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The Development of Digital Competences in Future Chemistry Teachers in Accordance with the DigCompEdu Requirements

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Abstract

This paper reports on the results of the research aimed at the creation of an e-learning course to support the teaching of the compulsory course Activating Methods in Chemistry Teaching (AMCT) in the LMS (Learning Management System) Moodle (Modular Object-Oriented Dynamic Learning Environment). This course was subsequently implemented into university teaching to develop students' digital competences in line with the European Framework for the Digital Competence of Educators (DigCompEdu). The research sample consisted of first year Master's degree students of chemistry teaching (N=18) at the Faculty of Science, P. J. Šafárik University in Košice. The research took the form of a one-group quasi-experiment performed during the winter semester of the 2023/2024 academic year. The scope of teaching in the e-course was over 9 modules for a total of 42 hours. The research instruments included the self-assessment card filled in by the students before and after completing the e-course, and a questionnaire developed by the authors. The evaluation of the comparison of the students' self-assessment cards shows an overall improvement in the students' level of digital competences and skills in the individual topics covered by the e-course. Significant development of digital skills was evident in the topics Computer Based Laboratory Activities, Online Applications and Use of a Digital Visualizer. The results of the questionnaire showed that students realised the benefits of the e-course for their future teaching practice. To optimise the e-course, it will be necessary to adjust the amount of time required for some topics and create more opportunities to use digital technology to address specific topics in chemistry.

Keywords: activating methods in chemistry teaching, e-learning course, higher education, self-assessment, teaching students

1. Introduction

Many European documents specify the requirement to develop teachers' digital competences, e.g., European agenda for adult learning 2021–2030 (Redecker, 2017), OECD Future of Education and Skills 2030 (OECD, 2018) and Digital Education Action Plan (European Commission, 2020).

Digital competences are essential for education, work, and active participation in society. Its lifelong development is therefore particularly important. To better understand the nature of these competences, the European Commission has developed the DigComp European Framework of Digital Competences for Citizens and in 2017, within this framework, the Joint Research Centre (JRC) developed the European Framework for the Digital Competence of Educators (DigCompEdu). Teachers' digital competences differ from those of other individuals, as the focus is on how teachers can use digital technology in education (Krumsvik, 2011; Røkenes & Krumsvik, 2014). Krumsvik (2011) defines digital competences of future teachers as proficiency in the use of digital technologies for educational strategies.

The DigCompEdu framework aims to capture and describe specific teachers' skills in 6 areas of digital technology use (Redecker, 2017).

1. **Professional engagement** relates to teachers' ability to use digital competences for the purpose of communication, professional collaboration with colleagues, use of digital technologies in practice, and for continuous professional development.
2. The teacher selects **digital resources**, creates new learning resources and digital content. He/she introduces digital devices and resources to increase the efficiency of teaching procedures. He/she uses digital technology to encourage cooperation among students and support group as well as independent learning.
3. **Teaching.** The teacher can teach using digital technology that supports independent learning in students as well as group work.
4. **Digital assessment.** The teacher uses digitally supported formative and summative assessment. He/she analyses the data collected on students' progress and provides feedback.
5. **Supporting students.** By using digital technology, the teacher supports active learning in students and allows them to proceed on various levels and at various speeds.
6. **Supporting students' digital competences.** The teacher introduces activities, tasks, and assessment that require the student to look up information, analyse and interpret it, and evaluate its trustworthiness and reliability.

Similar competences have been specified in the United Nations Educational, Scientific and Cultural Organization (UNESCO) in accordance with the goals of the Information and Communication Tools Competency Framework for Teachers (ICT CFT) (UNESCO, 2018). This publication delves even deeper. In terms of the curriculum and assessment, the teacher should be able to use search engines to find freely available digital educational materials.

Researchers agree that teachers' educational programmes should focus on developing digital competences (Gudmundsdottir & Hatlevik, 2018; Røkenes & Krumsvik, 2014). In this context, it is necessary to create educational materials for future teachers addressing the use of digital technology (Ranieri & Bruni, 2018; Ranieri et al., 2018; Tondeur et al., 2018). Moreover, it is necessary to provide teaching students with feedback on their practical performance during training (Banas & York, 2014; Ranieri & Bruni, 2018; Tondeur et al., 2012, 2018).

