Best Practices for Teaching Chemistry Disciplines to Graduates Majoring in Pharmacy During the COVID-19 Restrictions: A Systematic Review

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Abstract: The purpose of the study was to identify the - interventions that can be adopted for teaching chemistry disciplines to the graduates majoring in Pharmacy (Mpharm) in Ukraine. The study employed a systematic review methodology and a qualitative approach to synthesising the sources. The triangular assessment method was used to rate the short-listed instructional interventions for feasibility, transferability, and duplicability in the settings of teaching chemistry disciplines to pharmacy graduates in Ukraine. The review found seven eligible publications for the analysis. It was identified that the shortlisted instructional models were technology-mediated and positively affected students' skills and occupational knowledge. Three out of seven instructional models used chatbots and AI to automate the process of management of students learning activity which suggested that automation of the process of educational content delivery was becoming an emerging trend in instructional design. Having performed the triangular assessment method (TAM) analysis, three instructional models were given preference in terms of their use in medical education settings in Ukraine. These models were as follows: a) PhET simulations-based model, b) the model based on automated delivery of the course using the Smart Sender platform and c) the model based on automation of the Moodle-driven e-course using Dialogflow chatbot.

Keywords: *Pharmacy graduates, higher education, systematic review, teaching chemistry disciplines.*

Introduction

Chemistry is a central specialised discipline for medical students and a prerequisite for gaining qualifications (Koenig, 2019; McPherson, 2022; Melnyk, 2020). This discipline is essential for graduates majoring in Pharmacy because they are expected to be aware of the concepts related to chemical synthesis, development, and standardisation of pharmaceutical agents and bioactive molecules for the market, along with the chemical nature and properties of the medicines. As a learning outcome of this discipline, the graduates majoring in Pharmacy are supposed to demonstrate practical skills in dealing with chemicals in a lab, conducting a comparative analysis of medicinal products taking into account the chemical structure, mechanism of action, and pharmacological properties to identify the suitability of drugs for a certain patient. The graduates are also trained to be able to provide appropriate storage conditions for different drugs, and ensure the quality of pharmacy products, herbal medicinal raw materials, and medical products (Nizhenkovska et al., 2021). Being a laboratory-based discipline, before the global pandemic occurred, Chemistry was conventionally delivered using instruction methods based on face-to-face learning and teaching (Díez-Pascual & Jurado-Sánchez, 2022; Lapitan et al., 2021). Severe constraints to conventional educational activities resulted from COVID-2019 suspended face-to-face learning and teaching and imposed limitations on fostering students' – graduates majoring in Pharmacy are included – practical lab skills (Islam & Schweiger, 2015). Although instructors moved to virtual laboratories and platforms to deliver the Chemistry disciplines' content through video conferences and recorded presentations, it became apparent that those instructional tools did not address the issue comprehensively.

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The students lacked hands-on experience drawn from practical activities involving the use of laboratory material, gaining confidence in pharmaceutical control, and manipulating instruments in experiments which might cause the students to struggle later in their professional lives (de Vries & May, 2019). Since the above is still an instructional challenge, this study is inspired by a desire to revise the best practices for teaching chemistry disciplines to Masters of Pharmacy (Mpharm) so that the transition from face-to-face training to remote delivery of Chemistry laboratory courses to those students could be updated and smoother.

Literature Review

Brief Overview of the Training Process of Medical Students - pharmacy graduates included - in Universities in Ukraine

Medical education, and the training system of student Pharmacists specifically, has undergone several changes over the last fifteen years. These days, it is supposed to comply with the requirements of the medical education and medical system in the European Union area. The first change was driven by the tuning project within the Bologna process which was aimed at implementing comparable degrees, two cycle-based educational processes, the European Credit Transfer System (ECTS) system, academic mobility, and quality assurance into the training system (Kuklinova, 2017; Ross & Cumming, 2008). The second, and most recent change is related to the adoption of best practices of public healthcare reforms from the Czech Republic, Poland, and Baltic countries to Ukraine's public healthcare system and education (Kyrylenko, 2018). Lukashevska (2021) reveals that currently the Ukrainian medical education system is gradually being integrated with the European medical system. The greatest attention is paid to the quality of training medical students so that they are fit to work. The distinguishing feature of the training process of medical students (Pharmacists) in universities in Ukraine is the use of a stage-wise of monitoring of the quality of training through the integrated license exam under European Credit Transfer System (KROK) for medical undergraduates and graduates. The rapid transition to online education has become a challenge for both students and academicians in medical institutions. Although the use of computer technologies in education created an opportunity for flexible learning for a significant number of students, the lab-based university disciplines were complicated by distance learning. The obvious reasons for this were related to limited access to brick-and-mortar labs and a lack of computer software available to address this need (Yaremena et al., 2021). This problem necessitated the need for looking for feasible, transferable, and duplicable for teaching chemistry disciplines to MPharm students in Ukraine.

