

RESEARCH ARTICLE

Technology-enhanced constructivist learning environment for pharmacy students

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Abstract

Objective: This article focuses on constructive learning theory and demonstrates how digital technologies can develop cognitive and metacognitive abilities in pharmacy students. **Method:** The mixed methodology was used to analyse pharmacy educators' (n=10) and students' (n=26) perceptions of the efficiency of online digital resources for the creation of a constructivist learning environment. The authors adapted Constructivist Multimedia Learning Environment Survey by adding the rubric for self-reflective skills and teachers' support assessment. The qualitative data was collected by interviewing teachers and through self-reflective open discussions. After the session of webinars and self-paced MOOC on the constructivism approach, teachers transformed video lectures into interactive video lessons, conventional theoretic-oriented tasks into web cases and web quests. **Result:** Comparing the results of the initial students' evaluation of traditional learning materials and the updated ones, there were positive dynamics in all six domains (average item mean): learning to communicate (5.4 points), learning to investigate (7.8 points), learning to think (4.2 points), relevance (8.6 points), challenges (0.9 points), ease of use (1.2 points), and quality of support (7.2 points). **Conclusion:** Experts observed teaching activities for critical thinking and inquiry skills development, personalised communication, and integration of digital technologies. The results of the study indicated that there were positive transformations toward the constructivist learning environment.

Introduction

In response to the urgent transformations in the learning environment, the demands of the modern labour market, and the emergence of new technologies, universities are experiencing critical challenges. Today's teachers have to modify existing learning settings and strategies to make them applicable to innovative and evolving online learning environments.

In Ukraine, the new national curriculum for pharmacy students is aimed at the development of students' cognitive as well as metacognitive skills and requires teachers to engage students in the learning process with productive educational relationships with peers and teachers. This approach allows for creating a teacher-student partnership learning environment based on the acceptance of students' needs, experience, and interest that contributes to the knowledge construction instead of obtaining ready-

made knowledge provided by teachers. Consequently, with urgent transformations toward online education, the challenge arose how to satisfy students' academic needs and provide students' active involvement in the learning process.

Therefore, the key tasks of educational establishments are to implement principles of digital pedagogy and design digital educational resources to enable students access to courses despite any limitations. However, the innovative educational strategies require new teachers' interaction patterns, mastering skills of digital resources and equipment application, redesign of curriculum, materials, and activities with extended educational support and guidance. In addition, it is necessary to consider the challenges concerning motivation, self-organisation, and engagement of students in learning activities. Taken together, these aspects outline the new constructive concept of a technically integrated science educational environment for teaching pharmacy with a focus on

cognitive outcomes, enhancement of students' investigation skills, communication skills, self-reflection, and self-development. From this perspective, it is considered possible to make a shift in the pharmacy curricula from product-oriented to patient-centred and to develop graduates who will be able to serve as therapy and medication advisers. In Ukraine, the current attitude towards pharmacy education does not imply the development of active, critical, and self-reflective professionals.

Since the constructivism learning theory has confirmed its paramount adaptability and efficiency for teaching science (Kang *et al.*, 2010; Thomas *et al.*, 2014; Waterfield, 2015), the development of a technologically enhanced pharmacy learning environment should be based on the constructivism principles of collaborative construction of new knowledge, reflective thinking, integration of personal experience and interactive multimodal learning. A constructivist pharmacy curriculum will allow pharmacy students to become critical, autonomous, reflective, and self-directed practitioners.

As a result, this article focuses on Constructive Learning Theory (CLT) and aims to illustrate how CLT can be enhanced by digital technologies to develop cognitive and metacognitive abilities in pharmacy students. Moreover, the integration of CLT and technologies leads to follow-up transformations of teaching methods (Mirzaian and Franson, 2021). In this paper, the authors outline the process of CLT implementation and its integration with digital educational technologies in the pharmacy curriculum. The research outcomes were verified with the Constructivist Online Learning Environment Survey (COLLES), which allows observing changes in main CLT areas. This tool provides teachers with a possibility to learn more about students' perceptions of the extent to which the classroom learning environment enabled them to reflect on their prior knowledge, develop as autonomous learners, and negotiate their understandings with other students. This research hypothesis is that digital education technologies make constructive learning more engaging and productive.

