

A browser-based neuro-ophthalmic examination simulator for medical students: rule-based scenario generation and internal review

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Abstract

Background

Neuro-ophthalmic examination requires learners to connect ocular movements and pupillary responses with neurological dysfunction. We developed a Persian-language browser-based simulator combining visual examination, dynamically generated clinical scenarios and formative feedback.

Results

Version 1.22.3 was developed at North Khorasan University of Medical Sciences, Iran, using PHP 8, MySQLi database access and Materialize CSS. An expert system combines disease-finding rules with variable age and laterality. Students examine simulated findings, identify affected nerves and receive automated feedback. Three user roles support practice, scenario management and performance review. The three authors reviewed 200 randomly generated scenarios through meetings and a checklist. Execution was reported on 10 devices across mobile, desktop and Android television environments. Case-level ratings, error counts and device logs were not supplied; accuracy and compatibility rates cannot be calculated. Classroom use was reported, but no educational trial or validated usability study was completed. Online access is available for non-commercial use and reviewer assessment.

Conclusions

The platform integrates visual findings, rule-based case variation and instructor-supported practice. Internal review and deployment reports do not establish educational effectiveness or assessment validity. Independent clinical and technical evaluation followed by prospective learner studies is needed.

Background

Ophthalmic assessment is relevant to the education of all medical graduates, and published learning objectives emphasize recognition and initial management of important eye problems [1]. Neuro-ophthalmic examination adds a requirement to interpret ocular movements and pupillary responses in relation to neurological pathways [2]. A learner must connect what is observed with a plausible lesion and decide which findings distinguish alternatives. Repeated exposure to selected findings can complement clinical encounters in which the availability and combination of abnormalities are unpredictable.

Technology-enhanced simulation has been associated with learning benefits across health professions, although effects vary with the task, instructional design and comparator [3]. Virtual patient studies likewise show substantial variation across interventions and outcomes [4]. These findings justify

developing and evaluating relevant tools; they do not establish that any particular new application improves learning.

Ophthalmology offers several evaluated approaches. Simulator-based slit lamp training has been assessed in a randomized study using a structured practical examination [5]. The Virtual Ophthalmology Clinic was evaluated in a randomized trial of medical student learning [6], while 20/20 SIM was integrated into clerkship teaching and evaluated using learner surveys and knowledge assessments [7]. In 2026, a prospective study of EyelearnMR examined ocular motility education using a wearable mixed-reality device, a video-based assessment and a user experience questionnaire [8]. These examples show the importance of distinguishing implemented functions from demonstrated learner outcomes.

Computerized neuro-ophthalmic simulation is not itself new. Pupillary response simulation was described in 1991 [9], and the Virtual Patient/Eye Simulator combined ocular motor concepts, pupil reflexes and clinical cases [10]. The present project addresses a more specific implementation problem: integrating visual examination, rule-based scenario variation and role-specific performance review in a browser-based environment for Persian-speaking medical students. It does not claim priority for computerized pupils or virtual eye cases.

This article describes the application architecture, scenario generation process, internal review and access arrangements. Its contribution is an implemented educational platform with dynamically varied cases and instructor oversight. Educational effectiveness, usability and transfer to patient examination remain questions for prospective study.

Implementation

Development setting and chronology

The simulator was developed at North Khorasan University of Medical Sciences, Bojnurd, Iran, as an applied technology project and a product-oriented medical degree thesis. Development ran from Shahrivar 1401 (August–September 2022) to Aban 1402 (October–November 2023). Version 1.22.3 was released in Dey 1402 (December 2023–January 2024); the originating thesis was completed in March 2024. The Solar Hijri months are reported because exact development and release days were not specified.

Development comprised conceptual design, software design and implementation with internal review. Literature and existing software informed content selection. Amir Rahmanian Sharifabad led conceptualization and programming; Samira Jalalifar contributed the ophthalmic content; and Kimia Ashoorzadeh developed the clinical scenarios. Programming was undertaken by Amir Rahmanian Sharifabad and the company Tabib Rayanesh Fanavaran Vorna. Figure 1 shows the development stages and intended formative learning workflow.

