69.4% of respondents. Regarding the currency and relevance of the educational content, 66.4% expressed favorable evaluations. Content comprehensiveness was rated positively by 63.5% of participants, with particularly high satisfaction reported for the poisonous fungi section.

Comparison of questionnaire responses between trainees and interns revealed no statistically significant differences in overall satisfaction scores or in any individual questionnaire item (P > 0.05). Mean total scores were comparable between the two groups (Table 3).

Table 3. Comparison of questionnaire scores in internship and trainee participants

	Trainee	**Intern**	**P-value**
Questionnaire score, mean ± standard deviation	70.04±12.92	70.04±12.92	0.814

Values are presented as mean ± standard deviation. The P-value was calculated using the independent-samples t-test.

Discussion

In the present study, we developed and evaluated an educational website dedicated to poisonous plants and fungi, offering comprehensive information on clinical symptoms, diagnosis, and treatment of related poisonings. The platform was assessed by medical interns and trainees through a structured questionnaire, and the feedback was generally positive. Over 66% of participants rated the overall quality of the website as good or very good. Among the evaluated features, the content and image quality-particularly in the poisonous fungi section-received the highest satisfaction, with fewer than 4% rating it as poor or very poor. In contrast, the website's search functionality was identified as the main weakness, receiving the lowest scores.

These findings are consistent with previous studies from Peru and other regions, which have reported moderate satisfaction with virtual learning platforms. In such studies, perceived teaching effectiveness and technological reliability were key determinants of user satisfaction (12). The positive evaluations of content quality and visual presentation in our survey reflect similar conclusions, reinforcing the importance of user-centric design and multimedia elements in enhancing digital learning experiences. However, as seen in earlier work, technical limitations, such as inefficient search features, can negatively influence overall satisfaction (13).

Unlike traditional classroom-based programs, our web-based educational tool offers continuous and on-demand access to essential information, supporting real-time decision-making by medical students and healthcare providers. Prior research has emphasized the value of integrating digital and interactive educational resources into healthcare training to complement face-to-face learning and enhance service delivery. For instance, Bond et al. developed a website to educate healthcare professionals about vancomycin, using videos, images, humor, and self-assessment quizzes. Their approach led to improved satisfaction and learning outcomes. Although our website lacks humorous content and interactive quizzes, our results are in line with theirs in demonstrating the effectiveness of web-based educational tools. Notably, in contrast to Bond et al.'s study, no technical issues related to browser or operating system compatibility were reported by our users (14).

A systematic review by Sinclair et al. (15), reported that internet-based learning tools are at least as effective as traditional educational methods. They also highlighted the role of interactivity in enhancing communication between instructors and learners, consequence in better user experience. Although our study did not directly measure clinical behaviors or patient outcomes, the participants' positive perceptions suggest that such tools may indirectly support improved clinical practice through better knowledge acquisition. Similarly, Patel et al. developed a web-based histology atlas that received extensive use and positive feedback from medical students. Our findings align with theirs, further demonstrating that digital educational tools can enhance student learning outcomes and satisfaction (16).

Additional insight is provided by a study conducted at the University of Jordan, where 690 students from five health-related faculties were surveyed regarding mobile learning. While most students (92.6%) used smartphones and regularly accessed platforms such as YouTube for education (98.8%), many reported feelings of isolation. Approximately 63% of students believed that mobile learning should supplement rather than replace in-person instruction. Furthermore, the need for offline access and compatibility with various devices was emphasized. These findings indicate that satisfaction with digital tools depends not only on content quality but also on usability, interactivity, and emotional engagement (17). In comparison, our interactive digital atlas provides a structured, visually rich, and clinically relevant platform that supports both independent learning and classroom-based education. By addressing common limitations-such as lack of depth and limited interactive features-our atlas contributes meaningfully to multidisciplinary education in fields such as toxicology, botany, and public health.

A relevant study during the COVID-19 pandemic, conducted by AlQudah et al. (2024), examined satisfaction with online learning among students and faculty in health sciences education. The study revealed that while 74.3% of faculty expressed satisfaction, only 41.3% of students reported the same. Students appreciated the flexibility and improved communication offered by online learning but were negatively affected by technical problems and heavy workloads. Faculty, although generally satisfied, experienced challenges with increased workload and preparation time. Thematic analysis identified four primary factors influencing satisfaction: Study-load, Workload, Engagement, and technical issues (SWEET). The authors concluded that integrating synchronous and asynchronous teaching, incorporating interactive tools, and offering timely feedback significantly improved satisfaction (18). These findings resonate with our results, underscoring the critical role of usability, content quality, and technical reliability in the success of digital educational

platforms. Furthermore, our atlas's responsive design and institutional support reflect the recommended features for maximizing educational value and learner satisfaction. One of the limitations of the current study is the lack of a control group using traditional educational methods, which restricts our ability to directly compare the digital atlas's effectiveness. Future studies are recommended to include comparative designs to assess learning outcomes more objectively.

Conclusions

The findings of our study indicate that the development of a web-based educational tool on poisonous plants and fungi proved to be beneficial for medical students. This resource holds potential not only as a supportive learning aid in medical education but also as a practical reference for healthcare professionals managing cases of plant and fungal poisoning.

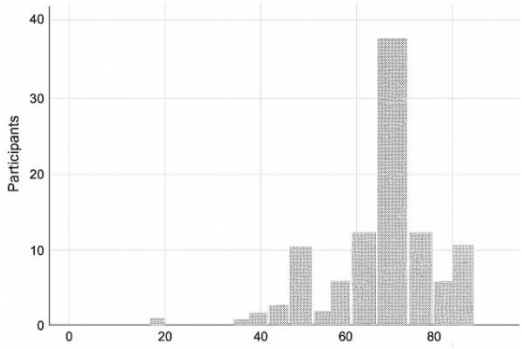

Figure 1. Participants' total score on the website, considering all aspects, based on their responses to the questionnaire questions.

Ethics approval and consent to participate

Informed consent was obtained from all the participants. There is no ethical issue to be considered.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

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Authors' contributions

BD contributed to the conceptualization, supervision, and project administration. AAT was responsible for methodology, data collection, analysis, and initial drafting of the manuscript. ZA participated in questionnaire design, statistical validation, and data interpretation. AR prepared educational content, conducted pilot testing, and served as the corresponding author. All authors reviewed and approved the final version of the manuscript.

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