

Supplemental Digital Content 1. Table of the included intervention studies (n=86)					
Authors, publication year, country	Study purpose	Academic discipline(s)	Main digital means of intervention	Methodology / design	Data collection method(s)
Achuthan et al ²⁰ 2017, India	To investigate changing learning modalities of laboratory environments with a focus on interventions to improve reflective thinking in skill-based education.	Engineering and Technical sciences (engineering)	Virtual laboratories	Two experimental groups; independent control group (reference group after 7 weeks); post-test	Questionnaire
Agraval et al ⁴⁵ 2016, India	To evaluate the effectiveness of virtual classroom training in improving maternal and newborn-related skills.	Health sciences (nursing)	Virtual classroom training	A pre- and post-intervention design, no control group	Checklist
Alnabelsi et al ⁸² 2015, UK	To assess and compare face-to-face teaching with synchronous e-learning using teaching on otolaryngological emergencies as an educational intervention.	Health sciences (medicine)	e-learning (synchronous = streamed lecture)	A randomized controlled trial	Test, scale
Alvarez et al ⁶³ 2017, Brazil	To evaluate the results in learning about assessment of acute pain in adults and newborns.	Health sciences (nursing)	Virtual learning object	Quasi-experimental	Questionnaire, test
Avci & Adiguzel ⁵⁵ 2017, Turkey	To explore the effects of using mobile instant messaging application WhatsApp on language proficiency.	Humanities (language)	Mobile application	Mixed methods	Peer evaluation form, scoring rubric, log files, interviews
Aydin & Dinc ⁷⁷ 2017, Turkey	To evaluate the effectiveness of web-based instruction on improving students' arithmetical and drug dosage calculation skills.	Health sciences (nursing)	Web site (designed)	Quantitative one-group with two measures	Skill Test
Azman & Esteb ⁴³ 2016, USA	To examine whether a concrete coin-flipping analogy and associated free web app for teaching provide students understanding of spin-spin splitting.	Physical sciences (chemistry)	Web application	Pre-test/post-test design	Survey, quiz
Bai et al ⁶⁶ 2016, USA	To assess the effectiveness of a newly developed web-based modules on learning motivations and outcomes.	Engineering and Technical sciences (engineering)	Online learning platform	Quasi-experimental	Scale, Knowledge Test

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Basitere & Ivala ⁹⁰ 2017, South Africa	To evaluate the effectiveness of the use of Facebook, clicker technology, and web-based homework systems for enhancing learning through interaction and dialogue activities.	Engineering and Technical sciences (engineering)	Social network site, clicker technology, web-based homework	Mixed methods	Facebook data, survey, interviews, test, summative assessment
Bellhäuser et al ⁹⁴ 2016, Germany	To explore the possibility of fostering self-regulated learning with the help of a web-based training. To demonstrate the effectiveness of WBT (web-based training) on SRL (self-regulated learning) knowledge, learning behavior, and performance.	Engineering and technical sciences (computer science, civil engineering, mechanical engineering, mathematics)	Online learning	Randomized control evaluation Pre- and post-test	Questionnaire, test, learning diary
Blau & Shamir-Inbal ²¹ 2018, Israel	To explore the role played by digital technologies in creating a space for student voices and enhancing teaching, learning, and assessment in an academic course.	Social sciences (education)	e-learning platform, videoconferencing system	Case study	Reflective documents, digital sources
Boada et al ³⁶ 2015, Spain	To evaluate the use of LISSA (serious game) as a tool to complement CPR (cardiopulmonary resuscitation) teaching.	Health sciences (nursing)	Serious game	A randomized controlled trial	Tests, performance evaluation, questionnaire
Bozoglan & Gok ²² 2017, Turkey	To investigate the impact of a mobile assisted dialect awareness program on dialect attitudes.	Humanities (language)	Mobile application	Experimental group & control group, randomized	Test
Carlson et al ⁷³ 2017, Sweden & Hong Kong	To explore how students perceived achieved learning outcomes after participating in a web-based, intercultural, peer-learning intervention.	Health sciences (nursing)	Online peer discussions	Qualitative and interpretative design	Reflective journal, interview
Carpenter et al ⁷⁵ 2015, USA	To compare a web-based curriculum with a traditional lecture format on students' cultural competency attitudes.	Health sciences (medicine)	Online learning module (website)	A randomized trial	Survey
Carter & Wiles ⁹⁶ 2016, USA	To compare the effects of two different sets of videos on students' knowledge of and attitudes towards climate change as well as how the two sets of videos were received by	Life sciences (biology)	Video	Pre-test-post test design	Survey, knowledge measure