Theoretical background

There is a large volume of published studies describing the role of constructivism learning theory in teaching science. However, the implementation of the constructivism framework into the process of pharmacists' teaching has been reflected in a limited number of sources.

Constructivism as an educational approach signifies the personal construction of knowledge through the creation of cognitive dissonance between pre-existing

knowledge and new information. The key requirement for efficient implementation of the approach is providing a collaborative, active, problem-based learning environment so that students can create meaningful connections between their prior knowledge, new information, and critical self-reflective learning practices. As the process of knowledge construction demands students' active engagement, the main task of a teacher is to create the environment to facilitate the construction.

From this perspective, Alt (2014) determined eight elements of a constructivist curriculum: knowledge construction, in-depth learning, authenticity, multiple perspectives, prior academic experience, teacher-student interaction, cooperative dialogue, and social interaction. Through these elements, the author confirms the importance of a collaborative and reflective learning environment intensified with mutual student-teacher interaction. Among basic characteristics of constructivism researchers (Fox, 2001; Pagán, 2006; Pascoe *et al.*, 2018) point out moving from generalisation to specific concepts; supporting students' curiosity, interactivity, and multimodality of learning to pursuit personalisation of knowledge construction; teacher-student negotiation; a dynamic process of knowledge acquisition and assessment as a learning tool.

Since the process of knowledge construction depends on the student's involvement, interpersonal and metacognitive skills are very important. To date, several studies (Lonie and Desai, 2015; Tsingos-Lucas *et al.*, 2016), have revealed the correlation between constructivism and students' self-regulated skills. Thus, Varunki and authors (2017) found that the level of academic achievement depends on students' self-regulatory skills and personal perception of the learning environment. If students are engaged in learning, clearly understand the value of the course for their future careers, and have a constructive dialogue with a teacher, it means that the constructivism framework has been integrated successfully. The significance of this correlation is supported in the empirical study of Koster and Vermunt (2020) who claim that constructivism awareness and self-regulation impact students' perception of learning nature and strategies "*... as this influences all aspects of deep learning (relating and structuring and critical processing) and stepwise learning (memorizing and rehearsing and analyzing) ...*"

Among the authors who analysed the constructivist approach for healthcare professionals, the authors of this article singled out the study of Thomas and colleagues (2014). The researchers highlight that constructivism means outcome-oriented learning by

action. Integration of this approach into personal education experience allows differentiating the learning activities from traditional lectures to discussions, small-scale action research, alternative assessment strategies, portfolio, and digital learning tools application. Moreover, the inclusion of authentic problem cases into the curriculum stimulates knowledge recontextualisation, which is the essence of constructivism itself.

Particularly, the inclusion of constructivism into pharmaceutical curriculum is described in Kang's and authors (2010) research. Scientists consider constructivism as a theory about learning that implies changes in teaching strategies. These strategies are student-centred and student-driven because active students' participation and internal motivation transform passive students into confident life-long learners. In a comprehensive study on pharmacy education, Lonie and Desai (2015) investigated the implementation of Transformative Learning Theory as an approach evolved from constructivism and based on its key principles. Researchers claim that both theories contribute to the development of mature, mindful patient-centred thinking of a future pharmacist. Acquired skills will enhance cognitive flexibility so that during the career path, students will be ready to respond to changes by critical evaluation of their assumptions and successfully adapt to new ideas.

Due to current requirements, the role of digital educational technologies has significantly increased and pharmacy education is not excluded. Data from several sources have identified the benefits and potential challenges associated with technology integration (Ezeala, Ram, and Vulakouvaki, 2013; Grindrod, Morris, and Killeen, 2020). Thus, Begley and authors (2015) carried out an empirical study on the efficiency of technology for pharmacy classes. The research was performed when technology was not widely used in pharmacy education and was considered an additional tool to the traditional way of learning. According to the results of their survey, the application of digital technologies caused more challenges than potential use because students used technologies mostly for non-academic purposes. However, the authors advised teachers to investigate the potential and threats of technology as well as study strategies of technology integration into the learning process as they create engaged student-centred learning.

