Digital Learning Designs in Physiotherapy Education: A Systematic Review and Meta-Analysis.

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Abstract

Background: The extent that digital learning designs can improve learning outcomes has been increasingly emphasized in higher education over the last decade, but the research within physiotherapy education is limited. This study identified different types of digital learning designs and their effectiveness in physiotherapy education.

Methods: The study was designed as a systematic review and meta-analysis of randomized and non-randomized trials. A search of eight databases on digital teaching and learning technology was conducted. Study selection, methodology and quality assessment were performed independently by three reviewers. The included studies were mapped according to the types of digital interventions and studies. For interventions that were similar, the learning effects were calculated using meta-analysis.

Results: Fifteen randomized and five control trials were included in the review; 8 of 20 articles were included in the meta-analysis. The main digital learning designs were blended learning, flipped classrooms, e-learning course designs and Mobil learning designs (apps) using different digital tools, software and learning platforms. The evidence from two meta-analysis showed statistically significant effects: flipped classrooms on knowledge acquisition, SMD of 0.41 (95% CI 0.20, 0.62) and websites (apps) on practical skills, SMD of 1.06 (95% CI 0.70, 1.42). A meta-analysis of website and knowledge acquisition favoured traditional teaching, SMD of -0.59 (95% CI -1.20, 0.03), but this was not statistically significant. Overall, the effects indicated that digital learning designs are more or equally effective than traditional classroom teaching for achieving learning outcomes.

Conclusions The findings of this review show various use of digital learning designs in physiotherapy education, ranging from e-learning using digital learning resources to more complex and coherent flipped learning designs. The results indicate that these designs improved or was equal effective compared to traditional classroom teaching. The meta-analysis revealed a significant effect on student learning in favour of flipped classrooms and websites (apps). However, these results must be confirmed in larger controlled trials or randomized controlled trials. Further research should investigate how digital learning designs can be used to facilitate students' learning of practical skills and behaviour as well as learning retention, learning approaches and preferences for studying in digital learning environments.

Background

During the last decade, digital learning designs have been increasingly emphasized in higher education. It has been claimed that digital learning will streamline, improve the quality of, reduce the costs for and enhance sustainable higher education (1, 2). A number of studies have explored how digital learning can transform, facilitate, support and enhance students' learning outcomes (3, 4). A digital learning design refers to a coordinated set of planned content, learning activities and assessment methods that fully or partly integrate digital learning technology to support students to achieve learning outcomes in a course (5, 6). These designs can be conceptualized in different ways regarding context and subjects, such as blended learning, flipped classrooms, Computer Assisted Instruction (CAI) design, remote online learning, online/e-learning courses, distance learning, Massive Open Online Courses (MOOCs) or Mobile learning applications (app). Digital learning designs are often conceptualized as synchronous online learning (i.e. being together at the same time) or asynchronous learning that is a relay of information with a time lag (e.g. video captures, discussion forums, answering multiple choice tests or writing together; (7). The various designs provide different opportunities for improving students' abilities for self-regulating, facilitate increased learning activities and make the learning process more transparent (3). Physiotherapy education is currently undergoing major changes in terms of strengthening educational quality (8). It is characterized by a combination of teaching theory, skills training and practice (9). The physiotherapy profession is intended to have an independent decision-making authority and an important role in interdisciplinary health teams (10). These are skills that can be associated with higher-order learning activities (11). Accordingly, physiotherapy education is important to ensure that highly qualified graduates are able to provide efficient services to the population in need of their competence. Students need to be introduced to learning activities that support and facilitate this competence. Flipped classroom designs can facilitate and support this process (12).

Several reviews have provided summaries of the different digital learning designs, however, they leave a mixed impression of these approaches and their benefits. Regarding blended learning, research shows better knowledge acquisition in health-profession students who received blended learning compared to traditional teaching (4, 13, 14). Research in flipped-classroom designs has emerged in health professional education (15, 16). One systematic review showed significant improvement in student learning (17), but another concluded that the results varied and showed no clear evidence that the flipped classroom produced better results (18, 19). Simulation and Mobile learning (apps) are growing fields to facilitate learning, especially when learning practical skills (3). For example, using virtual patients in the learning design, evidence shows that when compared with traditional teaching, virtual patients can more effectively improve students' skills, and at least as effectively improve students' knowledge (20). To our knowledge, there is only one systematic review from 2015 that summarizes studies on effects of digital learning technology in physiotherapy education (21). The results showed that online technology (e.g. web pages and discussion forums) has many advantages when used in physiotherapy teaching to achieve students learning. The aim of this systematic review was to identify and investigate the effectiveness of various digital learning designs in physiotherapy education.

Methods

This systematic review was carried out according to the PRISMA (Preferred Reporting Items for Systematic reviews and Meta-Analysis) guidelines (22). The protocol of the systematic review was registered in the international prospective register of systematic reviews (PROSPERO) with registration number CRD42019134917.

We included randomized controlled trials (RCTs) and controlled trials (CTs) that met the following criteria: (a) a study population of physiotherapy students in a physiotherapy education program (bachelor's, master's, DPT or PhD); (b) assessing the learning outcomes in a digital learning design (e.g. flipped classroom); (c) compared to traditional classroom teaching; (d) on final grades and students' self-reported learning outcomes (students' motivation, attendance, commitment, engagement and satisfaction with the learning design). We included only studies with summative assessments for the final exam (grades of a subject) to measure knowledge, skills or affective learning outcomes (such as values, attitudes and behaviours; (23).

The exclusion criteria were studies where less than half of the study population were physiotherapy students, studies that were aimed to train graduated physiotherapists in work life (e.g. courses and seminars that did not provide credits, ECTS), studies where the use of digital learning technology was not part of an explicit learning strategy and studies in languages other than English or Scandinavian.

Search strategy

Two Information specialists (MWG, EK) searched in the following databases: Medline, Cinahl, Education Resources Information Center (ERIC), Education Source, Scopus, Teacher Reference Center, Embase and Cochrane Central. The search period was from January 2010 to April 2019. To our knowledge, there are limited uses of learning designs in physiotherapy education before 2010. We therefore chose to refine the search to 2010, and this search had broader search terms for digital learning designs than Macznik, Ribeiro and Baxter (21). Examples of the complete search strategy are shown in the Additional file 1.

Selection of articles and data extraction

Three reviewers (NBØ, HTM, YR) independently screened the titles and abstracts from the literature search for relevance. We used Rayyan as a screening tool (24). The relevant articles were assessed independently in full text by the reviewers. The full-text articles that met the inclusion criteria were included in the review. Disagreement on selection of articles was solved by discussion until a consensus was reached.

The following data were extracted from the included studies by the first author (NBØ) and cross-checked by two of the other authors (HTM and YR): authors of the study, publication year, country, study design, characteristics of the population (e.g. level of education), characteristics of the interventions (e.g. flipped classroom) and comparisons

(traditional classroom teaching) and outcomes (e.g. grades and method of assessment). The final decision on the articles included was made in a discussion meeting where all authors participated.

Risk of bias assessment

We assessed the risk of bias of included RCTs and CCTs using the Cochrane's risk of bias tool (25). The risk of bias assessment was conducted by three reviewers (NBØ, HTM, YR) independently. Bias was assessed as a judgment using high, low or unclear for the five domains: selection, performance, attrition, reporting and other potential threats to validity (25).

Data analysis

First, the included articles were categorized according to the study design. Thereafter, the descriptions of the digital technologies and the descriptions of the learning designs and learning outcomes were used to group the articles into meaningful categories based on their similarities. We calculated mean difference (MD) for pooling similar continuous outcomes (e.g. students' satisfaction with the learning design reported on a Likert scale of 1–5) and we used standardized mean difference (SMD) where the included studies used different scales for the same outcome. For all outcomes, we reported the associated 95% confidence intervals (CIs). Double-data entries were performed. The meta-analysis is based on a random-effects model, as we expected heterogeneity across the included studies. Studies that reported similar populations, interventions and outcomes were pooled in the meta-analysis. For studies that were too heterogeneous for pooling, we presented the results in the text and tables.