The Slovak Republic draws on the European Union Digital Education Action Plan (2021 – 2027), setting out a shared vision for high quality, inclusive, and accessible digital education in Europe. It strives to promote the adaptation of education systems and vocational training in the member states for the digital age. The Digital Education Action Plan is of key importance in achieving the vision of European education until 2025 (European Commission, 2020).

The reasons for the insufficient use of digital technology in Slovak schools include difficult preparation for teaching with digital tools (51.5%), insufficient technical equipment (22%), and the inability to use such tools (20%) (Increasing digital competences – the growth of education in society, 2022; press release).

The digital competences covered by the teaching study programmes influence the way the graduates will use technology in their teaching practice (Agyei & Voogt, 2011), which is why researchers advocate for this focus (Gudmundsdottir & Hatlevik, 2018; Røkenes & Krumsvik, 2014).

To sum up, it is necessary to include digital technology in teacher education at universities.

2. Materials and Methods

2.1 Research aim and questions

The aim of the presented research was to develop an e-learning course supporting the Activating Methods in Chemistry Teaching (AMCT) course in the LMS (Learning Management System) Moodle (Modular Object-Oriented Dynamic Learning Environment). It was subsequently implemented into first year Master's degree students of chemistry teaching to develop students' digital competences in accordance with the European Framework for the Digital Competence of Educators (DigCompEdu).

Based on this aim, the following research questions were formulated:

RQ1: Is the implementation of this e-course in teaching efficient in terms of developing the selected digital competences specified by DigCompEdu?

- What are the levels of students' digital skills and knowledge before AMCT?
- What are the levels of students' digital skills and knowledge after completing AMCT?

RQ2: Do students consider the contents of this course useful for their future teaching practice?

2.2 Research approach

To achieve the research aim, a single-group quasi-experiment was performed during the winter semester (September – December) of the 2023/2024 academic year.

2.3 Research sample

Deliberate sampling was used. The research sample consisted of 18 first year Master's degree students of chemistry teaching combined at the Faculty of Science, P. J. Šafárik University in Košice. 15 were boys and 3 were girls.

2.4 Research instruments

The research instruments included a self-assessment card and a questionnaire developed by the authors.

2.5 Research procedure

In the preparatory phase, the contents of the AMCT e-course were designed in accordance with the requirements for the development of digital competences specified by DigCompEdu (Table 1).

Table 1: Compliance of the AMCT e-course topics focused on the development of digital competences with the DigCompEdu standard

AMCT e-course topic	Area of digital competence development according to DigCompEdu
LMS Moodle and E-Learning Tools	Professional engagement
Models and Modelling in Chemistry Teaching	Teaching Digital Resources
The Use of a Visualiser in Chemistry Teaching	Teaching Digital Resources
Computer-Assisted Chemistry Teaching	Teaching Supporting students
Assessment in Chemistry Teaching – Summative Assessment	Digital Assessment
Creation of Tasks and Interactive Tests Using Digital Tools for Summative Assessment (Google Forms, Kahoot).	Digital Assessment
Working with Slovak, Czech, and European Educational Portals and Platforms (VIKI, Metodický Portal RVP.Cz, Studiumchemie.Cz, Khan Academy, E-Twinning).	Professional Engagement Teaching Supporting Students' Digital Competences
Online Applications Useful in Chemistry Teaching (Wordwall, Learningapps, Flippity, Nearpod, Mentimetr)	Teaching Digital Assessment Supporting Students
Didactic Games in Chemistry Teaching	Teaching Supporting Students

Source: Own processing

The contents of the AMCT e-course topics were following:

Topic 1: LMS Moodle and E-Learning Tools

Students were introduced to the content and structure of the e-course in terms of working with distinct types of information resources (file, directory/folder, link to file or web page). In addition to the learning resources, students were presented with selected activities (assignment, survey, questionnaire, test, database, BigBlueButton, chat) promoting the student-teacher or student-student interaction.