Reading the current research on educational technologies, the opposite point of view can be observed. In a recent cross-sectional study Richardson and authors (2020) investigated the impact of technology on teaching style transformations. They analysed how virtual patient technology shifts

traditional lessons into an experiential learning environment where students are not afraid of mistakes and carry out personal investigations to formulate their assumptions. In other words, the technology allowed teachers to create an immersive constructive learning environment. The potential benefit of virtual reality is described in quite a several research (Coyne *et al.*, 2019; Ventola, 2019; Saienko *et al.*, 2020; Leshchenko *et al.*, 2021; Mirzaian and Franson, 2021). The majority of studies confirm that this technology fosters the development of communication and critical thinking skills.

Constructive learning is impossible to implement without students' active engagement that is driven by students' intrinsic motivation to learn. Canadian researchers Grindrod, Morris and Killeen (2020) proved that digital technologies impact students' motivation because teachers bring a real-world to class through videos, interviews, and simulation of problem-based case solutions. Moreover, students appreciated the immediate feedback that the platform provided after the tests or case solutions. The authors of the research carried out an empirical study on the efficiency of a computer-based platform application for the training of pharmacy students. Having analysed students' academic achievements and level of engagement during the training, the scientists concluded that computer-based education could change the students' attitude toward studying by increasing their intrinsic motivation.

The positive outcome of technology integration into constructive learning is highlighted in Doolittle and Hicks's (2003) research, where they explained the conceptual role of technologies for constructive activity development. First, technology offers up-to-date information that stimulates the constant adaption and construction of new knowledge. Moreover, the interactive mode of technologies implies the synergy of the context and real learning environment that is essential for knowledge upgrading. Second, the rapid development of advanced technologies with new options also contributes to the development of creative and critical thinking skills necessary for knowledge construction. Third, by suggesting authentic, speciality-relevant tasks for problem-solving learning, technologies enhance advanced knowledge acquisition and interdisciplinary extension.

Observed conclusions are in line with Jha's (2017) empirical research which claims that educational technologies transform learner-teacher interaction as well as instruction design that leads to more productive knowledge construction. By employing technologies for learning, students adjust the content to their real needs and possibilities, making knowledge more personally

meaningful. All of the studies reviewed here support the hypothesis that technology-enhanced learning contributes to the creation of a constructive, active learning environment. In the next section, the authors will support their hypothesis with the results of the empirical study.

Methods

The present study employs an action-mixed research design framework (Creswell, 2009) that combines qualitative and quantitative data collection tools. The key task was to obtain pharmacy educators' and students' reflections and perceptions of the efficiency of online digital resources for the creation of a constructivist learning environment. The mixed research framework was applied to provide evidence-based findings and the involvement of teachers and students allowed us to investigate the problem holistically. The results of the quantitative analysis provided us with statistical data, whereas qualitative analysis demonstrated the participants' opinions and attitudes towards the researched issue. As a main comparative element of the research, the authors chose initial and final findings contrasting which was considered as a naturally occurring event. During the experimental study, the participants from the teachers' cohort were working in self-organised groups so they could discuss challenges and solutions. For this case, the randomisation was admitted to be impractical because the observed concept was new to students as well as to teachers and it might demonstrate results of low significance. Furthermore, self-selected groups of teachers demonstrated a more motivated and responsible attitude toward the experiment.

The study procedure included some stages: An initial questionnaire for teachers about their assumption of constructivism learning theory and a questionnaire for students on the usage of traditional learning materials; The follow-up on the three webinars from the educational experts on the essence of the theory and the ways of its implementation in online learning materials and courses; Three classes observations of seven teachers and updated learning materials analysis; Final questionnaire of students and interviewing teachers and self-reflective open discussion on the results of the experiment.

Data collection and analysis tools

To verify how online digital technologies affect the formation of a constructive learning environment, the Constructivist Multimedia Learning Environment Survey (CMLES) designed by Maor and Fraser (2005)

was employed. This tool was used to investigate the students' and teachers' perception of online learning and teaching respectively. A major advantage of this tool is the content of the questionnaire that covers the key aspects of constructivist learning: students' communicative skills, quality of inquiry learning and reflective thinking strategies, authenticity, and complexity of online tasks. The original version of the tool included 30 questions distributed in six subsections (Maor, Fraser, 2005). The tool was upgraded and five questions on the quality of teachers' support during online learning and the quality of self-regulatory skills were added: a). I receive enough teacher's support, b). Teacher gives me possibility to demonstrate my prior knowledge, c). I plan how to carry out my investigation, d). I can assess my learning needs, e). I can assess my progress.