Results

Altogether, we included 20 studies (see Fig. 1) with 2,056 participants (study range N = 16–176). The students were at the bachelor's/undergraduate/entry level (n = 15), master's level (n = 1) and Doctor of Physical Therapy program level (n = 4). Of the included studies, seven were from the USA (39–45), five from Australia (26–30), four from Spain (31–34), three from Brazil (35–37) and one from Denmark (38). Fifteen of the studies had an RCT design (26, 28–38 43–45), and five were controlled trials (27, 39–42). All the studies were published between 2010 and 2019. A detailed overview of the included studies is displayed in Table 1.

Table 1
a. Characteristics of included studies: randomized controlled trials (RCT)

Author, year, country, study design	**Population**	**Intervention and Comparison**	**Outcome(s)**
Arroyo-Morales, 2012 Spain RCT	BA Physiotherapy second year n = 46	**Context**: theoretical acquisition and skills training on campus **Subject/skills**: palpation and ultrasound examination of the knee joint **Duration**: In-class: Two 2-hour sessions, traditional lectures Self-studies: 20 hours **Intervention**: In-class: traditional lectures Post-class: Free access to the ECOFISIO website **Comparison**: In-class: Two 2-hour sessions, traditional lectures Access to documents and books on the topic **Both groups**: 3-week self-study period	**Multiple-choice Questionnaire (MCQ)**: 20 questions (max 10 points). Also measured the time taken by the student to generate a reliable ultrasound image and to localize a specific knee structure by palpation **Objective structured clinical evaluation (OSCE)**: skills in palpation and ultrasound imaging of the knee. Grading system: 3 = excellent, 0 = incorrect (max 15 points each) **Students' evaluation**: quality of the educational intervention: competence of the teacher, students' acquisition of knowledge/skills, students' interest in participating in the study of another anatomic region and, for the experimental group, satisfaction with the ECOFISIO website. Also asked whether they would have preferred to be in another study group. 5-point Likert scale (5 = strongly agree, 1 = disagree)

Author, year, country, study design	Population	Intervention and Comparison	Outcome(s)
Blackstock, 2013 Australia RCT 1 and 2	BA Physiotherapy first year n = 349	**Context**: simulation training in campus and clinical placement **Subject/skills**: cardiorespiratory **Duration**: 4 weeks **Intervention 1**: Simulated learning environments (SLEs) videos. Delivered in 2 ways. Intervention 1: first week in the SLE, then 3 weeks in clinical immersion **Intervention 2**: 50% of their day in the SLE and 50% in clinical immersion during the first 2 weeks (1 full-time SLE week), then 2 weeks in clinical immersion **Comparison**: 4-week clinical immersion	**Practical exam**: assessment competency to practice in the cardio-respiratory field, measured in two clinical examinations using the Assessment of Physiotherapy Practice (APP): 7 key standards. 0–4 scale: 0 = infrequently/rarely demonstrates performance indicators, 4 = demonstrates most performance indicators to an excellent standard. N/A = not applicable and not assessed **Students' evaluation**: Scales for analysis of student's confidence rating for student's self-rating of confidence with patients in communication, assessment and management, 13 Likert items. Checked for reliability (Cronbach's α)
Cantarero-Villanueva, 2012 Spain Single-blind RCT	BA Physical therapy n = 44	**Context**: theoretical acquisition and practical training on campus **Subject/skills**: musculoskeletal palpation and ultrasound assessment of the lumbopelvic area **Duration**: 1 semester **Intervention**: 6 classroom hours (traditional lectures and practical training) and 20 self-study hours and free access to a website (ECOFISIO) on musculoskeletal palpation and ultrasound assessment **Comparisons**: In-class: traditional lectures and practical training. 20 self-study hours: access to documents and books on the topic	**OSCE**: ultrasound imaging, two components: musculoskeletal and skills in Ultrasound Imaging (USI). Grading system: 3 = excellent, 0 = incorrect. Maximum score: 9 (musculoskeletal) and 15 (USI) points. Validated. After OSCE: students invited to establish 2 additional measurements in the same model. Graded one at time using the same human model. **Students' evaluation**: quality of the educational program, 5-point Likert scale (5, strongly agree; 1, disagree). Participant assessments included competence of the teacher, participants' own acquisition of knowledge/skills, the complexity of the knowledge/skills, the possibility of participation using e-learning and for the experimental group, satisfaction with the ECOFISIO website

Author, year, country, study design | Population | Intervention and Comparison | Outcome(s)

Author, year, country, study design	**Population**	**Intervention and Comparison**	**Outcome(s)**
da Costa Vieira, 2017 Brazil Prospective controlled, randomized, cross-over study	BA Physiotherapy (2–4 year) n = 72	**Context**: theoretical acquisition on campus **Subject/skills**: physiotherapy in oncology (PHO) **Duration**: 2 days and six modules (three modules/day) **Intervention**: Group A: e-learning/traditional lectures/e-learning sequence E-learning: e-lectures. At the same time as group B, had the same e-learning classroom (storage material) using an individual computer, 5 minutes given to study with the computer Group B: Traditional lectures/e-learning/traditional lectures, 5-minute discussion with the teacher after the content ended. Study the slides' content, no professors for discussion. The same content was given to class A and B at the same time, and a sequential change. After each model, students had 30 minutes to change to the other classroom.	**Knowledge test**: seven relevant objectives, seven questions per module. Questions with few words, minimize the student's reading time and to increase the test's reliability. Three types of answers: true, false or do not know. Test contained 126 questions. Summative evaluation: end of each module, objective assessment: 21 questions. Three types of answers: true, false or do not know **Students' evaluation**: level of satisfaction with the different teaching methodologies and course content: free space to gather information about the course, evaluation format, and suggestions and criticisms

Author, year, country, study design	Population	Intervention and Comparison	Outcome(s)
Fernandez-Lao, 2016 Spain Single-blind, RCT	BA, Physiotherapy first semester n = 49	**Context**: theoretical acquisition and skills training in campus **Subject/skills**: musculoskeletal assessment competencies **Duration**: six learning lessons and 20 self-study hours **Intervention**: Free access mobile learning application (ECOFISIO): supplement to traditional lectures, access after the traditional lectures **Comparison**: In-class: traditional lectures and access to documents and books on the topic	**MCQ**: 20 questions and maximum 10 points. **OSCE**: skills assessed with two components: ultrasound and palpation. Grading system: 3 = excellent to 0 = incorrect. Maximum score: 15 (ultrasound) and 12 (palpation) points each **Students' evaluation**: quality of the intervention: 5-point Likert scale (5 = strongly agree, 1 = strongly disagree); 11 numeric point rating scale (10 = totally satisfied to 0 = totally unsatisfied)
Huhn, 2013 USA RCT	DPT Program, first year n = 53	**Context**: theoretical acquisition and skills training on campus **Subject/skills**: pathology II **Duration**: 1 semester **Intervention**: Virtual patient simulation (VP) on clinical reasoning, knowledge acquisition, transfer of knowledge, and students' perception of their learning. Six patient cases. Working individually in campus computer laboratory with the faculty facilitator available to answer only technical questions related to the function of VR program. **Comparison**: In-class: Large group discussion (LGD). Six patient cases.	**MCQ**: Health Science Reasoning Test (HSRT): clinical reasoning prior to and after completing six patient cases in their respective group. HSRT: 30-item test designed to assess skills of induction, deduction, analysis, evaluation, and inference. An overall score and scores for 5 sub-scales. MCQ: 50 questions **OSCE**: measure of transfer of learning. Each student's OSCE was observed and scored by a faculty member using a tool developed by the faculty of the UMDNJ program. Students' grades on professional behaviour and communication, safety, examination, evaluation, and interventions, using a 5-point scale

Table 1
b Characteristics of included studies – Controlled Trials (Cohorts)