Architecture and user roles

The application uses PHP 8 and a responsive interface built with Materialize CSS. Database access uses the MySQLi extension. The underlying database server product and version were not documented in the materials supplied for this report. The system runs through a web browser on personal computers, mobile devices and other internet-connected displays; no headset or examination-specific peripheral is required. It is therefore described as screen-based simulation rather than immersive virtual reality.

Access is organized through student, instructor and administrator roles. Students access educational content, assigned scenarios, examination practice and previous attempts. Instructors create classes and cases, allocate scenario access and inspect student activity. Administrators manage accounts, student–instructor allocation and system-wide reports. The development record also describes user profiles and messaging between authorized users. This management layer connects the examination models with teaching activity and performance review.

No independent security assessment is reported. The existence of authentication and role restrictions should not be interpreted as compliance with a particular information-security standard. Deployment involving identifiable learner records requires the institution's usual access and data-governance arrangements.

Knowledge base and dynamic scenario generation

The scenario generator is a rule-based expert system. Its knowledge base encodes relationships between diseases, expected examination abnormalities and typical ages. Scenario attributes can vary within this framework, including the affected side and age. Cases are therefore generated from structured clinical rules rather than being limited to a fixed list of written vignettes. The number of distinct scenarios cannot be inferred from the 200 cases used for internal review.

Instructors can define scenarios and control which attributes remain fixed and which may vary. Students can access assigned cases or enter random-case practice. This design aims to separate the underlying clinical pattern from incidental case attributes, enabling learners to encounter variations of a problem. It does not establish that all generated combinations are clinically plausible; that question requires systematic review of the knowledge base and its outputs.

The term expert system denotes the rule-based design. No trained machine-learning model, generative language model or model-training dataset is reported as part of the educational software. Clinical rules, age assumptions and case variation should therefore be assessed directly rather than interpreting automated generation as evidence of independently validated artificial intelligence performance.

Examination models and learner interaction

Educational content includes text, video and animation. An exploration mode allows learners to change examination parameters and observe representations of eye movements and pupil responses. The ocular movement controls offer intact nerves and oculomotor, trochlear and abducens injury states for each side. In scenario practice, the learner reviews the presentation, explores the available examinations

and selects the affected nerve and side from response options, covering cranial nerves II, III, IV and VI as applicable to the findings.

The software provides automated feedback and retains information about previous attempts. Instructors can access individual performance and scenario-level summaries. These functions support formative discussion, but their measurement properties have not been established. The precise weighting of responses and complete scoring specification were not supplied; no reliability or validity claim is made for numerical outputs.

Figure 2 reproduces original interfaces created by the development team. The screenshots document visual displays and controls. They are historical examples from the thesis and should not be treated as evidence that the animations or every interface label have been independently validated. Terminology discrepancies identified during manuscript preparation are discussed below.

Internal review and implementation checks

The internal review panel comprised the three authors: the researcher responsible for scenario development, the ophthalmology contributor and the physician-programmer responsible for conceptualization and implementation. Review used meetings, a checklist and examination of 200 randomly generated scenarios. The reviewers were development-team members rather than independent external assessors. The number of scenarios reviewed is a process count, not a measure of scenario accuracy.

Item-level checklist ratings, counts of inconsistent cases, agreement between reviewers and a version-linked correction log were not supplied. This report therefore does not claim that all 200 scenarios were correct, calculate a content validity index or present an accuracy percentage. Independent review of both rule coverage and generated outputs remains necessary.

The development record reports execution on 10 devices. The authors identified Android television, Samsung Android phones, iPhones, Macintosh computers, Windows systems and Ubuntu Linux among the tested platforms. Browsers included Firefox, Chrome, Samsung Internet and the iPhone browser. These platform and browser lists were not supplied as a complete device–browser pairing matrix. Version numbers, task definitions and failure logs were unavailable; the information describes the scope of developer testing without establishing universal browser compatibility.

Classroom use and instructional purpose

The software has been used in teaching classes. No educational trial has been completed, and learner numbers, teaching exposure, satisfaction measurements and examination outcomes were not supplied. Classroom use is therefore reported as deployment experience rather than an evaluation of educational effectiveness.