Educational Theory and Teaching Chemistry

The study found some studies that revealed pedagogical concepts and instructional models of delivery Chemistry at universities and medical schools (Islam & Schweiger, 2015; Lapitan et al., 2021; Opara, 2013; Šojat & Markic, 2015). Those sources mostly highlight a theoretical perspective of teaching Chemistry. For instance, Lee (2016) Opara (2013), Šojat, and Markic (2015) stated that the delivery of Chemistry disciplines to Pharmacy students should be based on learning theories that relied on inquiry, discovery, and problem-solving. Lapitan et al. (2021) analysed the delivery of Chemistry disciplines to Pharmacy students from the perspective of the use of cognitivism and constructivism approach because the curriculum Chemistry modules for training pharmacists are mainly multi-disciplinary. Some more studies highlighted the delivery of Chemistry at universities and medical schools from the perspective of adult learning theories that are used in the education and training of healthcare professionals-to-be who are in their undergraduate and graduate levels along with those who take post-graduation development courses (Aliakbari et al., 2015; Arab et al., 2015; Mukhalalati, & Taylor, 2019). However, a recent challenge related to COVID-2019 necessitated updating the theory and practice of teaching and learning Chemistry. In this regard, the revision of statistically or experimental proven effective interventions that address the issues related to the constant boom of online learning and training and those that can be adopted for teaching chemistry disciplines to Mpharm students in Ukraine seems relevant.

Therefore, the *purpose* of the study was to identify the feasible, transferable, and duplicable interventions that can be adopted for teaching chemistry disciplines to Mpharm students in Ukraine. The study drew on the research questions which were as follows: (a) What specific educational and training models, interventions, or approaches could be feasible, transferable, and duplicable for teaching chemistry disciplines to Mpharm students in Ukraine? (b) How effective could be those educational and training models or interventions or approaches in the settings of medical education in Ukraine from the perspective of instructors of medical universities?

Methodology

The study employed the methodology of a systematic review that consists of six steps as recommended by Siddaway et al. (2019) and it relied on Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to standardise the procedure of the review (Moher et al., 2015). Those steps were as follows: 1) specifying research questions; 2) defining inclusion and exclusion criteria; 3) running a database search for studies; 4) screening and shortlisting studies for full-text reading; 5) extracting irrelevant literature sources from included for full-text reading in the previous phase; 6) reporting the results of the review and assessing the feasibility, transferability, and duplicability

of the instructional interventions to be within the scope of this study. A qualitative approach to the synthesis of the sources was utilised because it fitted the empirical nature and purpose of this review. That approach was based on the keyword-based strategy to short-list the relevant articles which were analysed using descriptive content analysis (Kelley & Kelley, 2019). The literature search did not aim to be exhaustive but attempted to find the studies that revealed educational interventions which were verbally or statistically proven to be effective or/and innovative. The triangular assessment method (TAM) was used to rate the short-listed instructional interventions for feasibility, transferability, and duplicability in the settings of teaching chemistry disciplines to Mpharm students in Ukraine (Perez-Rodriguez & Rojo-Alboreca, 2017). The triangular assessment method (TAM) was used for the above purpose because it was found to be used for the same purpose in some other recent reviews and experimental studies (Bobrytska, Reva, Protska et al., 2020; Nozhovnik et al., 2022; Savluk et al., 2022). The TAM was also chosen to be used in the study because the method provided both numeric and verbal data which were important for evaluating the selected instructional models. The inclusion and exclusion criteria were specified using a template of the most common inclusion/exclusion criteria provided by the University of Maryland (2022). A search of literature that revealed educational and training models or interventions or approaches to teaching Chemistry disciplines to healthcare professionals-to-be was performed during 2021 and the first quarter of 2022. It was performed in academic databases such as Google Scholar, CrosRef, Scopus, Web of Science, PubMed, and ERIC. The sources search was performed by six reviewers with Ph.D. and Doctorate degrees in Pedagogics. To address any bias issue that could occur at this phase, the reviewers worked autonomously and used the critical appraisal checklist (CAC) that was based on inclusion criteria and was combined with the 4-point Likert relevance scale. The structure of the search strategy and its components were specified as recommended by Kugley et al. (2015). The keywords-based search combined several search terms into the search strings. Those search combinations included the ones that are as provided below:

a) teaching model OR method OR instructional approach OR instructional intervention