Author, year, country, study design	Population	Intervention and Comparison	Outcome(s)
Hyland, 2010 USA RCT	MA Physical therapy third year n = 33	**Context**: theoretical acquisition on campus **Subject/skills**: administration and management **Duration**: 1 semester, 9 days **Intervention**: Computer Assisted Instruction (CAI): unlimited access to the course website (Campus Pipeline). CAI-group received the professor's notes online in a lecture-style format to receive special examples included within the notes. Also received the same PPT pres., study questions and lecture online as the control group. Students could ask questions via email or online discussion and share personal experiences **Comparison**: In-class: PPT overheads as a teaching medium (TLI groups), 4 hours per meeting	**MCQ**: pre- and post-test examination: 25 and 50 MCQ, one answer and three distracters per question. Scored: percentage of questions answered correctly. Course grade: final course evaluative criteria: final exam (25%), final project (20%), health and wellness assignment (20%), ethics paper (15%), and two case studies (10% each)
Maloney, 2011 Australia RCT	BA Physiotherapy third year n = 49	**Settings**: theoretical acquisition and skills training on campus **Subject/skills**: complex clinical skills **Duration**: first half of the students' third year **Intervention**: 1) Pre-recorded video tutorials (PVT), 30 min., demonstration of the skill, text prompts, trigger, problem solving. 2) Students produced self-video (SSV): clinical performance, without tutor input or guidance **Comparison**: in-class: traditional teaching (TRAD), live demonstration of the entire skill. Pre-recorded video also showed during practical class, no replay opportunity	**OSCE**: clinical performance, written patient scenario. Grades out of 50 for each performance, 10 set performance criteria: completed well (full marks), partially completed (half marks) or inadequate (zero marks). Grades converted to a percentage **Students' evaluation**: survey: group-specific 10-min. questionnaire: perceptions of the utility and satisfaction with the teaching methods. Five-point Likert scale, 1 = strongly disagree, 5 = strongly agree, and free text

Author, year, country, study design	Population	Intervention and Comparison	Outcome(s)
Maloney, 2013 Australia RCT	BA Physiotherapy third year n = 60	**Context**: skills training on campus **Subject/skills**: clinical skills acquisition **Duration**: 2 weeks **Intervention**: Self-video task: promoting reflection on performance. Students demonstrate a 5-minute self-produced video recording: assess, for example, the ankle in the scenario. Video reviewed by remote online tutors, often with group feedback on common strengths and weaknesses observed. Students reflect on their strengths and areas for improvement. Students' own video clips, and the peer benchmark 'exemplar' video clip, remained online during semester, could be revisited by the student unlimited **Comparison**: In-class: clinical skills with regular practical tutoring	**OSCE**: two clinical skill stations, formative (quantitative and qualitative) feedback to the student on their performance **Students evaluation: s**tudent perceptions and experiences: paper-based questionnaire. Five-point Likert scale: 1 = strongly disagree, 5 = strongly agree and open-ended questions
Author, year, country, study design	**Population**	**Intervention and Comparison**	**Outcome(s)**

Author, year, country, study design	Population	Intervention and Comparison	Outcome(s)
Moore, 2012 USA RCT	DPT Physical therapy first year n = 33	**Context**: theoretical acquisition and skills training on campus **Subject/skills**: psychomotor skills efficient **Duration**: 3 weeks **Intervention**: Video podcasting. Lecture and podcast demonstrations of transfer skills. Students: encourage review of assigned readings and lecture notes, review and practice podcast skills. Formal class meeting: reviewed 2.5 hours of lecture and laboratory. Students moved directly to the laboratory component of the interaction, beginning with practice and case studies: utilized the skills depicted in the podcasts in complex patient scenarios **Comparison**: In-class: live instructor demonstration in the teaching of the basic psychomotor skills	**MCQ**: Written post-test: Cognitive performance **Practical exam**: Psychomotor performance using a scenario-based practical post-test, grading rubric; safety, fluency and accuracy **Students' evaluation**: Survey: the use of the two learning methods and reported study time. Seven Likert statements and five free-response questions

Author, year, country, study design	Population	Intervention and Comparison	Outcome(s)
Nicklen, 2016 Australia RCT	BA Physiotherapy third year n = 38	**Context**: theoretical acquisition and skills training on campus **Subject/skills**: CBL case, 'Rachel's pregnancy', the role of the physiotherapist during stages of pregnancy **Duration**: 1 week **Intervention**: Remote-online computer-based (RO-CBL): same case via remote-online access: web-conferencing (RO-CBL) with participants physically isolated from one another. Computer software 'WebEx'; written text and audio-visual means. Attend a second and third training session, both approx. 45 min. Students: try the program in their small groups **Comparison**: In-class: same case in traditional face-to-face **Both groups**: attend the first session, approximately 30 minutes, introduced to key features of interacting via web-conference	**MCQ**: post-intervention survey: after second CBL session: learning and self-assessed perception of learning, satisfaction and participants' demographics. 10 MCQ. **Students' evaluation**: perception of learning: measured for each examinable learning objective, 3-point scale with the options of superficial, moderate, and in depth; satisfaction with the RO-CBL was measured on a 5-point scale (strongly disagree to strongly agree).

Author, year, country, study design	**Population**	**Intervention and Comparison**	**Outcome(s)**
Noguera, 2013 Spain Crossover, RCT	BA Physiotherapy second year n = 70	**Context**: skills training on campus **Subject/skills**: practical manual therapy course in a laboratory **Duration**: two practical lessons of 5 hours each **Intervention**: anatomy-learning application for mobile devices (APP). First group: mobile device during the practical session. Afterwards, groups interchanged their roles for the second practical session. Second group: opportunity to use the APP **The review**: followed by a description of different manipulative techniques and a practical demonstration performed by the professor. After the professor’s explanations, students practice their manipulation technique in pairs (one of them simulating a patient). Each pair got an iPod	**MCQ**: a post-test questionnaire: assess the anatomical knowledge after each practical session. First questionnaire: immediately after the first session: 8 MCQ. Minimum rating: 0 = all questions wrong, 8 = correctly answered. Second questionnaire: immediately after the second session, 8 MCQ. First 4: open questions, remaining 4: MCQ. Ratings 0 to 8 **Students’ evaluation**: Likert scale: Question 1–17: range 1–5 and Questions 19 and 20: range 1–10. Questions 21 and 22: open questions
Author, year, country, study design	**Population**	**Intervention and Comparison**	**Outcome(s)**

Author, year, country, study design	Population	Intervention and Comparison	Outcome(s)
Rocha, 2017 Brazil RCT	BA Physiotherapy n = 71	**Context**: theoretical acquisition on campus **Subject/skills**: compulsory subject of Professional Practice and Ethics in Physiotherapy discipline (EPDF) **Duration**: once a week for 17 weeks **Intervention**: classes with extra time for educational video game (EVG). Quiz type. Game room was available until a new room was built with new questions Four formats. The more resources they earned, the more moves they could make **Comparison**: in-class: Attending regular time classes: once a week with both groups	**MCQ: s**pecific knowledge test (SKT). Final test, learning of the content; 80 questions, single and multiple choice, relationships between columns and true or false options **Students' evaluation**: satisfaction with the discipline (SAT), means of a scale, Likert format: 1 = not at all satisfied, 5 = very satisfied. Perception for learning content (LP), means of a scale, Likert format: 1 = learned nothing, 5 = learned a lot
da Silva, 2012 Brazil RCT	BA Physiotherapy fourth year n = 16	**Context**: theoretical acquisition on campus **Subject/skills**: respiratory therapy field **Duration**: 1 semester **Intervention**: interactive online environment, including multimedia resources (videos, animations, figures) and the conventional course classes. Attended the conventional course classes. After the end of the course: access to the teachers to ask questions and to study their online or conventional material in 2 weeks. Access to the online material: discontinued, after 2 additional weeks, all students were submitted to a final test **Comparison**: in-class: traditional course classes in bronchial hygiene techniques (BHTs). Access to teachers: ask questions and to study the online or conventional material in 2 weeks	**Knowledge test: s**cored from 0 to 10 points, 20 questions assessing the knowledge of the students addressed the three divisions of the module: therapeutic indications (eight questions); contraindications for the use of BHTs (six questions); concepts (six questions). Each correct question scored 0.5