The questionnaire included 35 questions. It was designed based on the Likert scale using the range of responses from 'Almost never - (1)' to 'Always - (5)'. To demonstrate inferential statistical evidence of the CMLES, paired t-test was used. The test demonstrated if there was a significant difference between the results of the first questionnaire when students evaluated traditional courses and materials and the results of the final questionnaire on constructivist learning online tools.

Among additional tools, the experts applied a rubric for the assessment of observed classes. The rubric included the following questions: How relevant were the learning material and online activities to students' professional practice; If a teacher employed activities for critical thinking and inquiry skills development; To what extent students were engaged in online peer communication; If students got enough teacher's support; if digital technologies corresponded the objectives of the lesson. The teachers' final interview and open discussion were analysed using descriptive statistics and content analysis.

Participants

The study involved 26 second-year Bachelor pharmacy students (19-21 years old) and ten educators of the Department of Medicinal Chemistry and Toxicology, Bogomolets National Medical University. The sample size was calculated using a sample size calculator from calculator.net. This calculator computes the minimum number of necessary samples to meet the desired statistical constraints. The following data was imputed: confidence level -95%, margin error-2.80%. The result demonstrated that 26 or more measurements/surveys were needed to have a confidence level of 95% and that the real value is within $\pm 2.80\%$ of the measured/

surveyed value. The Margin of Error was calculated using the same resource.

The second-year study students were selected because from the second course, students enter their speciality and study disciplines that are more specific. They just started learning basic professional knowledge and the authors consider it a critical period to equip students with the necessary skills. All students had the same educational background and learning environment. Students' participation was voluntary and they could refuse the participation without any academic consequences. The participants from the teachers' cohort represent the pharmacy lecturers; all of them had more than ten years of teaching experience. However, the issue of constructive learning was new to them. Teachers represented different disciplines but were united by the tools and methods of the class delivery. The circumstance of the last two years forced fast technology integration, thus there is a need to find out advanced ways to connect the pedagogy, content, and technology. As experts, three educators having a scientific degree in Education were invited from Igor Sikorsky Kyiv Polytechnic Institute. Their role was to provide educational and methodological support, review learning materials and observe practical classes.

The methodology of the research was approved by the Scientific and Methodological Board of the Department of Pharmacology, Bogomolets National Medical University. The teachers' participation was voluntary. Educators were selected randomly according to their wish to participate in the professional development course. All answers to questionnaires were anonymous and coded.

Results

The qualitative data collected from the questionnaires, class observations, and reflective discussions provided evidence on how the technically enhanced constructivist learning approach was perceived by teachers initially and the dynamic of meaningful transformations. The initial questionnaire on constructivism learning theory was suggested to teachers and included three questions: a). What are the principles of constructivism learning theory? b). What classroom strategies can you apply to introduce constructivism? c). How do you support constructivism in online learning environment?

The research findings revealed that the majority of pharmacy educators (n=12 out of 15) knew little about the constructivist learning theory. After the session of webinars and self-paced Massive Open Online Courses

(MOOC) on the constructivism approach, the results changed and more than 83% (n=10) of educators agreed to proceed with the experiment. The acquired knowledge improved the quality of learning materials, including the interactive web cases and web quests suggested for online classes and self-independent students study. For the initial assessment, the authors suggested to the students materials that were developed before the experiment, which included a set of videos, presentations, and tasks presented on the MOODLE platform and through the Google classroom. After the educational sessions and updating materials, teachers transformed video lectures into interactive video lessons, and conventional theoretic-oriented tasks into web cases and web quests. Comparing the results of the initial students' evaluation of traditional learning materials and the updated version (CMLES), positive dynamics in all domains were observed; however, the most significant transformations were noticed for such domains as learning to investigate, learning to think, and relevance. The comparative initial and final assessment is demonstrated in Table I.

Table I: Initial and final assessment findings data (Average item mean)

Domain	Initial (students n=26, questions n= 5)	Final (students n= 26, questions n= 5)
Learning to communicate	18.3	23.7
Learning to investigate	14.6	21.2
Learning to think	13.2	17.2
Relevance	14.2	22.4
Challenges working with technologies	17.6	18.5
Ease of use	21.2	22.4
Quality of teachers' support	18.7	25.4

According to the t-test results, this difference is considered to be statistically significant (Table II).