Topic 2: Models and Modelling in Chemistry Teaching

For this topic, a teaching text "Models and modelling in chemistry teaching" and 4 types of methodology focused on the use of ChemSketch in chemistry teaching were created. The methodology addresses drawing chemical formulas, reaction schemes, diagrams, chemical apparatus, and molecule models. Students were asked to work on a selected school experiment with emphasis on the description of the starting substances and their chemical formulas, write their chemical equations, and draw the apparatus. They proceeded to present the protocols using the BigBlueButton platform.

Topic 3: The Use of a Visualiser in Chemistry Teaching

A practical demonstration was created to provide instructions on using the visualiser. Students created a database with video-sequences of experiments as a multimedia teaching tool for the "Chemical action" topic. Videos and stills (photographs) from selected chemistry experiments

were saved to the Microsoft OneDrive cloud in a shared folder named "Working with Visualizer".

Topic 4: Computer Based Laboratory Activities

For this topic, a presentation with practical instructions for working with the Vernier measuring system including demonstrations was created. The following activities focused on computer-assisted experiments were conducted during classes: "Acid-base titrations", "How to stop heartburn", "Bulking powders" – also in terms possible for use in distance learning.

Topic 5: Assessment in Chemistry Teaching – Summative Assessment

Given the difficulty of this topic, lectures were delivered and provided in the form of presentations and text documents for the purpose of self-study. Students also used the ChatGPT artificial intelligence (AI) to generate chemistry exercises for grammar school chemistry classes.

Topic 6: Creation of Tasks and Interactive Tests Using Digital Tools for Summative Assessment

Practical instructions for working with Google Forms and Kahoot! including task and test examples were created. Based on them, students created basic digital forms of tasks and shared them within the class using the digital tools.

Topic 7: Working with Slovak, Czech, and European Educational Portals and Platforms (VIKI, Metodický portal RVP.cz, Studiumchemie.cz, Khan Academy, e-Twinning)

Instruction was focused mainly on the e-Twinning platform.

Topic 8: Online Applications in Chemistry Teaching

A presentation with an overview of various applications (Wordwall, LearningApps, Flippity, Nearpod, Mentimetr) useful in creation of tasks, exercises, tests, and didactic (even escape) game was created. This overview was complemented by practical demonstrations from a variety of primary and grammar school topics in chemistry.

Topic 9: Didactic Games in Chemistry Teaching

Examples of games were made available to students in several phases of the educational process; in the phase of motivation – jigsaw puzzle, crossword, wordsearch, puzzles; in the phase of fixation – learning wheel (checkpoint – individual tasks); in the phase of diagnosis/ evaluation of knowledge – competition, knowledge quiz, crossword puzzle, memory game, etc.

The educational materials designed for individual topics can also be used for self-study, through which the student gains greater independence and an opportunity to learn outside the classroom.

The contents of the AMCT e-course including the educational materials designed were transferred into the LMS Moodle environment.

During the winter semester (September – December) of the 2023/2024 academic year, the AMCT course was taught using the LMS Moodle e-course support. The scope of teaching was 3 lessons a week in 9 modules for a total of 42 hours. This course, focused on digital competence development, was attended by the first year Master's degree students of chemistry teaching combined.

3. Results and Discussion

3.1 Identification of students' opinions on their digital competence development according to DigCompEdu – based on self-assessment

The students of chemistry teaching (N=18) filled in the same self-assessment card before (September 2023) and after (December 2023) completing the AMCT course. In the self-assessment card, students were supposed to evaluate the level of their own digital competences and skills in the topics covered by the e-course (Table 1). For student self-assessment, a three-point scale was used: independently – with a classmate or teacher's help – I do not understand it yet. The self-assessment card results before and after completing the AMCT e-course can be seen in Figs. 1 and 2 (own processing).