Author, year, country, study design	Population	Intervention and Comparison	Outcome(s)
Ulrich, 2019 Denmark RCT	BA Physiotherapy 1: n = 28 2: n = 26 3: n = 27	**Context**: theoretical acquisition and skills training on campus **Subject/skills**: learning practical skills **Duration**: 1 month **Intervention**: 360° video used as e-learning. After pre-test: Group 1: received the lesson using 360° video: Samsung Gear VR. Group 2: received lesson using a regular video: a laptop **Comparison**: in-class. Group 3: traditional lesson from an instructor	**MCQ**: pre-test: each question, six possibilities, only one correct answer: the learning requirements from the treatments. Ex-post-test: after treatment, tested on learning, practical setting: patient (volunteer) and a teacher in physiotherapy education recorded the results. Graded: failed or passed for each question or task. Test based on the learning requirements from the lesson. **Students' evaluation**: questionnaire about the students' learning satisfaction and perception of the learning climate in each treatment group (after final test)
Author, year, country, study design	**Population**	**Intervention and Comparison**	**Outcome(s)**

Author, year, country, study design	Population	Intervention and Comparison	Outcome(s)
Covill, 2019 USA Comparative cohort study	DPT Physiotherapy first year Class A: n = 47 Class B: n = 54 Class C: n = 47	**Context**: theoretical acquisition **Subject/skills**: musculoskeletal content, patient management of the lower quadrant Duration: 81 lecture hours and 79 laboratory hours **Intervention**: Flipped classroom. Pre-class: pre-recorded lectures, readings, non-graded quizzes and discussion questions. In-class: faculty led large group question and case discussion, small group question and case discussion, polling software and quiz discussion. Class B and C: lecture hours were altered **Comparison**: Class A: 18 hours traditional lectures and 31 hours laboratory	**MCQ**: 10 examinations in the term delivered every 2 weeks; 83 examination questions maintained across all three cohorts specific to the content delivered. **Students' evaluation**: classes B and C (flipped classroom), received a post-course survey specific to student perceptions of the flipped method. Experience on a Likert scale (1–5)
Day, 2018 USA Cohort	DPT Physical therapy program first two semesters n = 112	**Context**: theoretical acquisition and skills training in campus **Subject/skills**: gross anatomy course **Duration**: 15 week-long courses **Intervention**: Flipped classroom (GA-F). Pre-class: short, instructor-created lecture videos prior to class, 15 minutes in length, total recording time per week: less than 60 minutes. In-class: 130 minutes/week, included the same activities from previous year. Students also participated in a 90-minutes-per-week prosected cadaver laboratory **Comparison**: In-class (GAT): traditional lectures and 90-minutes-per-week prosected cadaver laboratory	**MCQ**: three-unit examinations: three body regions. 60 MCQ. Grades: scores on Lower level (LL-MSQs) and higher level (HL-MCQs). Final exam: 120 MCQs, varied in levels of cognition on all examinations. Four examinations were of similar difficulty and content both years

Author, year, country, study design	Population	Intervention and Comparison	Outcome(s)
Deprey, 2018 USA Cohort	BA Physiotherapy fifth year 1: n = 44 2: n = 49 3: n = 50	**Context**: theoretical acquisition and skills training on campus **Subject/skills**: neurological disorders Duration: 2-hour time blocks, 3 days per week **Intervention**: Fully integrated flipped (fFLIP). Pre-class: five pre-recorded lectures. In-class: working in groups, answering instructor-posed questions and completed scenarios and required Internet search or open book or note review. Focus: student questions. Partially FC-design (pFLIP). Pre-class: recorded lectures. In-class: reiteration of the recorded lectures and discussion without special in-class work. Opportunity to ask questions or clarify concepts during the same 2-hour in-class. fFLIP and pFLIP: 2-hour balance test and measures lab. **Comparison**: In-class: five 2-hour in-class lectures, individual homework and 2-hour balance test and measures laboratory	**MCQ and short response question formats**: examination given at the completion of each three units. Examinations 1 and 2 included the same items for the 3 years of the study. Examination scores assessed for objective change in content knowledge. Primary outcome: scores on the second unit examination. Changes in scores from exam 1 to exam 2 were compared
Green, 2016 Australia Retro-spective cohort	BA Physiotherapy second year 1: n = 150 1: n = 160 3: n = 151	**Context**: theoretical acquisition and skills training on campus **Subject/skills**: gross anatomy **Duration**: 15 week-long courses **Intervention**: Fully blended. Pre- and in-class: online interactive videos, face-to-face (f2f) lectures, practical classes, clinical anatomy classes, f2f tutorials **Comparison**:1) In-class: traditional lectures, 2) in-class and some online content (interactive videos)	**Practical and written exam**: aggregate practical test mark (percentage) and written examination mark (percentage) **Students' evaluation**: students' feedback (SFS): Likert-style questions: 5 = strongly agree, 1 = strongly disagree and open-ended questions.

Author, year, country, study design	Population	Intervention and Comparison	Outcome(s)
Murray, 2014 USA Cohort	BA Physiotherapy third semester 1: n = 43 2: n = 35	**Context**: theoretical acquisition on campus and skills training on campus **Subject/skills**: pathological conditions of the extremities **Duration**: 1 semester **Intervention**: Flipped classroom: Pre-class: asynchronous online lectures in SAKAI (course management system). Length: 10–25 min., shorter than lectures in trad classroom, same content. Encouraged: take notes and bring questions to class for discussion. In-class: face-to-face class meeting. 15-minute session: clarify any information that was unclear from online lectures. Followed: 20–30 minutes PPT presentation on integration of the online lecture content into examination sequence. Class time per day (120–240 min.): group discussions of cases with emphasis on clinical decision-making **Comparison**: in-class: traditional face-to-face lectures **Both groups**: laboratory activities for skills development	**MCQ**:105 questions: answered correctly were tallied in aggregate and by cohort based on five areas: (1) total exam score (Total), (2) score on examination/evaluation questions (Exam), (3) score on intervention questions (Inter), (4) score on lower-level questions (LL), and (5) score on higher-level questions (HL).

For the eight studies (28, 29, 31–33, 39–41) that were similar in terms of design, population, interventions and outcomes, we conducted meta-analyses using Review Manager (RevMan5.3) software. Twelve studies (26, 27, 30, 34–38, 42–45) were too heterogeneous and are not included in the meta-analyses. They are described and summarized narratively in the text and Table 1.

Figure 1 and Table 1 about here

Description of interventions

All included studies compared digital learning designs to traditional classroom teaching. The duration of exposure to the digital learning design ranged from 10 hours to 1 semester. The digital learning design interventions integrated digital learning technology and learning activities in different ways. Different blended learning designs, and especially flipped classroom designs, e-learning course designs and websites (apps) were the main digital learning designs used in the included studies. In the blended learning design, 11 studies (26–29, 31–34, 38, 43, 45) used different formats (e.g. websites/apps, recorded videos/lectures, simulation learning videos/care cases/scenarios, podcasts, remote-online case-based learning, video self-production by students, videogames and 360° videos) to present and facilitate the learning materials and/or tools in the intervention. Four studies used flipped classrooms (39–42) with pre- and in-class activities using pre-recorded videos and group activities in class. Five studies (30, 35–37, 44) included e-learning courses designed using learning management systems or online course platforms, facilitating learning by multimodal online tools (videos, animation, figures, tasks, virtual cases) in different interactive online environments.

The four studies with flipped classroom designs (39–42) had the clearest description and expectation for the students to be prepared by completing pre-class activities (asynchronous online learning) before in-class teaching. Examples of pre-class activities were pre-recorded lessons and different tasks to achieve knowledge acquisition by listening, reading and/or observation. None of these studies described pre-class learning group activities using digital tools.

The in-class activities showed variations in learning activities, such as listening to the teacher and conducting observations in the classroom and practice (e.g. during a laboratory or clinical immersion). Regarding the simulation learning environment in a clinical immersion, the learning strategies were 'time-outs', 'rewinds', 'debriefing' and reflection sessions with a clinical educator (26). One learning design used web-conferencing by WebEx (computer software) where the students were physically isolated from one another. Students communicated through written text and audio-visual means using online whiteboards, sharing notes, and viewing, uploading and sharing documents (30). Another study (35) involved an e-learning classroom (storage material).These were a sequence of traditional/e-learning/traditional classroom designs and e-learning/traditional/e-learning designs with different forms of presentations between the two classes.