Table II: t-test statistic results

Data	Initial assessment	Final assessment
Mean	117.8	150.8
Standard deviation	17.3	10.0
Standard error of the mean	2.9	1.7
Number of questions	35.0	35.0
Number of students	26.0	26.0

The confidence interval was from 45.56 to 60.05. Intermediate values used in calculations were $t=14.7937$, $df=35$ standard error of difference = 3.569. To add visibility to the results, a diagram was created

and presented in Figure 1. The mean value for each domain of the initial and final questionnaire (students $n=26$, questions $n=35$) was calculated.

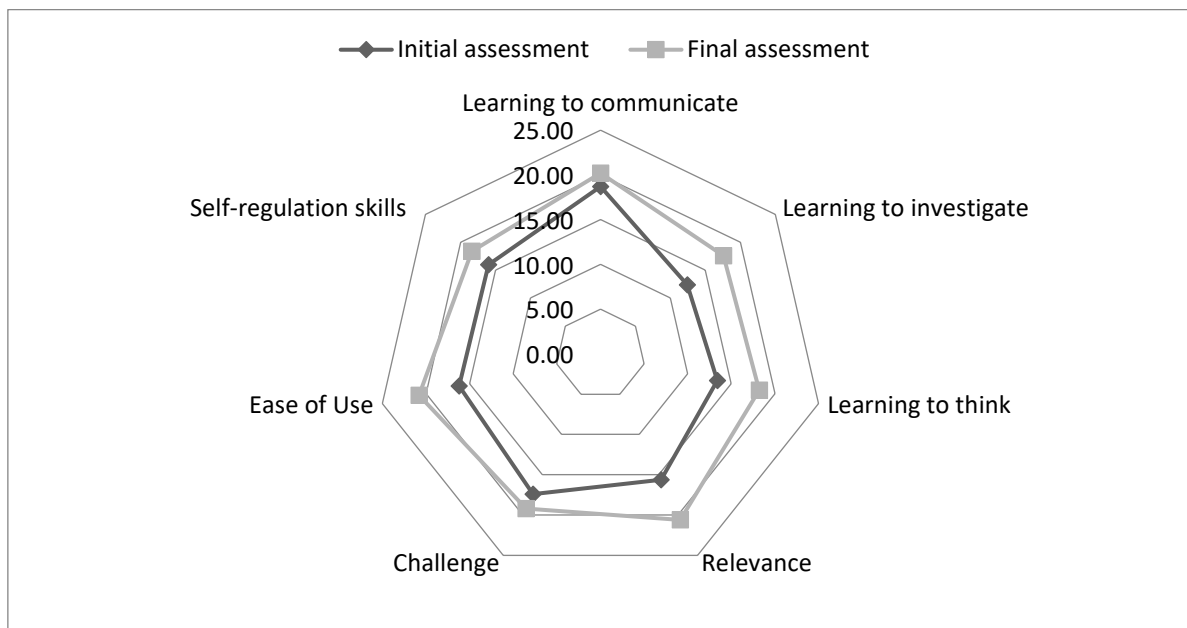


Figure 1: Experimental results of the initial and final surveys for each domain

Considering the observation results, the experts attended 21 classes and admitted that learning material of conventional versions, as well as a constructive variant, were relevant to the curriculum and future professional practice (classes $n=16$); however, constructive materials contained more real-life problems for solution. Teaching activities for critical thinking and inquiry skills development were employed in 18 classes. Peer communication and interaction with teachers were observed in all 21 classes, but with the prevalence of personalised communication from teachers instead of giving the same instructions to all students. Thus, students received more support from teachers and felt more confident and secure while solving tasks. The integration of digital technologies was relevant to classes' objectives at in 21 classes but with the following distribution: online collaborative work (classes $n=12$), individual online web cases ($n=17$), interactive web quests (classes $n=10$), interactive video lectures (classes $n=8$), discussions of cases and drugs description in professional websites (classes $n=14$). Experts also pointed out that students' engagement increased and the mode of communication transformed from the teacher-students (T-S) to student-student (S-S) interaction.

During the final interview with teachers and open discussion on the experiment results, the most

frequent content codes used by teachers while answering the questions was singled out: "active knowledge constructions", "students' engagement", "prior educational experience", "personalised learning", "real-life cases", "self-directed and self-organised skills", "inquiry skill".