The intended sequence is preparation, exploration of selected findings, case interpretation and feedback review. Repeated practice is a defensible instructional rationale in light of the wider simulation literature [11], but this application has not been tested as a mastery-learning curriculum. It supplements supervised clinical teaching: recognizing an on-screen pattern does not by itself demonstrate the ability to elicit the corresponding sign in a patient.

Manuscript preparation

An artificial intelligence language model assisted English drafting, organization, literature discovery and preparation of the development schematic. Study information was drawn from the thesis, additional factual information supplied by the investigators and the ethics certificates. No participant observations, experimental outcomes or scenario accuracy estimates were generated by the model. The interface images were created by the software developers and reproduced from the thesis.

Results

Implemented educational platform

The development output is version 1.22.3 of a browser-based neuro-ophthalmic examination simulator. Its principal functions connect visual sign exploration, rule-generated scenarios and role-specific performance review. Table 1 relates these functions to their educational purpose and supporting evidence. Together, they allow instructors to organize access while students practise interpretation and revisit previous attempts.

Table 1
Implemented functions, intended use and evidential boundaries.

Documented function	Intended educational use	Evidence and boundary
Multimedia content	Preparation using text, video and animation	Module described; engagement and learning not evaluated
Eye movement and pupil models	Explore examination findings by changing parameters	Original interfaces; independent clinical accuracy not established
Rule-generated scenarios	Vary age, laterality and findings within clinical rules	200 random outputs internally reviewed; no accuracy rate available
Automated feedback and history	Review responses and previous attempts	Screenshots and description; score validity not established
Instructor and administrator roles	Allocate access and review activity	Role functions documented; workload benefit not tested
Responsive browser interface	Access through personal smart devices	10 devices reported; no version-specific compatibility logs

Source: the thesis, original interfaces and additional development information supplied by the investigators. No educational effectiveness result is inferred.

The expert system varies clinical attributes such as laterality and age according to encoded disease–finding relationships. A generated scenario can be explored through the examination interface before the learner identifies the affected nerve and side. Internal review covered 200 random outputs, but the available evidence does not quantify the proportion of clinically consistent cases, severity of defects or improvement across software versions.

Internal review, cross-platform execution and use

Table 2 summarizes the available implementation evidence. The scenario count, device count and reported classroom use describe different activities and must not be combined into a participant sample. None provides a comparative estimate of learning benefit. No inferential statistical analysis was conducted because no learner outcome dataset or scenario-level rating dataset was supplied.

Table 2
Internal review and implementation evidence.

Activity	Reported scope	Interpretation and limit
Internal scenario review	3 authors; meetings, checklist and 200 random scenarios	Developer review; no scenario-level ratings or defect counts supplied
Device/platform execution	10 devices; Android TV, Samsung Android phones, iPhones, macOS, Windows, Ubuntu	Reported testing categories; not a paired compatibility matrix
Browser execution	Firefox, Chrome, Samsung Internet and iPhone browser	Versions, task results and failure logs not supplied
Classroom deployment	Used in teaching classes	No learner count, educational trial or outcome dataset supplied
Online access check	Student demonstration and two examination modules inspected on 16 October 2026	Limited manuscript-preparation check; not validation

Counts describe scenarios and devices, not a recruited learner cohort. Browser and platform lists do not establish every possible pairing.

Online access

The Persian-language application is hosted within the Med-Sim educational simulator platform [12]. The authors provide continuing access for non-commercial purposes and an evaluation account for reviewers. The supplied shared account allows access without individual registration. Source code can be provided confidentially to editors and reviewers for evaluation, while ownership remains with Amir Rahmanian Sharifabad and Tabib Rayanesh Fanavaran Vorna. The code has not been released under a public open-source license.

A limited access check on 16 October 2026 confirmed entry to the student demonstration and access to the eye movement and pupil-display modules. This was separate from the original development study and was not a predefined usability or compatibility evaluation. Instructor and administrator roles, all generated scenarios and scoring behavior were not independently inspected during this check.