OR

b) teaching AND/OR learning (search title and abstract)

AND

c) Chemistry OR Pharmaceutical Chemistry OR/Drug Standardisation course OR discipline OR course OR subject (search title and abstract)

AND

d) technology teaching OR technology teaching Chemistry OR online learning/teaching Chemistry OR distance learning/teaching Chemistry (search title and abstract)

AND

e) students majoring in Pharmaceutics OR Masters in Pharmacy OR Mpharm students OR medical university students OR university students (search title and abstract)

AND

f) global pandemic OR COVID-2019 OR lockdown 2020 (search title and abstract)

NOT

Children OR Child OR kids OR school (search anywhere).

The search terms were combined appropriately using Boolean operators so that they fit the respective database. The keyword-based search procedure was based on updated PRISMA 2020 for systematic reviews specified by Page et al. (2021) and it is presented in Figure 1.
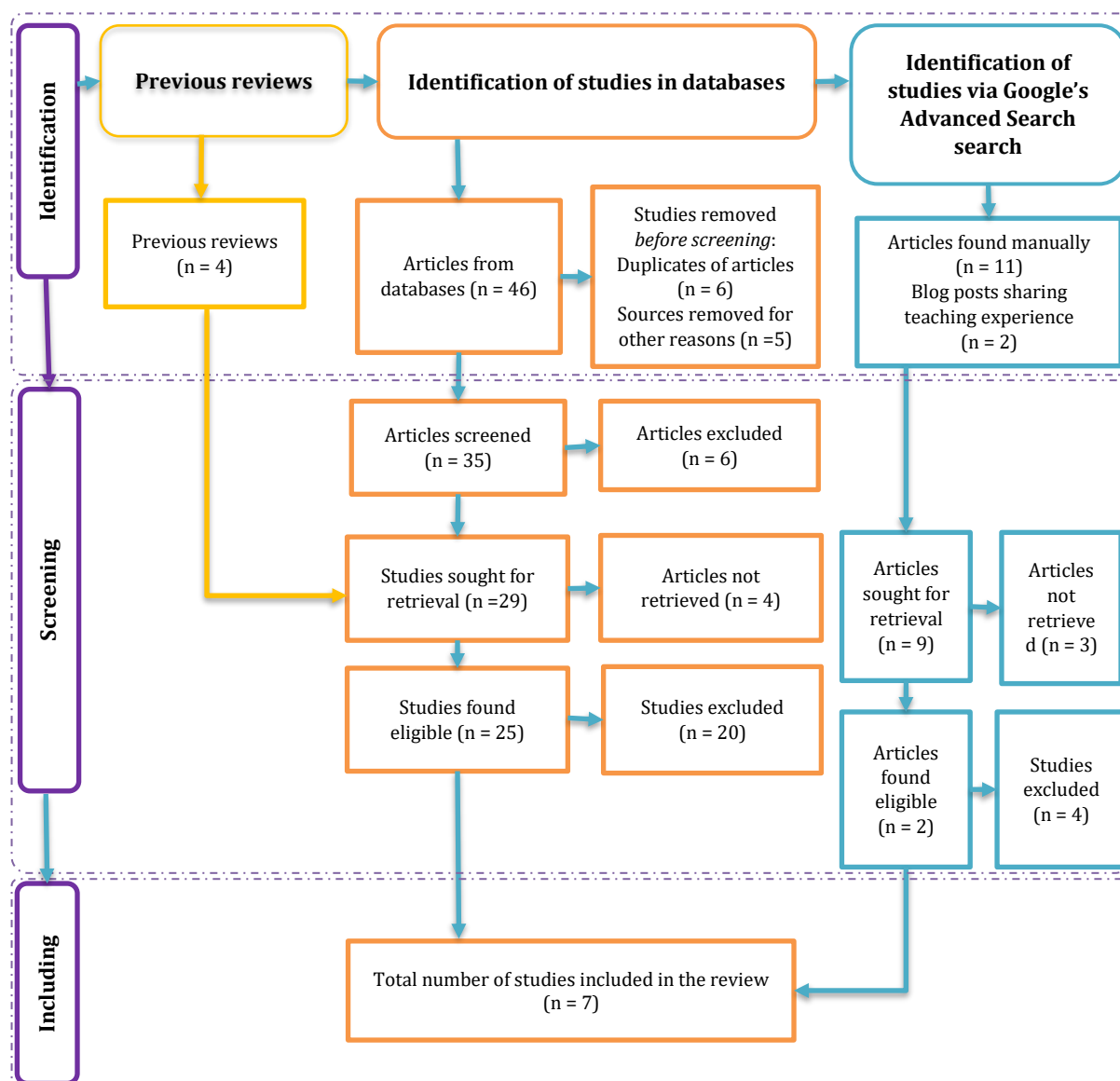
Figure 1. Keyword-based search flow diagram based on updated PRISMA 2020 for systematic reviews (Adopted from Page et al., 2021)