The results of the study indicate that there were positive transformations toward the constructivist learning environment. The next section, therefore, moves on to discuss the teaching strategies that led to these transformations.

Discussion

This study set out with the aim of assessing the importance of digital educational resources in the development of a constructive learning environment for pharmacy students. Constructivism learning provides a framework to ensure students' transformations into self-reflective autonomous thinkers who can withstand attitude-based information or underlying assumptions. This study supports evidence from previous observations (Fox, 2001; Kang et al., 2010; Pascoe et al., 2018), who found that integration of constructivism affects the mode of

teaching instruction and interaction with students. Pharmacy educators provided more sensitive and encouraging support with a focus on personalised students' needs, including more problem-based cases based on authentic material for stimulation of inquiry and critical thinking skills development. By solving inquiry-based web cases, students are taught how to adjust their assumptions when it is necessary to change the service delivery model for better patient outcomes, how to evaluate their solutions critically, and reflect on the results of the solution. These ideas are consistent with those of Tsingos and authors (2016), who highlighted the importance of critical thinking through the reflective practice of prior experience. Scientists explain that students can modify their perceptions while incorporating new experiences and knowledge. By challenging students to investigate a problem in different contexts through reflection on experiences, teachers give students a tool to become determined and responsible thinkers.

The chosen tool for the assessment of outcomes (CMLES) covers key areas of constructive learning, and it corresponds to the main directions of the transformations. Therefore, in this section, the most efficient teaching strategies for learning to communicate, learning to inquire and think critically, authenticity and relevance to the profession, quality of learning with digital resources, and self-organisational skills will be introduced.

Having analysed the experiment's quantitative findings, specifically CMLES results, the authors realised that among the domains of constructivism, multimedia learning, "Inquiry learning" (learning to investigate), and relevance had the most significant changes. It was explained by the fact that students did not experience such kind of learning before, and by employing technologies and real-life content of educational materials, students were able to become active participants in the learning process and could demonstrate their educational curiosity. The domain with the lowest changes was "Challenges using multimedia". This is obvious, as today's students are more digitally perceptive than teachers are. The domains of learning to communicate and self-reflection did not demonstrate statistically significant changes. The students initially did not experience any problems with communication. The opposite situation is with self-reflective skills, which are poorly developed and it was considered an issue for further investigations and improvement. The students did not clearly understand the meaning of these skills, and nor did they experience it in their secondary schools. Thus, the author's task is to promote learner autonomy and to explain to the students the correlation between the quality of learning and their academic achievements.

After the consultations with experts and discussions of constructivism pillars, it was concluded that to efficiently integrate constructivism into the classroom, it is crucial to establish a collaborative learning environment where teachers facilitate learning by adjusting materials and resources to students' level of background knowledge and possibilities. Students were actively engaged in the learning process by suggesting topics for discussion, performing collaborative scientific projects and peer-assessment. In other words, a student-teacher partnership will work if knowledge and authority are shared between all participants in the learning process.

With this in mind, the authors decided to change their communication models and pay more attention to teaching the students to communicate and co-construct knowledge by sharing and negotiating. Productive reflective dialogue supports students' curiosity and interest so in the classrooms, questioning techniques to identify arguments and assess alternative perspectives were employed. Instead of direct questions, "True/False" statements with the explanation of choice were suggested. While learning drug therapy management, students could be asked open-ended questions on critical evaluation of students assumptions: "What information should be shared with the patient to ensure a positive outcome?", "Why is it important to explain a patient drug interaction? A series of probing questions were efficient in disclosing details and provide a fuller picture: "What are additional risk factors, and what is the best management of them? Process questions can be useful to test the depth of knowledge about a particular topic: "How can you monitor the toxicity of a drug? Assessment questions were also of great help: "What did you discover?", "How did you find it out?" As an additional communicative tool, discussions on appropriate management of drug-induced diseases or causes of side effects, and methods of their prevention were also moderated. Through these techniques, the authors tried to provide social and collaborative knowledge construction with the assessment of alternative solutions. Regarding digital resources, collaborative tools for discussions and polls Lino, Miro, Padlet, and Nearpod were used. However, according to students' feedback, the most appreciated tool for answering questions was Flipgrid, where students recorded their answers and commented on them. As students explained, sometimes they did not know the answer in class, or they needed more time for thinking. They could record their answer at any time and send them to a teacher immediately without writing them and waiting for the next class.