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Chang et al ¹⁰¹ 2017, Taiwan	To test the effects of cultural competence education.	Health sciences (nursing, pharmacy, nutrition)	Social media application	A randomized controlled trial	Questionnaire
Chao et al ³⁹ 2017, Taiwan	To develop and implement an interactive, situational e-learning system integrated into the course, and to evaluate the effects of it on students' ethical decision-making competence.	Health sciences (nursing)	Online learning	Quasi-experimental	Questionnaire
Chaves et al ⁸⁶ 2015, Brazil	To assess the learning effectiveness of a serious game designed to support the teaching of software process modeling, and to compare game-based learning with a project-based learning method.	Engineering and Technical sciences (engineering)	Serious game	Experimental design (pretest/ posttest randomized control group design)	Test, questionnaire
Chingos et al ⁴⁴ 2017, USA	To test whether offering low-cost, online-only summer math preparation programs could improve students' math skills.	Physical sciences (mathematics)	Online education	Intervention and control groups, randomized, pre-post	Survey, interview, placement test scores, logs, transcript data, demographics
Choi et al ⁴⁰ 2018, Republic of Korea	To examine the effect of an experiment that introduced a mobile academic electronic medical record application for students in their practicum.	Health sciences (nursing)	Mobile application	Quasi-experimental	Questionnaire
Chyr et al ⁹⁷ 2017, Taiwan	To explore the effects of online academic help-seeking and flipped learning on students' development of involvement, self-efficacy, and self-directed learning.	Engineering and technical sciences (computing education)	Mobile application, video	Quasi-experimental	Skills examination, questionnaire
Dankbaar et al ⁴⁶ 2017, The Netherlands	To investigate whether students developed better patient safety knowledge and awareness and were more motivated after engaging with a serious game than after studying a simple e-module.	Health sciences (medicine)	Serious game and e-learning module	Randomly assigned to two groups + historical control group	Knowledge test, self-efficacy test, questionnaire, log data, interviews

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Davidson & Candy ⁵³ 2016, Canada	To describe the development and evaluation of an innovative teaching strategy that aims to better prepare students to engage in EBP (evidence-based practice).	Health sciences (nursing)	Game-based online course	One-group, descriptive, developmental evaluation	Survey, game platform analytics, narrative comments, grades
Davie et al ⁷⁸ 2015, USA	To compare outcomes of Quick Clips instruction with face-to-face instruction.	Health sciences (athletic training)	Quick clips videos	Quasi-experimental	Questionnaire, knowledge test, skill examination
Desplaces et al ⁷¹ 2015, USA	To test the effect that learning strategies, including learning tools and method of teaching delivery, may have on student synthesis of information. To examine whether use of e-learning tools and method of teaching delivery moderates the relationship between student readiness to learn and the students' ability to synthesize information learned during the semester.	Social sciences (management)	Online learning (e-learning tool)	Case study	Survey, e-learning tool, case study assignment
Diliberto-Macaluso & Hughes ⁵⁶ 2016, USA	To examine the impact of mobile applications or apps on student learning in an introduction to psychology course.	Social sciences (psychology)	Mobile application	Pre-posttest design, experimental and control groups – randomization	Test
Djukic et al ⁷⁰ 2015, USA	To examine the impact of two interprofessional education interventions on improving learners' knowledge, skills, and attitudes for interprofessional teamwork and collaboration.	Health sciences (nursing, medicine)	Virtual learning (team member)	Pre-test post-test design	Tests, scales
Evens et al ²³ 2017, Belgium	To examine the effects of an online learning environment on pedagogical content knowledge, content knowledge, and pedagogical knowledge.	Social sciences (education)	Online learning environment	Quasi-experimental	Questionnaires