The flipped classroom designs (39–42) facilitated collaborative learning in-class. Examples of activities were clarifying information from online lectures, group questions and case discussions, polling software and quiz discussions. For more information on the characteristics of the included studies, see Table 1.

Risk of bias assessment

We assessed the overall risk of bias of the controlled studies (cohorts; (27, 39–42) as higher than the risk of bias of the included RCTs (26, 28–38 43–45; see Fig. 2). The cohorts had a high risk of bias in the domains of selection bias and attrition bias. Besides, domains such as blinding and selective reporting were poorly described, and therefore the risk is unclear.

The RCTs' (26, 28–38 43–45) risk of bias was assessed as low or unclear in the domains of performance bias, detection bias and reporting bias (see Fig. 2). It is not possible to blind the students for digital learning design interventions. Therefore, we assessed the domain of performance bias as unclear.

Figure 2 about here

Meta-analysis

The effects of flipped classrooms on knowledge acquisition

We conducted a meta-analysis of flipped classrooms compared to traditional classroom teaching assessed on knowledge acquisition by multiple-choice questions (MCQs). Three controlled studies were included in this meta-analysis involving 364 students (39–41). The meta-analysis showed a SMD of 0.41 (95% CI 0.20, 0.62; see Fig. 3). The result was statistically significant and implied that students who participated in a flipped classroom earned higher grades/scores on the MCQ than students who were enrolled in a traditional classroom (see Fig. 3). Another study using flipped classroom interventions could not be included in the meta-analysis because of poor reporting of effect estimates (42). This study included 148 students and showed no significant differences between the study groups (see the Additional file 2, Table 2).

Figure 3 about here

The effects of websites (apps) on knowledge acquisition

We pooled two studies of 93 students using websites as digital learning designs compared to traditional classroom teaching on knowledge acquisition that were assessed by MCQ (31, 33). The meta-analysis showed a SMD of -0.59 (95% CI -1.20, 0.03; see Fig. 4). This result indicated better grades on MCQs among students who received traditional classroom teaching compared to students who received a website as part of their digital learning design; however, the results were not statistically significant.

Figure 4 about here

One study assessed the effects of websites for mobile devices (apps) by MCQ, and the outcome was practical skills (34). This study included 70 students. The intervention was an interactive course website developed for mobile devices. The results showed no statistically significant differences between the groups on the final exam. This result is in line with the meta-analysis.

The effects of self-videos on practical skills (skill A: cervical spine scenario)

Two studies assessed self-videos on objective structured clinical evaluations (OSCE; 28, 29) among 84 students. These interventions also included pre-recorded video tutorials (PVT) with demonstrations of the skill. The outcome was two practical skills: A (cervical spine scenario, see Fig. 4) and B (vestibular impatient, see Fig. 5). The meta-analysis showed a SMD of -0.08 (95% CI -0.92, 0.76; see Fig. 5). The meta-analysis showed that the results were not statistically significant difference between the groups on the final exam for skill A: cervical spine scenario.

Figure 5 about here

The effects of self-videos on practical skills (skill B: vestibular impatient)

Two studies assessed self-videos by OSCE among 84 students (28, 29). The outcome was practical skills B (vestibular impatient). The meta-analysis showed a SMD of -0.36 (95% CI -0.79, 0.08; see Fig. 6). No significant differences were observed in favour of digital designs using self-videos for skill B (vestibular impatient).

Figure 6 about here

One study included the video format; video podcasting investigated the effect on practical exam scores (45). This study included 33 students. It showed no statistically significant differences on practical exam scores comparing the video format and traditional classroom teaching. This was partly consistent with the effects of the meta-analysis regarding skill A. However, it was fully consistent with the effects of skill B. A second study included the video format; online interactive videos investigated the effects on practical and written exams (27). This study included 461 students. It showed statistically significant differences in scores comparing interactive videos and traditional classroom teaching. Finally, a third study included the video format of simulated learning environment videos (SLEs) and investigated the effect on practical exams (26). This study included 349 students. The single-blinded multi-institutional RCT study showed no significant differences in student competency in either RCT, although students in RCT 2 achieved a higher score in five of seven Assessment of Physiotherapy Practice (APP) standards. This result is consistent with the meta-analysis in skills A and B. These three studies (26, 27, 45) were not included in the meta-analysis due to their use of different interventions or outcomes compared to the studies that were included in the meta-analysis.

The effects of websites (apps) on practical skills

Three studies used websites as digital learning designs assessed by OSCE (31–33). The outcome was practical skills. These studies included 137 students. The meta-analysis showed a SMD of 1.06 (95% CI 0.70, 1.42; see Fig. 7) and a statistically significant difference in favour of digital website design.

Figure 7 about here

Students' evaluations of websites

Two studies compared digital websites to traditional classroom teaching on students' evaluations of the websites (31, 32). We chose the item, 'I was able to apply what I learned'. These studies included 83 students and used a Likert scale of 1–5 (5, strongly agree; 1, strongly disagree). The meta-analysis showed a SMD of 0.47 (95% CI -0.12, 1.06; see Fig. 8); the results were not consistent. Only one of the studies showed significant differences in favour of digital design using websites (31).

Figure 8 about here

Ten other studies that were not included in the meta-analyses assessed students’ evaluations of different types of digital learning designs and evaluation items (26, 28–30, 33–36, 38, 45). They used different Likert scales. The results from these studies are available in the Additional file 2, Table 2.

The effectiveness of other digital learning designs

Seven of the included studies (30, 35–38, 43, 44) used digital learning technology and/or outcomes different from those utilized in the studies included in the meta-analysis (26–29, 31–34, 36, 39–42, 45). One study used an interactive online environment (videos, animations, figures; (37) as digital design assessed by a knowledge test, and the outcome was theoretical acquisition. This study included 16 students. The results showed a significant improvement of theoretical acquisition among the students who participated in the interactive online environment compared to the students in the control group (see the Additional file 2, Table 2). A second study used e-lectures as a digital design (35) assessed by a knowledge test, and the outcome was theoretical acquisition. This study included 72 students. The results showed significant improvement of theoretical acquisition among the students who viewed the e-lectures compared to those who observed traditional classroom teaching (see the Additional file, Table 2). In a third study, virtual patient simulation (VP; (43) was assessed by MCQ, and the outcomes were theoretical acquisition and practical skills. This study included 53 students. The findings suggest no significant differences between the methods; however, the simulation group did score higher on all objective measures. A fourth study used web-conferencing (RO-CBL; (30) assessed by MCQ, and the outcome was theoretical acquisition. This study included 38 students. Of the 15 examinable learning objectives, 8 were significantly in favour of the control group, suggesting a greater perceived depth of learning. Furthermore, a fifth study used an educational video game (EVG; (36) assessed by a knowledge test, and the outcome was theoretical acquisition. This study included 71 students, and the results showed that EVG was able to improve performance in the specific knowledge test (SKT).

A sixth study assessed the effects of a course website (44). This study included 33 students and used a CAI as the intervention. The results showed no significant differences between the groups for baseline knowledge, final exam scores or final course grades. Finally, the seventh study used 360° video as the form of e-learning assessed by MCQ (38), and the outcome was theoretical acquisition. This study included 81 students. The findings indicated that there is no significant difference between 360° video and regular video (see Additional file 2, Table 2).

Discussion

This systematic review identified various types of digital learning designs integrating different tools, software’s and learning platforms conceptualized as flipped classroom, blended learning, remote online-learning, online/e-learning courses and CAI designs and dominated by asynchronous online learning. Regarding digital technology, educational video games, virtual reality (VR), Mobile learning applications (apps), audio files (podcasts), simulation programs and various video formats are the most-used tools in the learning designs.