Figure 1: Before AMCT e-course

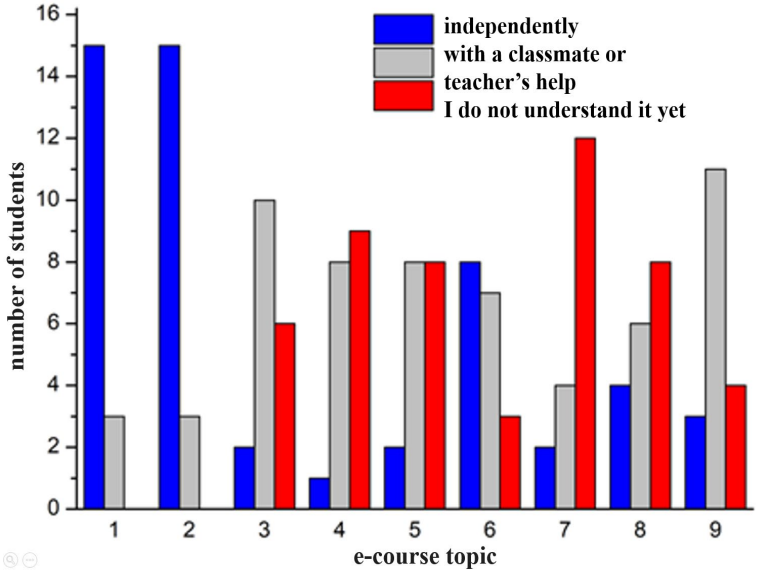
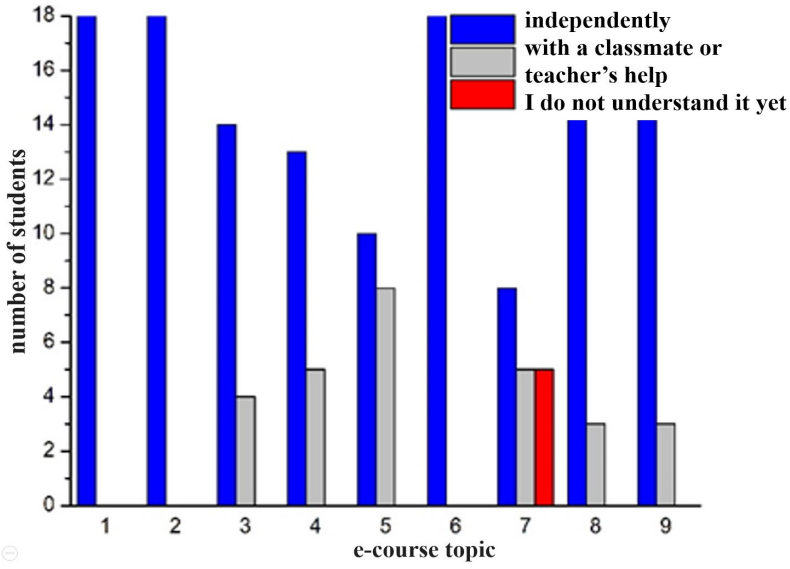


Figure 2: After AMCT e-course



The evaluation of the comparison of the students' self-assessment cards shows an overall improvement in the students' level of digital competences and skills in the individual topics covered by the e-course.

Beforehand, students were supposed to possess knowledge and digital skills related to the following topics:

Models and modelling in chemistry teaching, working with ChemSketch

Students developed the basic ability to work with this program during a course in their Bachelor's study. In the new study programme introduced in the 2024/2025 academic year, this topic is removed from Bachelor's study and transferred to the e-course in question.

LMS Moodle and E-Learning Tools

During the COVID 19 pandemic, most students used LMS Moodle for the purpose of distance study to access the educational materials, tasks, and exercises. Based on this, future work in the LMS Moodle environment needs to focus on developing the skills needed to create a quality e-learning course from a teacher's point of view and determine which modules/resources and activities can be useful. It is also necessary to identify how to motivate students towards individual and teamwork and determine which useful teaching management tools this environment provides.

The greatest contribution to the development of digital competences and skills was identified in the following topics:

Computer Based Laboratory Activities, Online Applications in Chemistry Teaching, Use of a Digital Visualizer, and *Didactic Games in Chemistry Teaching*

These topics were new to the students and, as it turned out, application of digital technology to a specific subject matter required more time than expected. Foulger et al. (2017) have also pointed out that training future teachers in the efficient use of technology applied to specific subject matter is necessary. This implies that it is necessary to pay more attention to the application of the technology-related knowledge in teaching specific chemistry topics. In terms of the Chemistry Teaching study programme, this e-course precedes the courses Chemistry Didactics I and Chemistry Didactics II in which this technological knowledge can be applied to specific chemistry topics as tasks for students. Ranieri et al. (2018) have concluded that future teachers want to acquire more information, not just about the technical aspects of digital technology, but also need more time to learn how to use them in practice. This ensures that their technological knowledge and skills are properly fixated (Pereira et al., 2016).