In the identification phase, the 4-point Likert relevance scale with 1 being used for 'poor relevance', 2 - for 'average relevance', 3 - for 'good relevance', and 4 - for 'excellent relevance' was by the reviewers to identify the relevant publications for screening. In the screening phase, the study used the criteria for inclusion and exclusion, and the critical appraisal checklist (CAC) to shortlist the articles for the final review.

The criteria of eligibility for inclusion of the studies were as follows: a) type of publication - electronically available full-text original books, articles, or observation reports; b) language of publication – English, and Ukrainian; c) the year of publication of the article is to be not earlier than 3 years; d) the source reveals or/discusses or/and reports the application and/or effectiveness of the instructional model or training model or intervention or approach to teaching Chemistry disciplines to healthcare professionals-to-be in the settings of distance learning or pandemic or lockdown; e) it is possible to categorise the instructional model or training model or intervention or approach; f) the data on the outcomes of the interventions are reported appropriately and consistently. The criteria for exclusion were as listed below: a) type of publication - editorials, opinion articles, unpiloted instructional initiatives, letters, commentaries, essays, and preliminary notes; b) duplicate sources or reports; c) similar design of interventions; d) insufficient reporting data; e) instructional projects/interventions/initiatives requiring considerable investments. The critical appraisal checklist (CAC) is provided in Appendix A.

The triangular assessment method (TAM) was used to address the second research question. The procedure of assessment used the predesigned two-layer hierarchy criteria that included five domains. The latter were as follows: a) transferability and duplicability; b) improvement of the quality of delivery of Chemistry; c) applicability in the settings of distance learning or pandemic or lockdown; d) applicability in the medical educational system in Ukraine; e) other

factors. The domains and criteria to assess identified instructional models for feasibility via TAM are depicted in Table 1.

Table 1. Domains/Criteria and Sub-criteria to Assess Identified Instructional Models via TAM based on prioritisation

Domain/criterion		Sub-criterion	
1	Transferability and duplicability	a	The instructional model is duplicable.
		b	It will make effective use of the resources of the institution.
2	Improvement of the quality of delivery of Chemistry	c	Widens the range of learning opportunities for students who learn Chemistry.
		d	Updates teaching methods to foster students' occupational skills within the Chemistry curriculum more efficiently.
3	Applicability in the settings of distance learning or pandemic or lockdown	e	Uses advances in technology.
		f	Contributes to the conventional teaching model.
4	Applicability in the medical educational system in Ukraine	g	Complies with requirements for the quality of instruction in medical institutions in Ukraine.
		h	Fits well in the curriculum of medical institutions.
5	Other factors	i	Fosters students' learning skills.
		j	Boosts students' motivation.

The above criteria and sub-criteria were used by the experts to prioritise the identified instructional models using their experiences to consider the weight of each criterion and sub-criterion. Not all criteria and sub-criteria were necessarily used by the experts.

Instruments

The critical appraisal checklist (CAC) for screening and shortlisting studies for full-text reading (see Appendix A), EndNote - X8 (Version 18.2.0.11343) software, and the triangular assessment method (TAM), and Google's Advanced Search were used as instruments throughout the review process. The critical appraisal checklist was adapted from Greenhalgh et al. (2005) and Joanna Briggs Institute (2020) and consisted of 11 items. The tool was used to shortlist the eligible sources for the final review. It was based on a 3-point scale with 'yes', 'no', and 'cannot tell'. The face validity and content validity of the CAC were identified by the six colleagues-experts with Ph.D. and Doctorate degrees in Instruction. The content validity index (I-CVI) was calculated as recommended by Polit and Beck (2006). The value for I-CVI was .84 which was acceptable for this number of experts. The same six volunteering colleagues identified whether the items on the CAC were relevant using the 4-point relevance scale. The Fleiss' Kappa coefficient was calculated to measure inter-rater agreement to determine the level of agreement between the raters using the values drawn from the above relevance rating. The value for Fleiss' k was .396 which meant 'acceptable agreement'. The tool was revised using the raters' feedback. It was then tested by the authors of the study. The EndNote - X8 (Version 18.2.0.11343) software was used in the identification phase of the search procedure to identify and remove duplicates of the publications. The TAM was used to answer the second research question which was aimed at measuring the feasibility of the identified instructional models by six experts in medical instruction with Ph.D. and Doctorate degrees. The TAM was regarded as valid by default given the fact that it was proven valid by Perez-Rodriguez and Rojo-Alboreca (2017).