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Fattah ²⁴ 2015, Saudi Arabia	To determine the effectiveness of using WhatsApp as a mobile learning technique to develop students' writing skills.	Humanities (language)	Mobile application	Quasi-experimental; pre-post test, experimental and control groups	Questionnaire, test
Fernández-Alemán et al ³⁷ 2016, Spain	To test the educational effectiveness of a mobile-based assessment approach that can be used to provide students with intelligent diagnostic feedback.	Health sciences (medicine)	Audience response system	Experimental and control groups, randomized	Online tool for administration facilities, tests, questionnaire, final examination
Fernández-Lao et al ⁴⁷ 2016, Spain	To investigate whether a mobile application as a supplement to traditional learning is useful in the acquisition of palpation and ultrasound skills in the shoulder area.	Health sciences (physiotherapy)	Mobile learning	Single-blinded, randomized controlled study	Clinical evaluation, questionnaire
Fernandes Pereira et al ⁹⁵ 2016, Brazil	To evaluate the influence of the use of digital applications in medicament calculation education.	Health sciences (nursing)	Mobile application	Experimental study; intervention and control groups, randomization post-test	Test
Fleming et al ¹⁰⁰ 2016, USA	To evaluate whether the student success associated with the U-Pace instructional approach would replicate for both economically disadvantaged students and students who are not economically disadvantaged.	Social sciences (psychology)	Online learning (instructional intervention)	Intervention and comparison groups in two universities (other randomized, other not)	Final grades, quiz, cumulative exam
Foster et al ⁴⁸ 2016, USA	To evaluate students' verbal empathy in a standardized patient interaction after being taught empathic communication by a virtual patient.	Health sciences (medicine)	Virtual patient	Three groups, randomized	Checklist, questionnaire
Franciosi ²⁵ 2017, Japan	To examine the effectiveness of computer game-based approaches in foreign language learning.	Humanities (language)	Online (computer) game	Study I: Quasi-experimental Study II: Cross-sectional analysis	Study I: Vocabulary test, writing task Study II: Vocabulary test + Quizlet score, writing task

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Gartmeier et al ²⁶ 2015, Germany	To investigate the effectiveness of three different versions of a training program (e-learning) on physician–patient and teacher–parent conversations.	Social sciences (education) and Health sciences (medicine)	e-learning with video cases	A randomized controlled trial	Questionnaire, simulated communications
Gyamfi & Gyaase ⁷⁹ 2015, Ghana	To assess students' perception of blended learning environments.	Social sciences (education)	Online learning	Formative experiment / pre-post	Survey, activity logs, interviews, observation, document analysis
Göktürk ²⁷ 2016, Turkey	To examine the effectiveness of digital video recordings on English as a Foreign Language learners' oral performance, in particular, on fluency + to examine the learners' perceptions of the use of digital video recordings in a speaking class.	Humanities (language)	Digital video	Mixed methods (pre- and post-test scores)	Speech samples, interview
Hazaea & Alzubi ⁶⁷ 2016, Saudi Arabia	To investigate the efficiency of using mobile technology in English as a Foreign Language reading classroom.	Humanities (language)	Mobile application, online resources	Mixed methods	Mobile application, self-reflection journals, interviews, test
Ijaz et al ²⁸ 2017, Australia	To test the learning effectiveness of using virtual worlds and virtual agents in history education.	Humanities (history)	Virtual learning environment	Three group pre- and post-test	Questionnaire
Kim & Suh ⁴⁹ 2018, Republic of Korea	To evaluate the effect of an interactive nursing skills mobile application for students' knowledge, self-efficacy, and skills performance.	Health sciences (nursing)	Mobile application	A randomized controlled trial	Checklist, scenarios, questionnaire
Kow et al ⁵⁰ 2016, Singapore	To evaluate the outcome of patient safety perception using the PASSED game.	Health sciences (medicine)	Mobile (serious) game	Pre-post, one group	Questionnaire
Lameris et al ⁷² 2015, The Netherlands	To determine whether formative testing using an Internet-based application can positively affect study behaviour as well as study performance.	Health sciences (medicine, biomedicine)	Mobile application	Post-test, one group	Exam grades, information regarding the individual scores, questionnaire
Lanken et al ⁶⁸ 2015, USA	To examine whether an Internet-based learning module and small-group debriefing can improve trainees' attitudes and	Health sciences (medicine)	Online learning	A cluster randomized controlled trial	Surveys, interviews

