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Scientific paper

Exploring Teachers' Technological Pedagogical Content Knowledge as an Indicator for the Planning of In-service Teacher Training in Chemistry Education

Mojca Orel,[1,*] Cirila Peklaj[2] and Vesna Ferk Savec[3]

[1] *Gimnazija Moste, Zaloška 49, 1000 Ljubljana, Slovenia*

[2] *Faculty of Arts, Aškerčeva 2, 1000 Ljubljana, Slovenia*

[3] *Faculty of Education, Kardeljeva ploščad 16, 1000 Ljubljana, Slovenia*

** Corresponding author: E-mail: mojca.orel@guest.arnes.si*

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Abstract

This study examined how teachers teaching chemistry at different levels of education perceive their levels of technological pedagogical content knowledge (TPACK) and examined the relationship of TPACK perceive levels with age, gender, teaching at different levels of education, time spent teaching chemistry, and frequency of information and communication technology (ICT) use. The study involved 261 teachers, 246 women and 15 men, from all over Slovenia, who have been teaching chemistry for an average of 18 years at different levels of education, with an average age of 45 years. The results showed that teachers teaching chemistry content perceive a high level of TPACK. There is a statistically significant correlation between age, time spent teaching chemistry, and frequency of ICT use with the perceived level of technological pedagogical content knowledge. Younger teachers, those with less professional experience and teachers who use ICT more frequently rated their TPACK higher. Based on the results of the survey, guidelines for planning the in-service teacher training that would support the development of TPACK of teachers teaching chemistry content were developed.

Keywords: Teacher demographic characteristics; information and communication technology; technological pedagogical content knowledge; chemistry teaching; in-service teacher training.

1. Introduction

In the information age, science teachers are constantly confronted with new opportunities and challenges resulting from the rapid pace of discovery in science and the remarkable development of information and communication technology (ICT), both of which simultaneously provide new opportunities and are a source of new ideas that can be effectively implemented in the processes of learning and teaching in science,[1] which also implies for chemistry education being one of the science education disciplines. With the development of ICT, it has become imperative for teachers to use modern technologies in the processes of learning and teaching, and it is necessary to transform pedagogical knowledge and redefine teachers' qualifications accordingly.[2] The role of ICT should not be understood as a potential replacement for great teachers but as a valuable tool that can be used transformatively in their hands.[3] Therefore, continuous in-service teacher training that would support the development of technological pedagogical content knowledge (TPACK) is crucial for successfully integrating teachers' technological pedagogical content knowledge in the planning and delivering science content instruction. Research results have shown that teacher training positively affects the development of TPACK.[4–7] It is important that the delivery of in-service teacher training that would support their development of TPACK is directly linked to teachers' needs and the use of pedagogical approaches in the classroom and that training does not focus only on technological skills.[8,9] Thus, it is important to note that it is not only technological knowledge that suffices to bridge this gap, but the integration of pedagogical, content and technological knowledge.[10–12] In order to plan relevant in-service teacher training in chemistry education that would support their development of TPACK, it is, therefore, valuable to use teachers' perceived level of technological pedagogical content knowledge as one of the indicators of teachers' needs related to the efficient use of ICT in chemistry learning.

1. 1. TPACK

Technological pedagogical content knowledge (TPACK) is the integration of technological knowledge (TK), which includes knowledge of how to use different software and hardware; pedagogical knowledge (PK), which includes knowledge of learning processes, different strategies and methods of teaching and learning, and content knowledge (CK).[13,14] Mishra and Koehler[13] also included technological knowledge in Shulman's[14] concept of pedagogical content knowledge (PCK). This was not an entirely new concept, but they were the first to clarify the links between all three components and their intersections in pairs.[15] They emphasized that to integrate ICT and pedagogical knowledge into subject area teaching effectively, it is important to establish a dynamic relationship between all knowledge components.[16]

Because content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK) are integrated, four new skills emerge: pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK), and technological pedagogical content knowledge (TPACK).[13] Thus, a total of seven skills are summarized in Table 1 and schematically depicted in Figure 1.

In 2007, the TPCK model was renamed to make it easier to pronounce the acronym; 'TPACK' stands for 'Technological Pedagogical And Content Knowledge'.[17] In 2008, Koehler and Mishra added contexts to the TPACK model, with the intention that the TPACK model not exist in a vacuum but be placed in specific contexts, as represented by the outer dashed circle in the TPACK model in Figure 1.[16] In 2019, the word 'context' in the basic TPACK model was replaced by 'contextual knowledge' (XK, derived from 'conte**X**tual **K**nowledge'. Contextual Knowledge (XK) in the TPACK model is encompassed by a dotted circle and represents the teacher's knowledge of the context, which includes everything from the teacher's awareness of the available technologies to the teacher's knowledge of the school, state or national politics.[18]

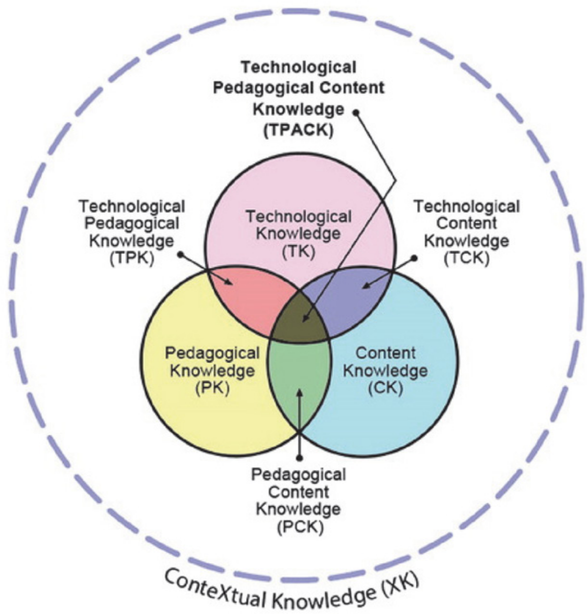

Figure 1: TPACK Model.[18]