The next aspects that required the most transformations were learning to inquire and to think

critically. According to Maor and Fraser (2005), the constructivist classroom should incorporate such principles as prior knowledge eliciting and cognitive dissonance creation. In this perspective, students were taught by answering the questions via direct observation and research. The algorithm for an inquiry-based activity was developed: a teacher evokes students' prior knowledge on a topic through pre-tests, the introduction of an experimental video evaluating the effects of different drug formulations, and warming-up activities. When the students understood the gap between their knowledge and new facts, the new material (theory, case, practical chemistry test, etc.) was suggested, but the new information was incomplete, so the students posed questions and together searched for answers under a teacher's supervision. Having gathered the complete information on a topic, the next was to move on to authentic real-life practical cases or exercises, and the final stage is a teacher and peer assessment.

The constructive application of digital resources is highlighted in the empirical study of Ezeala, Ram, and Vulakouvaki (2013), where researchers confirm meaningful learning outcomes after the integration of technologies that simulated process-oriented inquiry learning. Thus, for practical cases and quizzes the platform PharmDia, and collaborative mind maps on case solutions were used and the students presented using MindMaster. For flashcards and quizzes on pharmacology the authors found gamifying RxHero application. These resources add interactivity to classes and serve as a motivation tool when students have to overcome difficult levels of tasks.

As additional tools, virtual laboratory workshops, an online platform Neuron for e-courses with interactive problem-based learning projects were also designed. The method of project training is aimed at achieving the predicted learning outcomes. The use of this method involves a clear definition of didactic requirements and developed specific skills such as collective and individual work of students, problem-solving and planning of further actions, involvement of research methods of information retrieval, drawing up a project work plan, fixing intermediate results. Among other meaningful and inquiry-oriented strategies, web cases solution that requires the combination of chemistry knowledge and specific profession-related knowledge, e.g. bio evaluation of medications, and antagonists types identification was employed. The cases are authentic and deal with the production of medication, pharmacokinetic and pharmacodynamics problems. To find solutions to web cases, students had to work in groups, delegating roles to group mates: theoretical substantiation of the solution, identifying the connection of substance peculiarities and its medical

application, finding practical implementations or limitations of medication, medical application of medication. All these tasks are easier to perform using online tools such as online encyclopedias, profession-related websites, listening to experts' podcasts, or watching videos.

Discussing the constructivist learning environment, the essence of metacognition skills of self-regulation and self-reflection must be emphasised. These skills are crucial for future pharmacists as they should be ready to reflect on their solutions, perform lifelong self-directed learning for continuous professional development, and self-evaluation of resources and needs (Steuber *et al.*, 2017). Metacognitive skills are necessary to perform the self-assessment of new constructed knowledge quality and relevance. Therefore, every activity included reflective questions on the results assessment, mistakes analysis, and prognosis of future actions for prevention of mistakes. As a valuable tool, a digital portfolio of achievements that every student had to complete after an educational module was employed. The platform, "Explain Everything" allows demonstrating to students such activities as "thinking aloud". This tool is used for the creation of screencasts that demonstrate the performance of every stage for chemical calculations. While watching their videos, students can easily find a mistake and reflect on its causes.

To successfully implement the suggested strategies, the authors would like to recommend pharmacy educators engage students' experiences, appreciate students' alternative solutions, use authentic learning material, encourage students' ownership of the learning results, create collaborative projects with the use of multimodal digital resources, and develop metacognitive skills.

Conclusion

The most obvious finding to emerge from this study is that technical-enhanced constructivism learning theory transforms the traditional lecture-based teacher-centred environment into an inquiry-based personalised process of knowledge acquisition. Among the most significant shifts, the possibility to involve students' prior knowledge in the creation of alternative conceptions and metacognitive skills development should be admitted. It would not be possible to achieve these results without innovative teaching strategies such as teacher-student dialogue, alternative assessment, students' participation in assessment criteria development, open-ended discussions of authentic inquiry-based web cases, and collaborative

work on digital platforms with a focus on communication skills development in different formats. Further research could also be conducted to determine the effectiveness of digital educational technologies for the development of metacognitive skills.

Conflict of Interest

All authors declare no conflict of interest associated with this work.

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