Discussion

Contribution and relationship to existing software

The application brings together visual examination models, dynamically varied clinical scenarios and instructor-supported performance review in a browser-based Persian-language environment. Its most relevant design feature is the connection between a rule-defined clinical condition, the examination findings available to the learner and the nerve-level interpretation requested at the end of the case. This architecture provides a concrete platform for further educational investigation.

Published pupil simulation and integrated eye simulators predate this project [9, 10]. Novelty cannot therefore rest on showing computerized eyes or pupils alone. Slit lamp simulation addresses a different examination task [5], while virtual ophthalmology case platforms provide closer educational comparisons [6, 7]. EyelearnMR uses a wearable mixed-reality approach to ocular motility teaching [8]. Table 3 identifies these relationships without implying that unreported features are absent from comparator tools.

Table 3
Contextual comparison with published educational software.

Published approach	Main focus	Reported evaluation	Relationship to this application
Computerized pupil [9]	Pupillary responses	Software description	Establishes prior pupil simulation
Virtual Patient/Eye Simulator [10]	Ocular motor concepts, pupils and cases	Development poster	Demonstrates prior integrated eye simulation
Virtual Ophthalmology Clinic [6]	Virtual ophthalmic patient encounters	Randomized trial	Comparator for case-based educational evaluation
20/20 SIM [7]	Ophthalmology cases in clerkships	Surveys and knowledge assessments	Comparator for curriculum integration
EyelearnMR [8]	Ocular motility using a mixed-reality headset	Prospective learner assessment	Different hardware and interaction; no head-to-head comparison
Present application	Rule-generated cases, screen-based findings and role-based review	200-case internal review; reported device execution	No demonstrated comparative educational advantage

This is a literature-based comparison, not head-to-head testing. Unreported features of comparator tools are not treated as absent.

No direct comparison with another application has been performed. A browser-based design may reduce the requirement for dedicated simulation hardware, but development, maintenance and teaching costs were not measured. Neither cost-effectiveness nor superiority over existing software can be inferred. The Persian interface supports the originating teaching context while limiting immediate evaluation by international users; an English navigation guide accompanies the confidential reviewer access instructions.

Meaning of internal review and deployment

The review of 200 generated scenarios describes the scale of an internal inspection, not its accuracy or independence. Without the checklist items, case-level decisions and defect log, it is impossible to distinguish comprehensive clinical checking from a more limited functional walkthrough. The same distinction applies to device execution: use on several platforms supports describing deployment scope, but does not establish a pass rate across specified operating-system and browser combinations.

Use in classes demonstrates that the software has entered teaching practice. It does not establish whether students find it usable, whether feedback changes their reasoning or whether clinical performance improves. These are distinct outcomes requiring appropriately designed learner studies. The contribution of this report is developmental and descriptive.

Feedback, clinical interpretation and limitations

Assessment validity concerns the interpretation and use of results [13]. Correctly choosing an affected nerve from response options is narrower than independently eliciting findings, generating a differential diagnosis and examining a patient. Scores should therefore be used for formative feedback unless evidence supports a broader interpretation. No evidence currently supports high-stakes ranking or certification.

Rule-based generation places responsibility on the encoded clinical assumptions. Typical ages should guide plausible case variation without being treated as absolute diagnostic boundaries. Lesion laterality, eye movement behavior, pupil responses and the stored answer need to remain consistent when attributes are randomized. Developer review is susceptible to shared assumptions and familiarity, which strengthens the case for independent clinical checking.

The demonstration examined during manuscript preparation contained terminology discrepancies: a pupil-display module was reached through a menu item labelled corneal reflex, and the afferent nerve label used ophthalmic in association with cranial nerve II. These are reported interface discrepancies; they do not establish the correctness or incorrectness of all underlying rules. The authors have identified them for correction, but completion has not been verified. The historical screenshots are retained with an explicit note rather than altered to suggest a corrected release.

Other limitations include the absence of scenario-level review results, a complete knowledge-base and scoring specification, version-specific compatibility logs, independent usability evaluation and educational outcomes. The exact database server and dependency versions remain unspecified. Accessibility, security and cost-effectiveness have not been evaluated. Generalizability beyond the originating institution and Persian-language teaching context is unknown.