The main findings showed statistically significant differences or equal results in favour of digital learning designs in 18 of the 20 studies compared to traditional classroom teaching. Two of our meta-analysis showed a statistically significant improvement for flipped classrooms (39–41) and websites/apps (31–33). The meta-analysis of flipped classrooms showed effects favouring the intervention for student learning outcomes and grades. This is in line with another systematic review (18), but in contrast to the conclusions drawn by another review (46). Further, the effects of using a website/app on practical skills showed statistically significant differences in favour of digital websites (31–33). This is supported by another systematic review (3). On the other hand, the meta-analysis of using websites/apps on acquisition of knowledge indicated better grades on MCQs among students who received traditional classroom teaching compared to those who visited a website as part of the digital learning design. However, the results were not statistically significant, and the meta-analysis included fewer than 100 participants, so the results need to be interpreted carefully. Regarding students' evaluations of the statement 'I was able to apply what I learned' in two studies (31, 32), the meta-analysis showed that the findings are not consistent. This is in line with the results from student's evaluation in the studies that were not included in the meta-analysis.

Six of twelve studies (27, 34–37, 42) that were not included in the meta-analysis showed statistically significant effects of the intervention. Five of these twelve studies (26, 38, 43–45) showed results equal to the control group. One of these twelve studies showed results in favour to traditional classroom teaching (30).This leaves a somewhat mixed impression of the effects of different learning designs and is in line with another review regarding different learning designs (3, 21).

Ten studies (26, 28–30, 33–36, 38, 45) that were not included in the meta-analysis reported students' self-reported learning. These studies showed, overall, a positive experience and high satisfaction with the digital learning design. One study showed lower satisfaction (30) and another showed high variance in students' satisfaction between the cohorts in the study (27). On the other hand, the outcomes show significant differences in favour of digital learning designs in these two designs. These two studies are in line with another paper regarding the relationship between students self-reported learning and grades and "where students in the active classroom learned more, but they felt like they learned less" (53, p. 1).

One explanation of the results in the flipped classroom designs is that the pedagogical possibilities within the flipped classroom setting facilitate pre-class learning activities and enhance self-regulative abilities among students, flexibility and transparency in the learning process (47). These pedagogical possibilities can be explained and thereby lead us to expect the model to be effective and to enhance students' learning outcomes.

Regarding the results from the website/app (31, 33) on practical skills, several explanations can be offered. Interactive apps can be a useful tool because they are flexible, accessible, interactive and give the students the ability to observe how to perform practical skills. Demanding aspects of mobile learning "are the links between and the need to facilitate different sustainable pedagogical and learning strategies by integration, support, interactive use and appropriate choice of tools" (3, p. 32). Another explanation is that learning is promoted when learners are engaged in applications on their newly acquired knowledge of skills (5).

In these studies, student in the intervention group were given free access to a website/app immediately after the traditional classroom teaching finished. An aspect and explanation regarding the significant differences between m-learning (app) and traditional learning resources and their context (books, articles and classroom teaching or laboratories) in learning practical skills is that the mobile learning activities can be designed in alignment with the learning outcomes and the assessment form (48). Another explanation of the results showing no significant effect on knowledge acquisition is that, if the app is mainly designed to learn practical skills, then the knowledge aspect might not be supported or facilitated as a learning outcome. On the other hand, to learn skills it is necessary to acquire knowledge, although this might not be expressed as an expectation in the app's design, or it might not be facilitated by reading about or completing tasks that can support knowledge acquisition. The behaviourist learning approach is often used in mobile learning designs in higher education where teachers are the content deliverers, and this seems to dominate higher education teaching practices (3, 49). In a critical perspective, apps must be integrated into the system of learning for different learning materials (e.g. books, articles), and the content, learning activities and technology must be designed in such a way that they are aware of one another and complement each other to achieve the learning outcomes (52).

Overall, the effects of the digital learning designs in the studies that were not included in the meta-analysis, indicated that planned learning designs that integrate digital learning technology, have a great potential to enhance learning or to be equally effective for achieving learning outcomes (e.g. grades). These findings can be explained by and are in line with other studies showing results regarding increased student involvement, critical discussions and increased student–teacher contact (50). However, there is also a criticism here, which raises questions about technology optimism and the uncritical belief that the use of technology leads to learning in itself (51). It is how digital tools are implemented and used pedagogically that matters for students' learning outcomes, not the technology itself (3).

There is the potential to complete meaningful learning activities in digital learning designs to facilitate physiotherapy students' learning, for example, critical thinking and thereby higher-order learning activities, and to support the shaping of an independent decision-making authority as a professional physiotherapist once they graduate from a physiotherapy program (11). Facilitating digital learning designs also challenges and has implications for the professional educator's role and teaching practices in physiotherapy education when moving from a transmission to a transformative teaching practice (e.g. flipped classroom designs; 4, 12, 52).

Strengths and limitations

We consider several aspects as strengths in this systematic review. First, we developed a rigorous and comprehensive search strategy on digital learning technology in learning design developed by two of the authors (NBØ, YR) together with two information specialists at the campus (MWG, EK). Second, we find it possible to be able to synthesise and conduct a meta-analysis even though the included studies had varied interventions, small sample sizes and varied forms of effect size.

However, the review has some limitations. Several factors, including weak study designs (single cohorts), underreporting of statistical methods and educational intervention details and non-validated measures methods (multiple choice questions and self-report questionnaires), may limit the potential to influence current practice. Studies also had methodological challenges regarding assessing the risk of bias for all the included studies. The results are also limited because only one study included long-term (2-semester) follow-up to assess learning retention.

The included studies used various conceptions of digital learning designs. This generates an unclear terminology and can make it difficult to compare designs and synthesize the results.

There is also a need for more robust studies, such as experimental designs, control variables and the use of statistical methods and reporting of the results, especially in the flipped classroom designs. More in-depth and follow-up research studies assessing learning retention, students' approaches to learning and preferences to studying in a digital learning environment would also be beneficial. Furthermore, scholar should study the experiences and attitudes of teachers towards developing and implementing digital learning designs in physiotherapy education.

Conclusion

This systematic review showed various uses of digital learning designs in physiotherapy education, and the results indicate that different digital learning designs improvement or have an equal effect compared to traditional classroom teaching in physiotherapy education.

The meta-analysis revealed significant effects on student learning in favour of the flipped classroom and websites developed for mobile devices (apps). However, these results need to be confirmed in lager control trials or RCTs. Further, the evidence from all the included studies showed mixed results; however, the studies indicate overall that digital learning designs are even more effective or equivalent for student learning outcomes compared to traditional teaching in terms of knowledge acquisition and practical skills. The generalization of this finding is limited to the physiotherapy population studied in this review. This review highlights the need for improvements in methodological designs of future studies. To summarize, the findings in this review may form a basis to be able to critically assess which digital learning designs should be further investigated, and especially in which situations digital learning designs can be used to facilitate students' learning of practical skills and behaviour. Further, there is also a need to do follow-up research studies on learning retention, students' learning approaches and preferences for studying in a digital learning environment.

Abbreviations

CAI; Computer Assisted Instruction, MOOCs; Massive Open Online Courses, App; Mobile learning application, CI; confidence interval, RCT; randomized controlled trial, CT; controlled trial, MD; mean difference, SMD; standardize mean difference, MCQ; multiple-choice question, OSCE; objective structured clinical evaluations, SKT; knowledge test,

SLE; Simulated learning environment videos, EVG; Education Video Game, VP; Virtual Patient, RO-CBL; web-conferencing.

Declarations

Ethics approval and consent to participate

Not applicable.

Consent for publication

Not applicable.

Availability of data and materials

The datasets used and/or analysed for this study are available from the corresponding author upon reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors' contributions

NBØ and YR designed the study, collected and analysed the data, designed the methodology and wrote the article. HMT contributed to the study design, data collection and analysis and to designing and writing the methodology chapter. TDM contributed to the study design, the final analyses and writing the manuscript. All authors read and approved the final manuscript.