Similar conclusion can be drawn about the topic *Assessment in Chemistry Teaching – Summative Assessment*, i.e., the technological viewpoint as such is insufficient. First, students need to understand how tasks are designed based on the revised Bloom's taxonomy as well as the procedure of creating tasks with discontinuous text such as graphs, tables, or models. Afterwards, they can proceed to use digital tools (Google Forms, Kahoot, Socrative) to create tests with tasks on the required level. Although some of the students already had previous experience with these digital tools (which they gained during the optional course Modern Didactic Technology during their Bachelor's study), after completing the e-course, it is evident that they have progressed not only in their understanding of task design, but also in their digital skills.

In terms of the topic *Working with Slovak, Czech, and European Educational Portals and Platforms*, students focused mainly on e-Twinning. This platform allows chemistry teachers to create, share, and present projects, and develop cooperation; most students did not have previous experience with e-Twinning. In terms of e-course optimisation, more time will be dedicated to this digital competence.

3.2 Identification of students' attitudes to and opinions on this e-course in term of their future teaching practice

Students' opinions and attitudes were identified by a questionnaire developed by the authors. Since first year Master's degree students of chemistry teaching (N=18) would not complete any courses in pedagogy and psychology until December 2023, when they were administered the questionnaire, their opinions were compared to those of second year Master's degree students of chemistry teaching (N=16), who had completed this e-course in the 2022/2023 academic year. Subsequently, the second group completed courses in pedagogical and psychological basics, chemistry didactics as well as teaching practice.

The opinions of the first and second year Master's degree students of chemistry teaching on the AMCT e-course contents (according to individual topics) regarding its usefulness for their future teaching practice can be seen in Figs. 3 and 4 (own processing). In the questionnaire, students assessed individual topics using a five-point scale from "strongly agree" to "strongly disagree".

Do you believe that the contents of the Activating Methods in Chemistry Teaching e-course are beneficial in terms of preparation for your future teaching practice?

Figure 3: First year Master's degree students of chemistry teaching

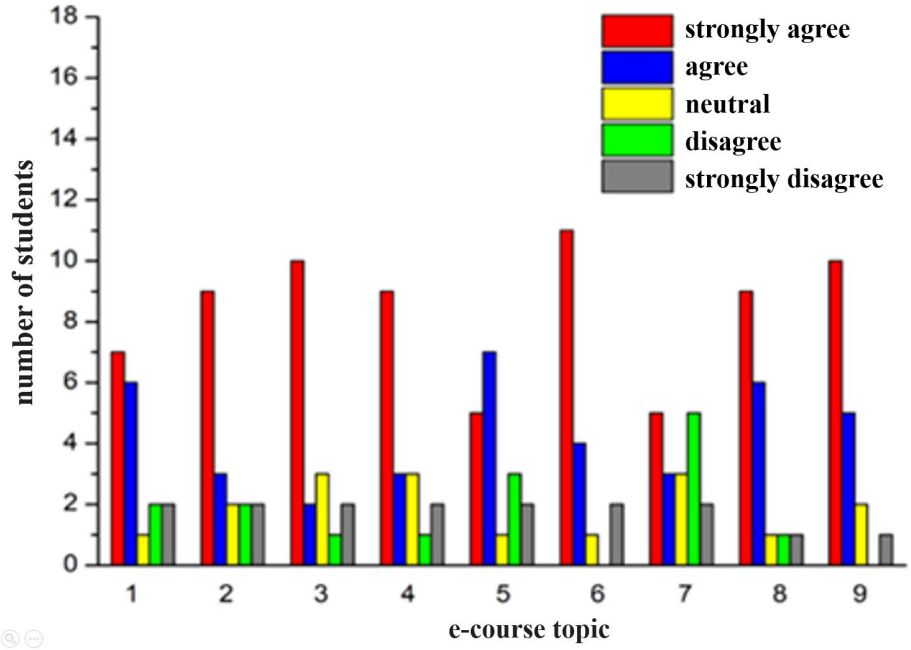
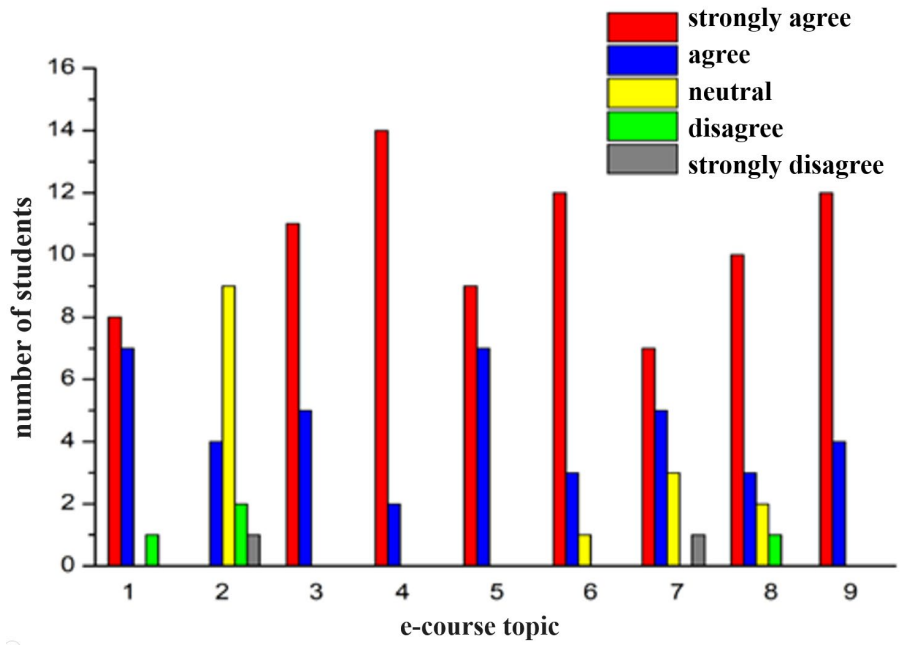