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	communication skills toward patients with substance use disorders.				
Lee et al ⁴¹ 2016, South Korea	To identify the effects of a mobile-based video clip on learning motivation, competence, and class satisfaction.	Health sciences (nursing)	Mobile video clip	A randomized controlled trial	Survey , knowledge test, procedure checklist, scale
Leung et al ²⁹ 2015, Hong Kong (China)	To study the effects of exposure to the two types of virtual patient—interactive and longitudinal—on student learning.	Health sciences (medicine)	Virtual patient	2x 2 cross over design	Questionnaire, essay questions paper, questionnaire, login data
Liu et al ⁸⁸ 2017, USA	To investigate the impact of an adaptive learning intervention to provide remedial instruction in biology, chemistry, math, and information literacy.	Health sciences (pharmacy)	Online learning (adaptive learning system)	Mixed methods design Pre/post test	University admissions data, performance test, scale, survey, interviews
Long et al ⁸⁵ 2016, USA and Middle East (Lebanon)	1) To report the results of the effectiveness of the EBR (evidence-based research) tool to improve the overall online research and critical appraisal skills of learners engaged in EBP (evidence-based practice).	Health sciences (nursing, nutrition, pharmacy)	Online tool	A mixed-method, quasi-experimental (1), two-population randomized controlled trial (2)	A series of questions, EBR-tool data
Lu et al ⁹² 2017, Taiwan	To evaluate the effectiveness of the learning analytics experiment.	Engineering and technical sciences (computer science)	MOOC / learning analytics	Pre/post test Experimental / control group	Questionnaire, skill test
Martin & Ertzberger ⁸³ 2016, USA	To examine the effects of different types of reflection during here and now mobile learning on student achievement and attitude.	Social sciences (education)	Mobile application (virtual expert)	Quasi-experimental	Test, survey
Millis et al ⁹³ 2017, USA	To examine whether implementing game-based features to an existing Intelligent Tutoring System would affect learning and, to a lesser degree, motivational and other noncognitive components.	Social sciences (education)	Serious game embedded to ITS	A pre-test, post-test randomized control design 2 experiments	Test, survey
Murphy et al ⁷⁴ 2017, UK and Somaliland	To evaluate PBL (problem-based learning) applied to peer-to-peer global mental health e-learning.	Health sciences (medicine)	Online tutorials	Mixed methods	Surveys, questionnaire
Nickerson et al ⁸⁹	To explore the influence of mobile learning on	Social sciences	Mobile learning	Pretest – posttest	Knowledge test,