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Figures

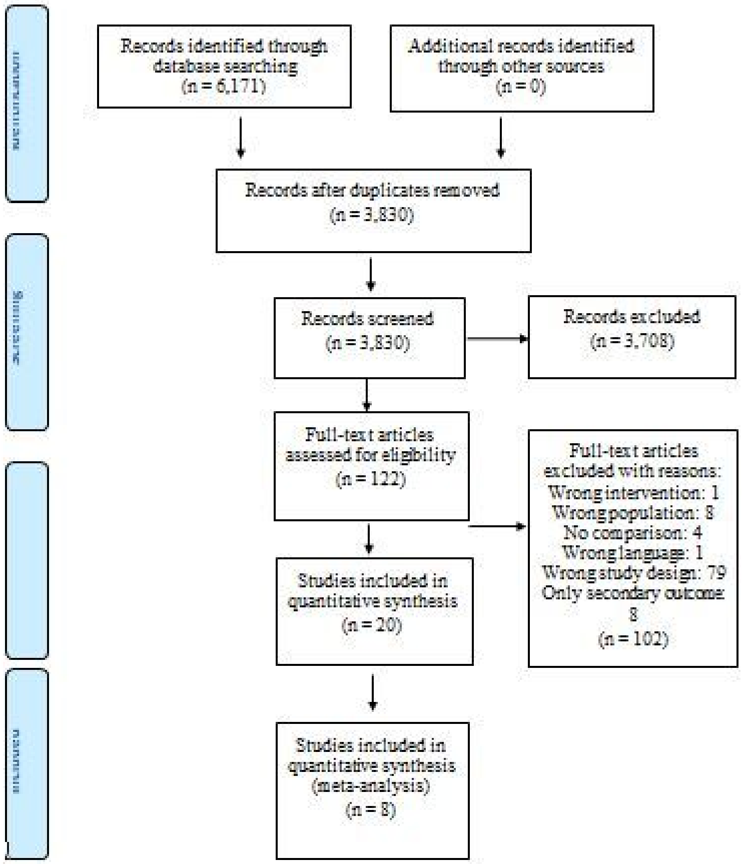

Figure 1

PRISMA flow chart of the records and study selection process

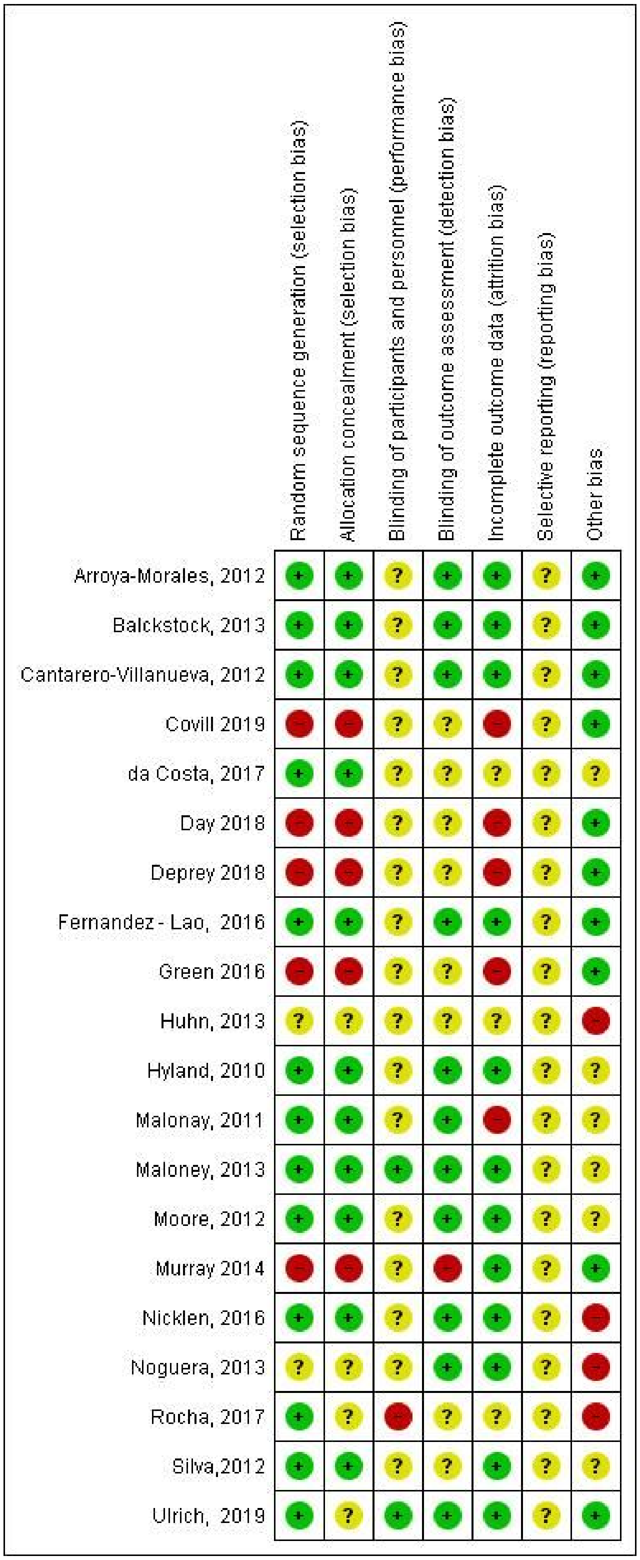

Figure 2

Risk of bias summary for RCTs: review authors' judgements about each risk of bias item for each included study

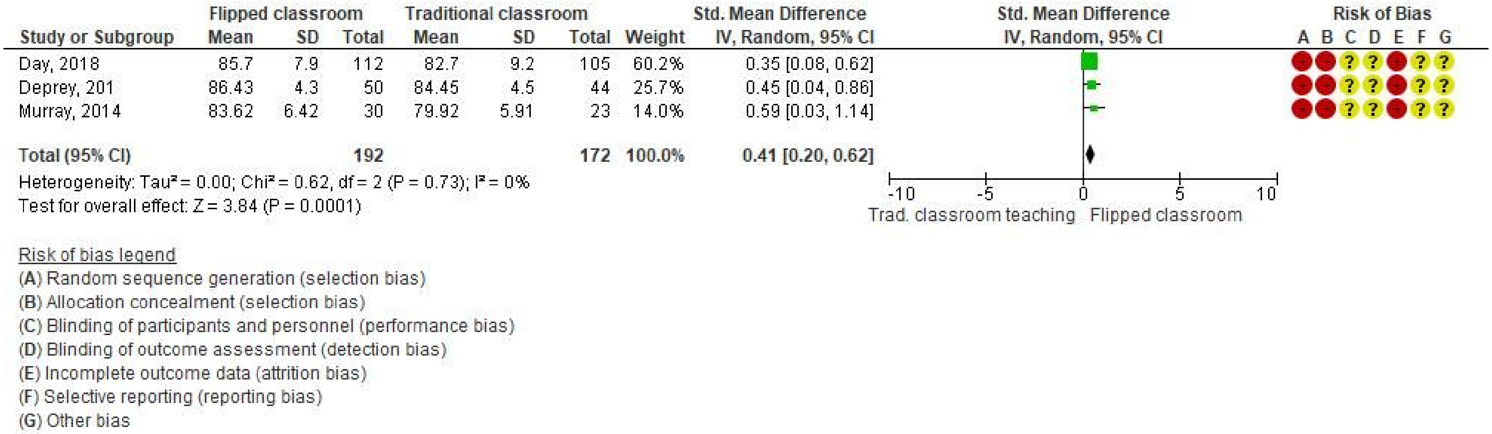

Figure 3

Forest plot of flipped classrooms assessed by MCQ. Outcome: knowledge acquisition. CT = control trials.