Priorities for evaluation

The first priority is a version-linked clinical and technical audit. Independent reviewers should inspect disease-finding rules and a reproducible set of generated cases, document inconsistencies and verify corrected outputs. Technical testing should specify devices, operating systems, browsers and tasks, including touch and pointer input. Terminology, findings and feedback should be checked together rather than treating corrected labels as sufficient evidence of clinical accuracy.

A learner study should distinguish usability from educational effectiveness. Defined tasks and observed errors can inform interface refinement. A subsequent comparative study could assess interpretation of previously unseen findings and independently rated clinical examination performance. The primary outcome and sample size justification should be specified prospectively; retention and clinical transfer should be separated from immediate test performance.

Reporting can be strengthened by specifying simulation exposure, case content, feedback timing and assessment procedures [14]. Intervention descriptions should also state who delivers the activity, its duration and any tailoring [15]. These are priorities for future research; no trial sample, effect size or successful educational outcome is claimed here.

Conclusions

A browser-based neuro-ophthalmic examination simulator was developed with a rule-based scenario generator, visual examination models and instructor-supported performance review. The development team reviewed 200 generated scenarios and reported execution across several device and operating-system categories. The software has been used in classes and is available for non-commercial access and confidential reviewer assessment. These findings describe an implemented resource; independent clinical validation, reproducible technical testing and prospective educational evaluation remain necessary.

Availability and requirements

Project name: Neuro-ophthalmic examination simulator within the Med-Sim educational simulator platform.

Project home page: see reference [12]. The interface is in Persian; confidential demonstration access and an English navigation guide are provided separately for reviewers.

Version: 1.22.3; released in Dey 1402 (December 2023–January 2024).

Operating systems: browser-based. Reported testing included Android television, Android phones, iPhones, macOS, Windows and Ubuntu Linux. This list is not a version-specific compatibility guarantee.

Programming language and interface: PHP 8 and Materialize CSS; database access through MySQLi. The database server and dependency version details are not available in this report.

Other requirements: internet access and a browser. Reported browser testing included Firefox, Chrome, Samsung Internet and the iPhone browser; minimum supported versions have not been specified.

License and restrictions: proprietary software owned by Amir Rahmanian Sharifabad and Tabib Rayanesh Fanavaran Vorna. Hosted access is provided for non-commercial use. The authors state that access is continuing, without a scheduled expiry. Redistribution, commercial use and public source-code reuse are not licensed by this statement.

Source code: available confidentially to editors and reviewers for assessment through the corresponding author; not publicly released under an open-source license. Intellectual-property ownership is retained by the owners.

Abbreviations

AI

artificial intelligence

MySQLi

MySQL Improved interface

PHP

PHP:Hypertext Preprocessor

TIDieR

Template for Intervention Description and Replication.

Declarations

Ethics approval and consent to participate

The project was approved by the Research Ethics Committees of North Khorasan University of Medical Sciences on 2 October 2022 (IR.NKUMS.REC.1401.047), under the approved title “design neuro ophtalmology examinations simulator application.” The Persian and English approval certificates were checked during manuscript preparation. Review was undertaken by the three authors as development-team members. No external participants were recruited for that review, and no patient data or learner-level educational outcomes are presented. Participant consent was not applicable to this internal author-team software review; no committee-issued consent waiver is claimed.

Consent for publication

Not applicable. The reproduced software images contain schematic eye displays and do not contain identifiable patients or learners. The software images and graphics were created by the development team.

Funding

North Khorasan University of Medical Sciences provided less than 20% of development costs. The remaining costs were funded personally by ARS. ARS also led conceptualization and programming, as described in the author contributions.

Author Contribution

Authors' contributions ARS conceived and conceptualized the project, designed the rule-based expert system architecture, secured internal project funding, supervised the software development, coordinated the internal scenario testing, and critically revised the manuscript for important intellectual content. SJ contributed to the clinical knowledge base, designed the clinical scenarios and neuro-ophthalmic rules, participated in the internal review of simulated cases, and contributed to drafting the manuscript. KA participated in literature review, clinical rule structuring, interface testing across devices, drafting of the initial manuscript, and prepared the figures and tables. All authors read and approved the final manuscript.