Results

The search phase of the review found a modest number ($n = 7$) of eligible publications that addressed the first research question. Those publications presented seven educational and training models, interventions, or approaches that could be feasible, transferable, and duplicable for teaching chemistry disciplines to Mpharm students in Ukraine. The instructional models (IM) were as follows: IM 1 – the model based on open-access videos and tutorials shown via the online Blackboard Collaborate platform; IM 2 – the model based on automated delivery of the course using the Smart Sender platform; IM 3 – DLPCA-driven model; IM 4 – PhET simulations-based model; IM 5 – The model based on NEURON information system integrated into the MOODLE LMS; IM 6 – The model based on automation of the Moodle-driven e-course using Dialogflow chatbot; IM 7 – The model based on the platform LIKAR_NMU integrated with MOODLE LMS. Table 2 shows the results of the analysis of the publications that were shortlisted for the review.

Table 2. Results of the analysis of the publications shortlisted for the review

#	Author(s), year	Description of the instructional model	Sample	Effect	Clarity of data, yes/no/cannot tell
1	Díez-Pascual & Jurado-Sánchez, 2022	**IM 1.** The use of visualised open-access videos and tutorials (virtualised laboratory experiments learned in Chemistry courses) recorded by the instructors in combination with a follow-up mini-test to check students' awareness of ways to solve a practical case. These were delivered via the online Blackboard Collaborate platform.	50 students formed a cohort	A 100% pass rate after the use of the described online instructional model compared to a 70% of pass rate when the course was delivered face-to-face.	Yes
2	Lychuk et al., 2021	**IM 2.** The use of the Smart Sender platform to automate the delivery of the ESP course. The platform relies on chatbots and employs the push factor to drive the students learning process.	76 students (EG – 38 students, CG – 38 students)	A statistically proven positive influence on students' learning motivation, engagement, time management, and mental speed.	Yes
3	Lapitan et al., 2021	**IM 3.** The use of a complex instructional model entitled Discover, Learn, Practice, Collaborate and Assess (DLPCA) which is five-component and blended learning mode-based.	168 students (Physical chemistry 1 (n=77) and Analytical chemistry (n=91), during 2019–2020.	Found a positive influence of DLPCA on students' learning experience and academic performance. It boosted the teaching tools of the instructors. The majority of students 211 (72.5 %) in 2019 and 216 (96.1%) were satisfied with the online component used in DLPCA.	Yes
4	Okrepka, 2020	**IM 4.** The use of interactive simulations PhET to deliver General and Inorganic Chemistry to Masters of Pharmacy. The predesigned instructions and protocols were developed for the students to perform educational labs and research assignments. The learning effect was assessed using MOODLE-based tests.	50 first-year Masters of Pharmacy (EG – 25 students and CG – 25 students)	Improved the EG students' quality of curriculum-determined knowledge up to 72%	Yes
5	Nizhenkovska et al., 2020	**IM 5.** The NEURON information system integrated into the MOODLE LMS was used to create a self-study lab-based environment. Students were trained to design purchase funnels for 'promoting' sales of medical and healthcare products as a part of entrepreneurship training.	91 students (EG – 46 students, CG – 45 students)	EG students showed improvement in self-directed learning skills, entrepreneurial potential, computer literacy, and Grade Point Average (GPA) by approximately 20%.	Yes
6	Bobrytska, Reva, Beseda et al., 2020	**IM 6.** The automation of the Moodle-driven e-course using Dialogflow chatbot which was programmed to verbalise lectures along with the commonly used instructions to engage the students in a learning process, give feedback and answer FAQs and evaluate the student's progress.	76 students (EG – 38 students, CG – 38 students)	A statistically significant difference between the EG and CG groups proved a positive change in their vocational competence due to the use of the automated instructional model. It was positively perceived by EG students.	Yes
7	Pushkarova et al., 2021	**IM 7.** The use of the platform LIKAR_NMU which is based on MOODLE LMS to deliver Analytical Chemistry. The model also involved the use of messengers such as Viber, Telegram, and WhatsApp to manage synchronous communication.	n of students not specified	It was found effective in fostering students' skills and raising awareness of Analytical Chemistry. The surveyed students agreed that both pre-recorded video lectures and live lectures were equally beneficial to them.	Yes

Note: IM – instructional model.