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2017, United Arab Emirates	students' acquisition of conceptual knowledge of business communication as well as on the development of their communication skills.	(business communication)		Intervention / control	comprehension test
Nguyen ⁸⁷ 2015, Vietnam	To assess the impact of the web-based simulated game practiced in operations management courses on students' intrinsic motivation and their use of deep learning strategy.	Social sciences (education)	Online (simulation) game	Quasi-experimental	Questionnaire
O'Bannon et al ³⁰ 2017, USA	To examine the effects of an interactive textbook on student achievement.	Social sciences (education)	Interactive textbook	Mixed-methods	Exam scores, survey, blog posts, interviews
Oner & Adadan ³¹ 2016, Turkey	To investigate the effectiveness an integrated web-based portfolio system on student' reflective thinking skills + the role of feedback instructions and the usability of portfolio software.	Social sciences (education)	e-Portfolio	Mixed-methods	Portfolio entries, questionnaire
Park et al ¹⁰³ 2016, Korea	To identify the educational effects of a blended e-learning program on self-efficacy, problem solving, and psychomotor skills for core basic nursing skills.	Health sciences (nursing)	e-learning education	Quasi-experimental	Questionnaire, skill monitoring
Pellas & Kazanidis ³² 2015, Greece	To measure and compare student engagement after completing courses through the virtual world in blended or online instructional formats.	Engineering and technical sciences (computer technology)	Virtual world	Quantitative	Questionnaire
Pourmand et al ⁶² 2015, USA	To evaluate the impact of an online asynchronous training module on the ability to detect electrocardiogram abnormalities of an acute myocardial infarction.	Health sciences (medicine)	Online learning module	Pre-post test	Test
Pusponegoro et al ⁵¹ 2015, Indonesia	To evaluate the effectiveness, acceptability, and usability of web-based training on a simple, gross motor screening method in infants.	Health sciences (medicine)	Online learning module	Two-group pre- and posttest design with randomization	Questionnaire, scale
Remón et al ³³	To examine learning and engagement obtained	Engineering and	Smartphone	(Mainly) Post-test	Question and answer

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2017, Spain	with the use of smartphones and tablets.	technical sciences (engineering)	application, tablets		methods, questionnaire, test
Rojjanasrirat & Rice ⁶⁴ 2017, USA	To evaluate changes in evidence-based practice knowledge, attitudes, and practices of students before and after completing an online introductory research/EBP course.	Health sciences (nursing)	Online learning	A prospective one-group pretest-posttest design	Questionnaire
Rolskov Bojsen et al ⁹⁹ 2015, Denmark	To examine the effect of a stand-alone web-based ECG (electrocardiogram) tutorial and to assess the retention of skills using multiple follow-up intervals.	Health sciences (medicine)	Online learning module	Pre-test & post-test (& retention test)	Test
Sabatino et al ¹⁰⁴ 2017, USA	To assess impact of educational intervention students' prescribing skills, perception of preparedness to prescribe, and perception of pharmacist as collaborator.	Health sciences (nursing, pharmacy)	Online education module	Prospective pre-post assessment	Assesment tool, survey
Salajegheh et al ⁶⁹ 2016, Australia	To investigate the effectiveness of e-learning for the development of X-ray interpretation skills.	Health sciences (medicine)	e-learning course	Quasi-experimental	Questionnaire
Schneider et al ³⁸ 2015, Germany	To find out whether web-based case-oriented multimedia learning and teaching platform (CASUS) leads to an improved learning outcomes and how students react this form of teaching.	Health sciences (medicine)	Online learning / Virtual patient	A randomized study (pre-post-test)	Tests, questionnaire
Shang & Chen ⁸⁰ 2018, Taiwan	To investigate the impact of online autonomous learning on English as a foreign language students' reading ability.	Humanities (language)	Online learning (reading tool)	Pre-test and post-test Control & experimental	Comprehension test, questionnaire, interview
Shih ⁵² 2018, Taiwan	To investigate the effects of teaching English for specific purposes in a language laboratory and through the mobile LINE app.	Humanities (language)	Mobile application	Quasi-experimental Randomized groups	Test, quiz, questionnaire, observation, reflection, interview
Sobocan et al ⁹⁸ 2016, Slovenia	To examine the effect that a virtual patient has on overall knowledge, test performance, and improvement of diagnostic thinking ability in comparison to paper PBL.	Health sciences (medicine)	Virtual patient	A randomized controlled study	Knowledge exam, questionnaire