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Availability of data and materials

The application is available through the Med-Sim platform [12]. Representative interfaces and a schematic development workflow are included in this article. Confidential source-code access for editors and reviewers can be arranged through the corresponding author while intellectual-property ownership is retained. No learner outcome dataset was analysed for this report. Scenario-level checklist

ratings, error counts and device-level logs were not supplied for analysis; the reported review and device counts should not be treated as an accessible validation dataset.

Competing interests

ARS is a co-owner and developer of the software. The other owner is Tabib Rayanesh Fanavaran Vorna, which also contributed programming. ARS personally financed most development costs. These ownership, development and financial relationships are disclosed as potential competing interests.

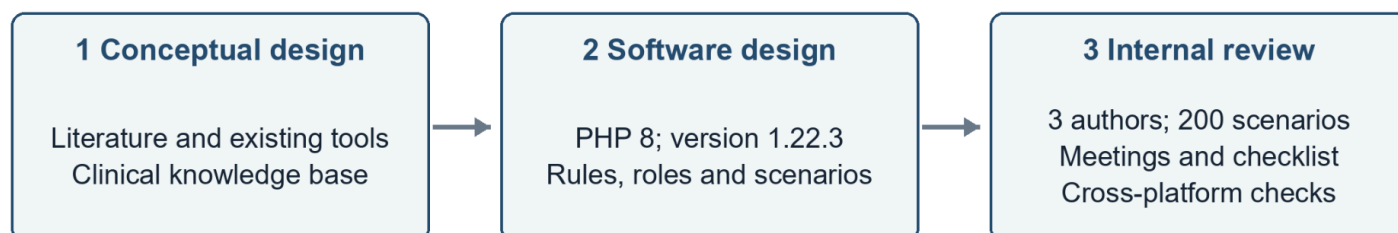
References

1. Graubart EB, Waxman EL, Forster SH, Giaconi JA, Rosenberg JB, Sankar PS, et al. Ophthalmology objectives for medical students: revisiting what every graduating medical student should know. *Ophthalmology*. 2018;125(12):1842–3. 10.1016/j.ophtha.2018.08.032.
2. Lueck CJ, Gilmour DF, McIlwaine GG. Neuro-ophthalmology: examination and investigation. *J Neurol Neurosurg Psychiatry*. 2004;75(Suppl 4):iv2–11. 10.1136/jnnp.2004.055293.
3. Cook DA, Hatala R, Brydges R, Zendejas B, Szostek JH, Wang AT, et al. Technology-enhanced simulation for health professions education: a systematic review and meta-analysis. *JAMA*. 2011;306(9):978–88. 10.1001/jama.2011.1234.
4. Kononowicz AA, Woodham LA, Edelbring S, Stathakarou N, Davies D, Saxena N, et al. Virtual patient simulations in health professions education: systematic review and meta-analysis by the Digital Health Education Collaboration. *J Med Internet Res*. 2019;21(7):e14676. 10.2196/14676.
5. Deuchler S, Abu Dail Y, Koch F, Buedel C, Ackermann H, Flockerzi E, et al. Efficacy of simulator-based slit lamp training for medical students: a prospective, randomized trial. *Ophthalmol Ther*. 2023;12(4):2171–86. 10.1007/s40123-023-00733-w.
6. Succar T, Zebington G, Billson F, Byth K, Barrie S, McCluskey P, et al. The impact of the Virtual Ophthalmology Clinic on medical students' learning: a randomised controlled trial. *Eye (Lond)*. 2013;27(10):1151–7. 10.1038/eye.2013.143.
7. Tran JH, Loebel E, Edouard M, Quehl T, Walsh E, Ginsburg R, et al. Creating ophthalmology experiences in undergraduate medical education: pilot of a case-based learning ophthalmology tool. *BMC Med Educ*. 2023;23:559. 10.1186/s12909-023-04514-8.
8. Tan CJM, Yong WWD, Lin HEHA, Oh J, Yong HSR, Khew FMJ, et al. Application of mixed reality for ophthalmic clinical skills and diagnosis: prospective study. *JMIR Med Educ*. 2026;12:e71338. 10.2196/71338.
9. Bullock JD, Rowley BA, Kuehne LA. The computerized pupil. *J Clin Neuroophthalmol*. 1991;11(1):50–2. PMID:1709178.
10. Lasslo R, Keltner J, Henderson G. Virtual Patient/Eye Simulator – evolution of a futuristic teaching tool. *Proc AMIA Symp*. 2002:1074. PMCID:PMC2244366.