As can be seen in Table 2, all identified instructional models are technology-mediated. These are also based on either a blended or online learning environment. All of them provide a positive effect on students' skills and occupational knowledge. These models improve students' learning skills, increase their motivation, engagement, and mental speed, and boost students' entrepreneurial potential and computer literacy. The models are positively perceived by both students and teachers. Interestingly, three out of seven instructional models use different tools such as chatbots and AI to automate the process of management of students learning activity. The latter implies that automation of the process of educational content delivery is becoming an emerging trend in instructional design. It can be noted in Table 2 that the MOODLE LMS dominates in medical higher institutions in Ukraine.

The results of the use of the TAM to identify the feasibility of the identified instructional models in the settings of medical education in Ukraine from the perspective of instructors of medical universities are presented in Figure 2. It is necessary to make clear that the TAM uses numeric values to show the extent to which the raters are confident in their decision. The closer the rater's numeric value is to zero, the more certain they are in their decision.
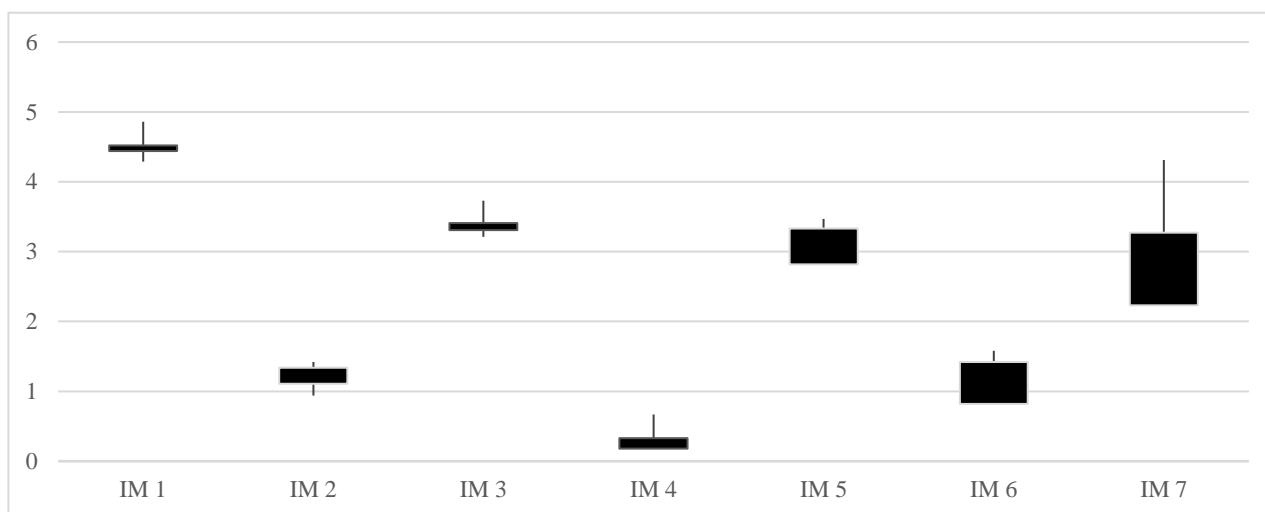

Figure 2. Results of the use of the TAM to identify the feasibility of the shortlisted instructional models in the settings of medical education in Ukraine

As depicted in Figure 2, the raters gave utmost preference to instructional model 4 – the 'PhET simulations-based model' in their judgements. It seemed also clear that the raters' values were not dispersed which indicated that their decisions were quite unanimous and this model was deemed relevant for the pandemic-transformed settings of medical education in Ukraine. The IM 2 (the model based on automated delivery of the course using the Smart Sender platform) and IM 6 (the model based on automation of the Moodle-driven e-course using Dialogflow chatbot) were of more or less the same level of interest for the experts. The verbal comments of some experts were as below:

> *'... automation of the learning management process using chatbots has got huge potential for institutions... costs reduction, workload reduction, efficient use of facilities is just some of many benefits...'*

However, the experts' judgements for IM 6 were more dispersed compared to the judgements for IM 2. This could be interpreted that the experts viewed IM 2 as more beneficial for students and teachers than IM 6. The IM 1 (based on open-access videos and tutorials shown via the online Blackboard Collaborate platform) was rated the lowest by the experts which implied that they considered it a lot like a conventional training model. The rest of the models - IM 3 – DLPCA-driven model, IM 5 – based on the NEURON information system integrated into the MOODLE LMS, and IM 7 – based on the platform LIKAR_NMU integrated with MOODLE LMS – were rated approximately the same by the experts. It seemed that those models showed insufficient innovation in comparison to the other models.