Figure 4: Second year Master's degree students of chemistry teaching



A comparison of students' answers (Figs. 3 and 4) shows that both groups consider the course topics useful for their teaching practice. Second year student were more confident about their agreement, which results from the fact that this group already had the opportunity to apply their knowledge during their teaching practice. They saw and hands-on experienced how digital technology can be used in teaching and learning and could reflect on it.

First year students consider summative assessment less important in comparison to their older colleagues. On the other hand, second year students consider working with ChemSketch less important.

4. Conclusions

The presented research showed that from the viewpoint of usefulness for their future teaching career, students assessed the Activating Methods in Chemistry Teaching e-course positively in terms of digital competence and skill development.

The results indicate that less time should be dedicated to ChemSketch, while more time should be dedicated to the use of the visualiser as well as task, test, and didactic (escape) game designing using a variety of online applications (Wordwall, LearningApps, Flippity, Nearpod, Mentimetr). However, ChemSketch proved efficient in teaching about carbohydrates (Marpaung et al., 2020; 2021). The use of the visualiser in chemistry teaching leads to longer-term results in comparison to the traditional procedures (Stieff, 2019).

The implementation of digital assessment tools in teaching allows teachers to effectively track students' progress and recognize the opportunities to motivate and encourage them to succeed in summative assessment as well (Gokulnath, 2019).

Given the fact that communication skills belong among the most important for both teachers and students, their development requires specific attention. In terms of e-course optimisation, didactic game design will be focused on. Via e-Twinning, Slovak university students will be involved in the search, sorting, and processing of information on escape game designing. E-Twinning projects support teachers' professional growth by allowing them to develop digital competences and create teaching materials, and also by promoting interdisciplinary cooperation (Acar & Peker, 2021; Akdemir, 2024).

In teacher education, digital competence development cannot take the form of an isolated course, it is necessary to incorporate it across different courses. It should be part of the curriculum, subject matter, and pedagogical aspects, i. e., attention should be paid not only to technological integration, but also to teaching and learning assessment.

4.1 Limitations and further research

This study has certain limitations. Firstly, it is a case study on a small research sample. Secondly, the e-course duration was limited to 42 lessons. Since digital competence is a complex topic, it would be desirable to extend the e-course duration to incorporate more applications and procedures for the purpose of future research.

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