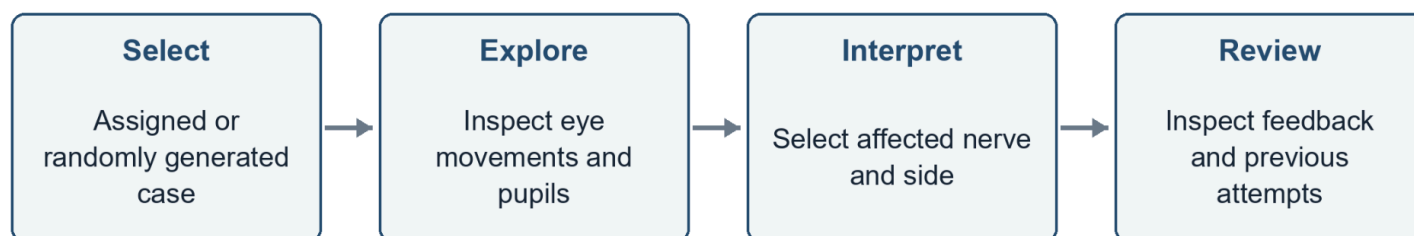
11. McGaghie WC, Issenberg SB, Cohen ER, Barsuk JH, Wayne DB. Does simulation-based medical education with deliberate practice yield better results than traditional clinical education? A meta-analytic comparative review of the evidence. *Acad Med.* 2011;86(6):706–11. 10.1097/ACM.0b013e318217e119.
12. Med-Sim. Educational simulator platform: neuro-ophthalmic examination simulator. <https://medsim.ir/>. Accessed 16 October 2026. Persian-language demonstration; authenticated access required.
13. Cook DA, Beckman TJ. Current concepts in validity and reliability for psychometric instruments: theory and application. *Am J Med.* 2006;119(2):e1667–16616. 10.1016/j.amjmed.2005.10.036.
14. Cheng A, Kessler D, Mackinnon R, Chang TP, Nadkarni VM, Hunt EA, et al. Reporting guidelines for health care simulation research: extensions to the CONSORT and STROBE statements. *Simul Healthc.* 2016;11(4):238–48. 10.1097/SIH.0000000000000150.
15. Hoffmann TC, Glasziou PP, Boutron I, Milne R, Perera R, Moher D, et al. Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. *BMJ.* 2014;348:g1687. 10.1136/bmj.g1687.

Figures

REPORTED DEVELOPMENT



IMPLEMENTED LEARNER WORKFLOW



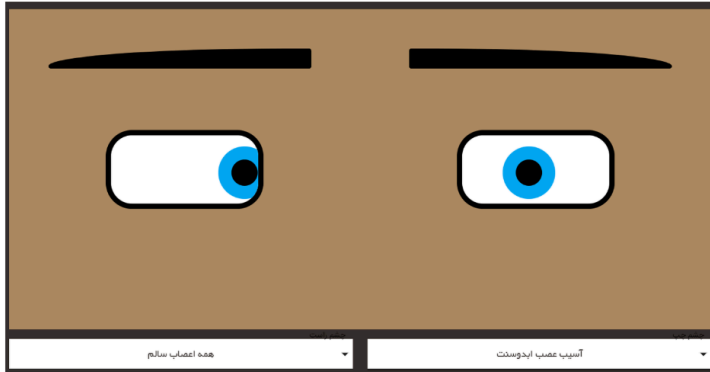
NEXT: INDEPENDENT EVALUATION

Clinical accuracy and terminology | Technical compatibility
Usability | Learning outcomes | Validity of score interpretation