Discussions

The study sought to identify feasible educational and training models to use for teaching chemistry disciplines to graduates majoring in Pharmacy in Ukraine. It also attempted to evaluate the probable effectiveness of those educational and training models. The novelty of the study is in updating existing systematic reviews. This study contributes to the review performed by Noesgaard and Ørngreen (2015) in terms of identifying factors making e-learning effective and applicable in the settings of medical education. It also enriched the review study performed by Djordjevic (2014) who suggested that chemistry educators were expected to diversify the instructional tools so that students could acquire or update their inquiry-based learning skills, and develop an enthusiasm for this field of science. As far as we know, this has been the first systematic review that specified the list of instructional models which could

be adopted or modified and used for teaching chemistry disciplines to medical students majoring in Pharmacy in Ukraine in the settings of distance learning or pandemic-caused lockdown.

The search phase of the review found a modest number (n=7) of eligible publications that addressed the first research question. Those publications presented seven feasible, transferable, and duplicable educational and training models that could be used for teaching chemistry disciplines to MPharm students in Ukraine. All identified instructional models are technology-mediated and can be used in either a blended or online learning environment. All of them provide a positive effect on students' skills and occupational knowledge. This study found that the models improved students' learning skills, increase their motivation, engagement, and mental speed, and boost students' entrepreneurial potential and computer literacy. The shortlisted models were positively perceived by both students and teachers. Interestingly, three out of seven instructional models used different tools such as chatbots and AI to automate the process of management of students learning activity. The latter implied that automation of the process of educational content delivery is becoming an emerging trend in instructional design. The findings that are drawn from this study agree with the previous research. They added value to the findings on learning theories and their applications in the training process of healthcare practitioners that was drawn by Mukhalalati and Taylor (2019). They go along with Taibu et al. (2021) who implied that PhET simulations feature the inquiry lab which is based on the questions of scientific purpose, evidence, and evidence-based interpretations. The simulations are also supported by comparison and evaluation of the benefits that can be drawn from the obtained evidence (de Vries & May, 2019). These simulations involve students in communicating, working out, and justifying explanations. In addition to the above, Salame and Makki (2021) opined that PhET simulations are safer, cleaner, more cost-efficient, flexible, and time efficient than conventional chemistry experiments. These instructional and other benefits of those interactive simulations make them an invaluable instructional opportunity to meet challenges that are related to the global shift to online curriculum delivery. The above results of the review align with Lychuk et al. (2021) and Sullivan (2022) who opines that E-learning automation improves the speed, accessibility from any destination, and comfort for students during the learning process along with efficiency in mentoring students, grading their assignments, providing feedback, and administration.

The results of the TAM-based evaluation of the estimated effectiveness of the identified instructional models by the representatives of medical universities implied that virtual simulations and automated learning were given preference. The raters were almost utmostly in favour of the adoption of the IM 4 – the 'PhET simulations-based model' in their judgements. The judgements were supported by the raters' values which were not dispersed and indicated that their decisions were quite unanimous and this model was deemed relevant for the pandemic-transformed settings of medical education in Ukraine. The IM 2 (the model based on automated delivery of the course using the Smart Sender platform) and IM 6 (the model based on automation of the Moodle-driven e-course using Dialogflow chatbot) were of more or less the same level of interest for the experts. The reason for the above results could be related to the benefits the models may bring to institutions and communities. Those advantages seem to be cost-reward benefits, better learning opportunities in both the short run and long run, and lower risks because those instructional models are found to be becoming best practices. These benefits are to mean that simulations and automated instructional models are a one-time investment. They are an economical solution for institutions. The quality of those electronic educational products is easier to monitor and update through the involvement of different stakeholders. If properly designed and maintained, those instructional models can ensure a high standard of training and a high level of learning outcomes. Last but not least, those educational models are digital generation (youth) friendly and provide long-term computer literacy and life-long learning potential payoffs. The above results of the rating of the IMs are in line with Lynch (2018) who stated that the benefits of technology-enhanced learning are in student engagement in learning and collaboration. In combination with its student-centeredness, technology-mediated learning can boost students' achievements. The raters' judgements are aligned with Seery (2016) who concluded that technology was used to deliver Chemistry limitedly, and the benefits of technology as a reusable resource were undervalued.