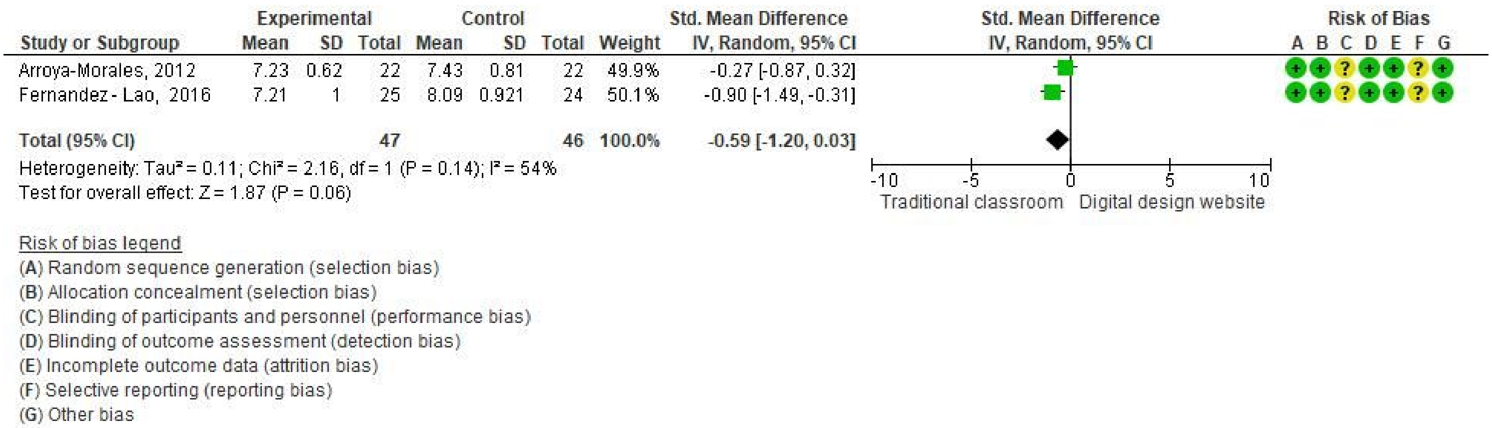

Figure 4

Forest plot of websites assessed by MCQ. Outcome: knowledge acquisition. RCT = randomized controlled trial.

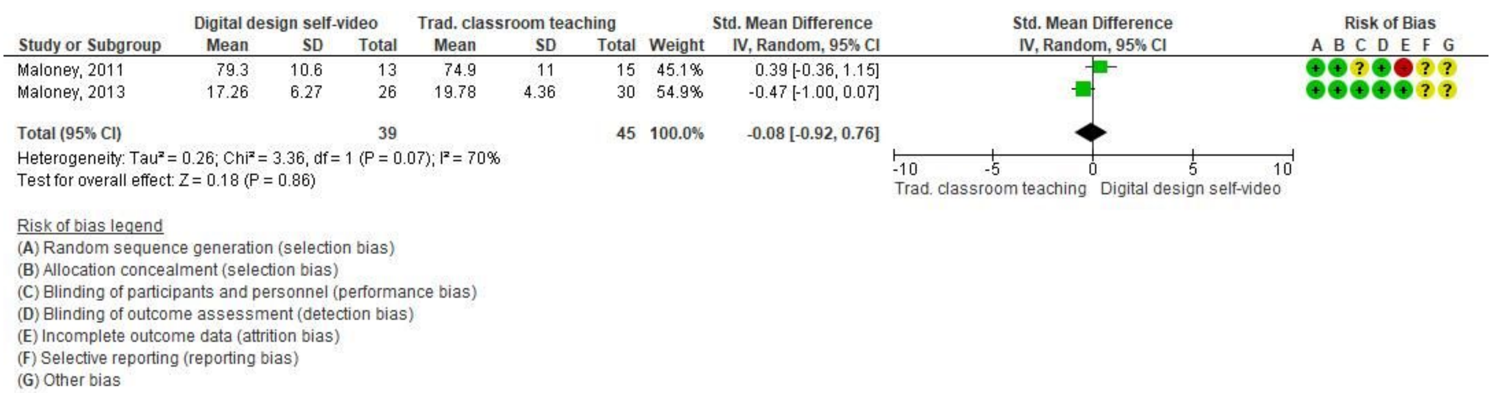

Figure 5

Forest plot of self-video assessed by OSCE. Outcome: practical skills A. RCT = randomized controlled trial.

Figure 6

Forest plot of self-video assessed by OSCE. Outcome: practical skills B. RCT = randomized controlled trial.

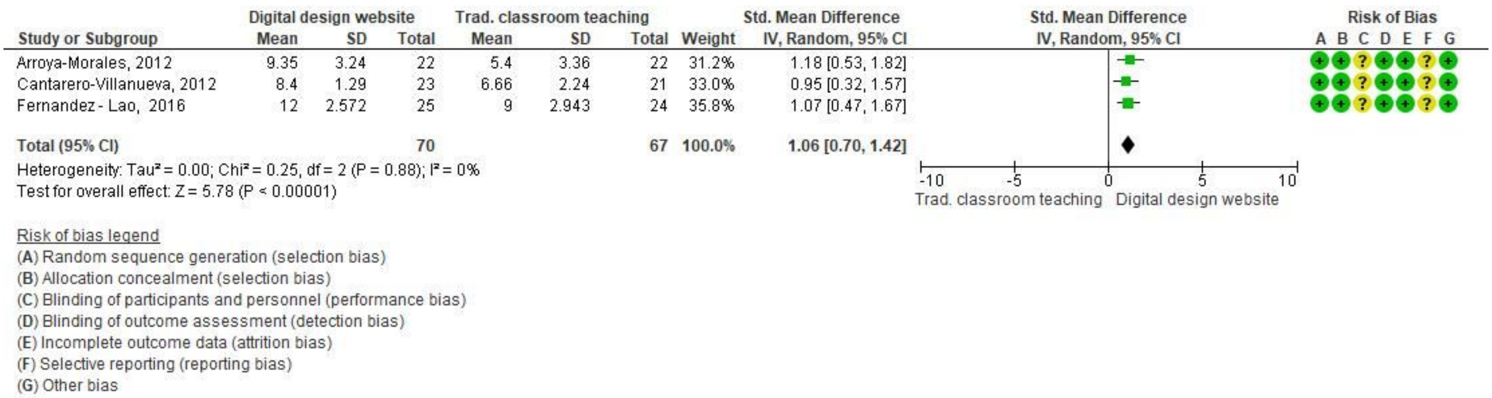

Figure 7

Forest plot of websites assessed by OSCE. Outcome: practical skills. RCT = randomized controlled trial.

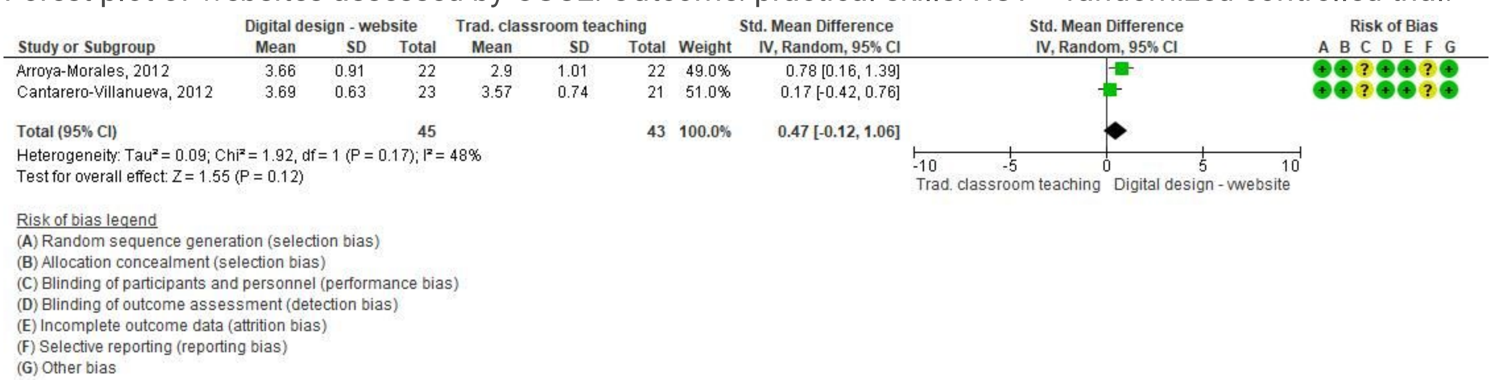

Figure 8

Forest plot of student’s evaluation. Intervention: website. Item: ‘I was able to apply what I learned’. RCT = randomized controlled trial.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- supplement12.pdf
- supplement13.pdf