

Enhancing Virtual Learning in Medical Education: Strategies Emerging from the COVID-19 Pandemic in Iran



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Table S1. Traceability matrix: Round-1 strategy items consolidated into final set.

Domain	Round-1 item(s) (Examples)	Action	Final Round Strategy Label	Rationale
Learner	Counseling & psychological support for students	Retained	Provide psychological counseling & support for students	High consensus; no overlap needing merge.
Learner	Provide PPE to medical teams & interns	Retained	Provide personal protective equipment to medical teams & interns	Distinct operational item.
Learner	Certificates/licences for student volunteers	Retained	Issue certificates/licences for student volunteers	Distinct policy lever.
Learner	Financial aid (tuition relief, devices, free internet)	Retained	Provide financial aid to disadvantaged students	Distinct equity lever.
Learner	Dorm stay scheduling & permits for practical/clinical	Retained	Schedule dorm stays & issue permits for practical/clinical	Context-specific but unique.
Learner	Safe rest areas for students in hospitals	Retained	Create safe retreats for students in hospitals	Distinct safety item.
Learner	Learner-centred (andragogical) approaches	Retitled	Adopt learner-centred pedagogies	Clarified terminology; same scope.
Process	Social network of officials/intermediaries for comms	Retained	Create a social network for rapid academic communications	Distinct governance/comms item.
Process	Update/advance-prepare course materials	Retained	Proactively update and pre-prepare course content	Distinct content workstream.

Domain	Round-1 item(s) (Examples)	Action	Final Round Strategy Label	Rationale
Process	Discussion / assignment / test / messaging modules	Merged	Leverage LMS core modules (discussion, assignments, quizzes, messaging)	Four detailed items were merged into one integrated strategy.
Process	National E-Library of Medical Sciences	Retained	Develop the National Electronic Library of Medical Sciences	Distinct national infra.
Process	Integrate similar general courses into one virtual class	Retained	Consolidate similar general courses into shared virtual classes	Distinct efficiency lever.
Process	Interactive dashboards for monitoring course activity	Retained	Use interactive monitoring modules for educational performance	Distinct analytics item.
Process	Part of practical/internship via educational videos	Retained	Deliver portions of practical/internship via instructional videos	Distinct substitution tactic.
Process	Apply lessons learned; address weaknesses in practicals	Retained	Apply virtual-learning lessons to strengthen practicals/internships	Meta-improvement item.
Process	Integrate educational management systems (EMS/LMS)	Retained	Integrate educational management systems	Platform integration, no overlap.
Process	Promote team-based/active/self-directed learning	Retained	Promote team-based, active, self-directed learning with online projects	Pedagogical strand.
Process	Redefine landscape/mission/values/goals/plan	Retitled	Strategic reframing of educational mission & plans	Clearer title, same content.
Process	Develop clinical education accreditation standards (e.g., LCME)	Retitled	Align clinical education with recognized accreditation standards	Localized title, same objective.
Process	Regular reports to vice-chancellor & COVID committee	Retained	Provide regular reports to academic leadership & crisis committee	Distinct governance item.
Process	Flexibility in course quality standards/prereqs/e-content	Retained	Introduce flexible standards for courses, prerequisites, e-content	Policy lever.
Process	Manage change via local/national/international collaboration	Retained	Manage change with multi-level collaboration & stakeholder engagement	Systemic change item.
Process	Develop collaborative/interactive learning model	Retained	Develop a collaborative/interactive learning model	Umbrella pedagogy—kept.
Process	Postpone internships until full containment	Retained (low priority)	Postpone internships until COVID-19 is fully contained	Retained with low score; time-bound.
Technical Infra	24/7 online IT helpdesk for users	Retained	Develop an online IT support system (24/7)	Core enabler.
Technical Infra	Server enhancement (capacity, uptime)	Retained	Enhance server infrastructure	Distinct infra item.
Technical Infra	Platform/system security (auth, privacy)	Retained	Improve platform & system security	Distinct security item.
Technical Infra	Integrate online education technologies	Retained	Integrate online education technologies	Umbrella integration.
Technical Infra	Remote robotic microscopy	Merged	Alternative technologies for remote anatomy/lab learning	Merged with AI, digital libraries, simulation, and haptic technologies.
Technical Infra	AI-assisted learning tools	Merged	↑ Same	—
Technical Infra	Digital libraries	Merged	↑ Same	—
Technical Infra	Clinical simulation laboratories	Merged	↑ Same	—
Technical Infra	Virtual haptic laboratory	Merged	↑ Same	—
Technical Infra	Tech & social media to optimize virtual conferences	Retained	Optimize virtual conferences using appropriate technologies	Event-tech strand.
Technical Infra	Adobe Connect; BigBlueButton; Skype; Skyroom; Zoom	Merged	Standardize synchronous platforms for virtual classes	Merged similar platforms/brands into a single strategy.
Technical/Assessment	Assess dental diagnostic skills; clinical reasoning without procedures	Retained (relabeled)	Assess diagnostic reasoning where clinical procedures unavailable	Evaluation-oriented nature; reassigned to the appropriate domain.
Instructor	Train faculty (online/offline/face-to-face) on ed-tech	Retained	Provide faculty training on platforms & e-infrastructure	Core capacity-building.

Domain	Round-1 item(s) (Examples)	Action	Final Round Strategy Label	Rationale
Instructor	Provide e-content authoring software	Retitled	Provide authoring tools/templates for multimedia e-content	Clearer title.
Instructor	Direct contact with academic staff for problem-solving	Retained	Ensure staff accessibility for problem-solving & information exchange	Distinct comms item.
Instructor	Encourage faculty to produce e-content/packages	Retained	Incentivize faculty participation in e-content development	Distinct incentive lever.
Instructor	Needs assessment & e-content quality control with learners	Retained	Conduct needs assessment & e-content QA before programs	QA/UX strand.
Instructor	Let faculty decide sync/async mix per course context	Retained	Delegate authority on sync/async balance to course teams	Local tailoring.
Assessment	Monitor uploads/assignments/quizzes/activities/feedback	Retained	Implement activity & feedback monitoring indicators	Assessment analytics.
Assessment	Pre-assessment of students before interventions	Retained	Conduct diagnostic pre-assessments	Core FAME-high item.
Assessment	Review academic achievement strategies across programs	Retained	Review program-level achievement strategies	Quality oversight.
Assessment	Diversify teaching/evaluation methods	Retained	Diversify teaching & assessment methods	Broad assessment reform.
Assessment	Replace finals with short-cycle tests/reports	Retained	Replace final exams with short-cycle assessments & reports	Anxiety-reducing/fairness.
Assessment	Survey student satisfaction & experience	Retained	Survey students' e-learning satisfaction & experience	Voice-of-student.
Assessment	Conduct online exams	Retained	Conduct secure online examinations	Distinct modality item.

Table S2. Traceability matrix: Round-1 strategy items consolidated into final set.

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