However, the TAM-based evaluation of the instructional models found that the experts' judgements for IM 6 were more dispersed compared to the judgements for IM 2. This could be interpreted that the experts viewed IM 2 as more beneficial for students and teachers than IM 6. The IM 1 (based on open-access videos and tutorials shown via the online Blackboard Collaborate platform) was rated the lowest by the experts which implied that they considered it a lot like a conventional training model. The rest of the models - IM 3 – DLPCA-driven model, IM 5 – based on the NEURON information system integrated into the MOODLE LMS, and IM 7 – based on the platform LIKAR_NMU integrated with MOODLE LMS – were rated approximately the same by the experts. It seemed that those models showed insufficient innovation in comparison to the other IMs.

Conclusion

This has been the first systematic review that specified the list of instructional models which could be adopted or modified and used for teaching chemistry disciplines to Mpharm students in Ukraine in the settings of distance learning or pandemic-caused lockdown. The review found seven eligible publications for the analysis. It was identified that the shortlisted instructional models were technology-mediated and positively affected students' skills and occupational knowledge. Three out of seven instructional models used chatbots and AI to automate the process of management of students learning activity which suggested that automation of the process of educational content delivery was

becoming an emerging trend in instructional design. Having performed the TAM-based analysis, three instructional models were given preference in terms of their use in medical education settings in Ukraine. These models were as follows: a) PhET simulations-based model, b) the model based on automated delivery of the course using the Smart Sender platform and c) the model based on automation of the Moodle-driven e-course using Dialogflow chatbot. The study added value to the previous findings on learning theories and their applications in the training process of healthcare practitioners-to-be. The instructional benefits of the selected IMs are related to the smoother shift to online curriculum delivery of Chemistry to medical students. The findings revealed the trend towards the use of chatbots and AI to automate the process of management of students learning activity which must be considered by scholars and curriculum makers.

Recommendations

The current study can be considered the initial step in systemising the educational models that seem to be feasible and effective for teaching chemistry disciplines to students majoring in Pharmacy. However, the outcomes of this review should be treated with the limitations in mind which are related to the learning delivery modes such as technology-mediated, blended, or online teaching and learning. Future research could further examine how the combined shortlisted models could influence the Mpharm student's learning skills, motivation, mental speed, entrepreneurial skills, and computer literacy and contribute to those students' professional backgrounds. Future researchers should design and test technological and instructional modifications to the above models. It is recommended for practitioners to experimentally test how the automated instructional models that are based on the combined use of PhET simulations, chatbots, Moodle MLS, and AI are capable to reshape the curriculum and improve the teaching and learning process of chemistry disciplines in medical universities. The above implies that training the instructors in using PhET simulations, chatbots, Moodle MLS-integrated chatbots, and AI should be given primary significance.

Limitations

The main limitations of this review were the year of publication and the language of the sources. Those were supposed to be the publications of three recent years published in English and Ukrainian.

Conflict of interests

The authors have no conflict of interest to declare. No financial support from any organisation for the submitted work was provided.

Authorship Contribution Statement

Nizhenkovska: Concept and design, data acquisition, critical revision of the manuscript, final approval. Reva: Data acquisition, data analysis & interpretation, writing a draft of the manuscript, supervision, and final approval. Chkhalo: Conceptualisation, data acquisition, data analysis & interpretation, critical revision of the manuscript. But: Data acquisition, data analysis/interpretation, editing. Manchenko: Data acquisition, data analysis/interpretation, editing.

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Appendix

Appendix A. Critical appraisal checklist for screening and shortlisting studies for full-text reading (adapted from Greenhalgh et al. (2005) and Joanna Briggs Institute (2020)).

Reviewer_____ Date _____

Author(s)_____ Year _____

Record number _____

#	Item	Yes	No	Cannot tell
1	The publication purpose is congruous with one or both research questions under the study. The rationale for the research is revealed clearly.			
2	The research methodology is congruous with the research question(s) or objectives.			
3	The research methodology is congruous with data collection methods.			
4	The identified educational and training model or intervention or approach seems to be feasible, transferable, and duplicable for teaching chemistry disciplines to Mpharm students in Ukraine.			
5	The research design is explained clearly.			
6	The sampling technique is clearly described and justified.			
7	The intervention outcome is proven to be reliable and significant.			
8	The relation between the outcome/effect size and the use of the educational and training model is revealed clearly.			
9	The sample provided feedback.			
10	The study relies on easy-to-follow analytic logic.			
11	The study agrees with technological and teaching/learning advances in training healthcare professionals-to-be.			

Overall appraisal: Include ❏   Include for full-text reading ❏   Include for final review ❏

Exclude ❏   Comments: (reasons for exclusion): _____

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