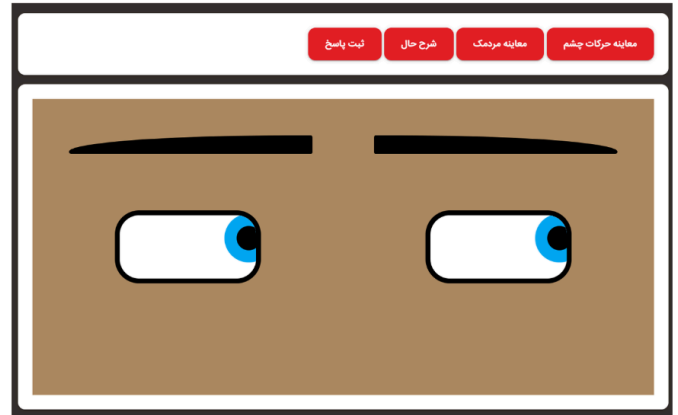
Figure 1

Development process and intended formative workflow. Solid boxes summarize development and implemented functions. Internal review involved the three authors and 200 randomly generated scenarios; no scenario accuracy rate is implied. The dashed box identifies subsequent independent clinical, technical and educational evaluation. This is a newly drawn schematic rather than a participant recruitment flowchart.

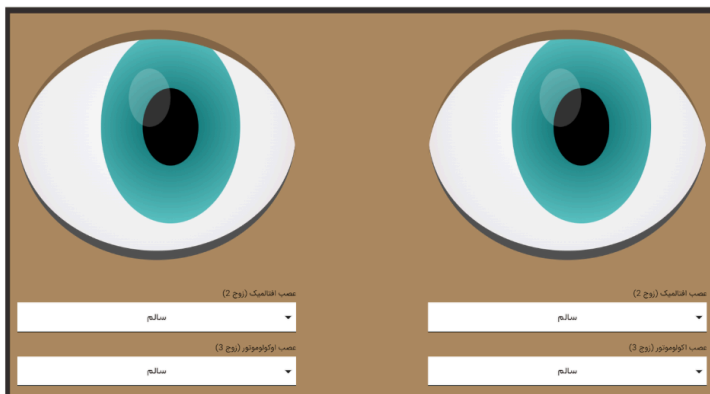
A Ocular movement: sixth nerve example



B Scenario-mode eye movement display



C Pupil display and parameter controls



D Simulated pupil illumination

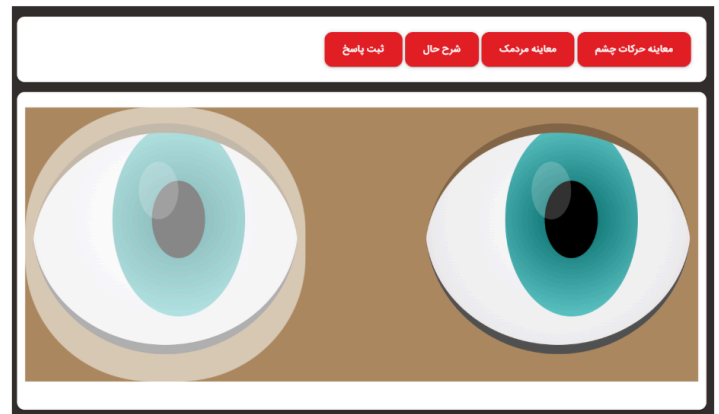


Figure 2

Original examination interfaces created by the development team and reproduced from the thesis. (A) Ocular movement model with left abducens nerve injury selected. (B) Eye movement display in the scenario interface. (C) Pupil display and parameter controls. (D) Simulated illumination during pupil examination. Interface labels remain in Persian. The red tabs in panel D denote eye movement examination, pupil examination, case history and answer submission. The afferent nerve label in panel C contains an identified terminology discrepancy; a corrected release has not yet been verified. Images were arranged into a labelled plate without changing the clinical display or translating embedded interface text. Static illustrations do not establish the accuracy of the animations.