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Steinke et al ⁶¹ 2016, USA	To evaluate a web-based social-cognitive intervention for evidence-based sexual counseling.	Health sciences (nursing)	Online education module (website)	A pre-post-test design.	Questionnaire
Swart ⁵⁴ 2017, Canada	To determine to what extent incorporating explicit critical thinking instruction and technology-enhanced learning environments contribute to development of critical thinking.	Health sciences (nursing)	Classroom response system Online discussion forum	Mixed methods	Skills test, survey, online discussion postings
Tan et al ⁴² 2017, Singapore	To describe the development and evaluation of a serious game to improve students' knowledge, confidence, and performance in blood transfusion.	Health sciences (nursing)	Serious game	A clustered, randomized controlled trial	Questionnaire, scale, tool
Tezer & Çimşir ⁸⁴ 2018, Turkey	To examine the impact of using mobile-supported learning management systems in teaching web design on the academic success of students and their opinions on the course.	Engineering and technical sciences (computer programming)	Mobile application	A mixed method design (Quasi-experimental)	Test, questionnaire
Thalluri & Penman ¹⁰⁵ 2015, Australia	To investigate the success of Facebook as an educational tool.	Health sciences (medicine, nursing)	Social media application	Post-test	Questionnaire
Thomas & Fellowes ⁵⁷ 2017, UK	To find out if mobile technology could improve field-based learning using the ability to identify birds as the study metric.	Life sciences (biology)	Mobile application	Pre-and 2 post-tests	Spots test, questionnaires
Tsai ¹⁰² 2016, Taiwan	To compare the effects of online team-based learning and co-regulated learning on improving students' computing skills.	Engineering and technical sciences (information management)	Online learning (Moodle)	Quasi-experimental Pretest–posttest design	Skills test, exam
Van Lancker et al ⁹¹ 2016, Belgium	To evaluate the effectiveness of an e-learning course compared with a face-to-face lecture on medication calculation.	Health sciences (nursing)	e-learning course	Quasi-experimental design	Test, participant logging information
Velan et al ⁶⁵ 2015, Australia	To compare the efficacy and perceived impact of interactive e-learning modules versus static versions of validated clinical decision rules for learning about appropriate imaging referrals.	Health sciences (medicine)	Online learning	A multicenter, randomized, crossover trial	Knowledge assessment, questionnaire
Virtanen et al ⁵⁸	To compare the students' satisfaction with a	Health sciences	360°–ubiquitous	Quasi-experimental	Questionnaire

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2017, Finland	ubiquitous, learning environment based on 360°– technology and a traditional web-based online learning environment.	(biomedical laboratory science)	learning environment		
Wake et al ⁸¹ 2017, USA	To investigate the effects of virtual coaching as an innovative approach to conducting clinical internships.	Social sciences (education)	Online / virtual coaching	Descriptive study, convenience sampling	Focus groups
Wang ³⁴ 2017, Taiwan	To examine the effectiveness of a self-paced mobile learning integration instruction.	Humanities (language)	Mobile application	Quasi-experimental	Reading test, questionnaire
Woodham et al ⁷⁶ 2015, UK	To explore how students interpreted and evaluated information from video- and text-based materials presented in the context of a branched, interactive, online, virtual patient designed for PBL.	Health sciences (medicine)	Virtual patient	Convergent parallel study design	Survey, discussion
Yang ⁵⁹ 2017, USA	To investigate whether the effects of pragmatics instruction delivered via a self-access website in a Chinese as a foreign language learning environment vary according to learners' language proficiency.	Humanities (language)	Online learning (website)	Pretest-posttest design	Survey, test, reflective e-journals
Yilmaz ⁶⁰ 2015, Turkey	To investigate the effects of a live virtual classroom on students' achievement in distance learning and to determine students' opinions about the live virtual physics classroom in distance education.	Engineering and technical sciences (computer education)	Online learning (virtual classroom)	Post-test	Exam scores, interview
Yilmaz & Yurdugul ³⁵ 2016, Turkey	To compare concept-focused discussion environments in terms of learning perception, usefulness perception, contribution quality, and student learning styles relative to the traditional discussion environments.	Social sciences (education)	Online learning (asynchronous discussion boards)	Experimental design (experimental and control groups) (groups randomized)	Scale