There are three levels of TPACK perception: low, average and high. According to research, teachers perceive a high level of TPACK.[2,4,19–22] In a study involving pre-service teachers found that for the factor (part of the items in the TPACK questionnaire) design, exertion and ethics, teachers perceived high level of TPACK, while for proficiency, they perceived an average level of TPACK.[21] Çoklar and Özbek also reached the same results for primary and secondary school teachers,[19] while Arslan found that pre-service teachers perceived high TPACK in all four factors.[4] The same results were reached by Şentürk et al., who found that primary and secondary school teachers and educators perceived a high level of TPACK in all factors.[22]

Table 1: Description of TPACK.[13]

Knowledge	Description
Content knowledge (CK)	Knowledge of subject matter.
Pedagogical knowledge (PK)	Knowledge of learning processes, different strategies and methods and techniques of teaching and learning.
Technological knowledge (TK)	Knowledge of how to use different software and hardware.
Pedagogical content knowledge (PCK)	Knowledge of strategies and methods for teaching and learning content with respect to subject matter content.
Technological content knowledge (TCK)	Knowledge of how to use appropriate technology to present content in a subject area.
Technological pedagogical knowledge (TPK)	Knowledge of which technology to choose when using a teaching and learning strategy or method.
Technological pedagogical content knowledge (TPACK)	It is the integration of technological knowledge, pedagogical knowledge and content knowledge.

1. 2. Teachers' Demographic Characteristics and Association with Perceived Levels of TPACK

Older teachers find it more difficult than younger teachers to integrate TPACK into the classroom.[23] Younger teachers are more likely to use ICT daily, making it easier to incorporate it into the classroom.[24] Younger teachers are more confident and experienced in adapting to and using new technologies. Their greater confidence and experience allow them to pick up new tools more quickly and adapt them to the specific needs of their students. Age may affect ICT integration and TPACK because older teachers tend to perceive greater barriers to ICT integration.[25] Existing research confirms that older teachers perceive lower TPACK levels than younger teachers.[26,27]

Research on the association of teachers' gender with perceived levels of TPACK is inconsistent. Some research has shown no statistically significant gender differences in perceived TPACK.[4,20,28–31] The gender difference in TPACK scores could be because male teachers tend to demonstrate more confidence and efficacy in ICT knowledge and skills.[32] In addition, male teachers are more interested in technology than female teachers are.[33] In a study,[34] it was found that male teachers perceived higher levels of TPACK than female teachers do. This finding suggests that researchers and practitioners must consider gender when designing training programmes to develop teachers–knowledge of integrating technology into the classroom.

Liu et al. found that teachers with less teaching experience (1–5 years and 6–10 years) perceived significantly higher levels of TPACK than those with more teaching experience (11–20 years and over 20 years).[35] Teachers with less experience are also younger, having been introduced to ICT at a young age, and also use it more frequently in their daily lives, which allows them to integrate it more easily into the classroom.[24] Less-experienced science and mathematics teachers tended to perceive their level of TPACK significantly higher than more experienced teachers do.[30] These findings were consistent with those of other researchers.[26,36]

Frequent ICT use is also related to teachers' perceptions of TPACK levels.[4] The frequency of ICT use increases perceptions of TPACK levels.[2,4,21,37]

However, unlike frequent ICT use, the level at which a teacher teaches is not related to the perceived level of TPACK.[34,38]

2. Research Problem and Research Questions

TPACK has become very important as technology has become integral to teaching and learning chemistry. In reviewing research on TPACK, the number of studies in this area increased from 2003 to 2013.[39] More than half of the research on TPACK has focused on TPACK in teachers in general, while relatively little research has examined TPACK in teachers of specific subject areas. However, most of the research was conducted in science and mathematics education. Most research has been conducted with preservice teachers, followed by secondary, primary and university teachers.

The number of publications on TPACK in chemistry education increased slightly between 2018 and 2020, while it decreased in the 2020–2023 period. They selected 22 publications from the Scopus database that were published between 2011 and 2022. No articles were published on the subject in 2012, 2013, 2016 and 2018, while the number of citations to articles increased during the 2018–2022 period and fluctuated during the 2011–2018 period. In addition, most of the articles were published by Indonesian researchers.[40]

Despite a variety of research,[4,5,7,39,41,42] the use of TPACK in teaching chemistry remains relatively unexplored, especially in terms of opportunities for more effective planning of training for teachers on the potential of ICT to support the learning and teaching of chemistry content, respectively. This area, therefore, represents a good opportunity for further research in the future. As technology has become an integral part of teaching and learning chemistry, ICT in chemistry has become important, and therefore, teacher training in this area is essential. Before developing worthwhile training, examining the relationship between teacher demographics and TPACK is essential in order to apply these findings to the design of training and to encourage, for example, age groups that are weaker in the integration of TPACK in the classroom to undertake in-service teacher training that would support their development of TPACK.

This study aims to investigate how teachers teaching chemistry content at different levels of education perceive their level of TPACK and to examine the factors that influence it.

The following two research questions were asked in the context of the study:

1. Which of the three levels of TPACK are perceived by teachers teaching chemistry?
2. Is there a statistically significant relationship between a teacher's perceived level of TPACK and the teacher's age, gender, the level of education they teach, the time spent teaching chemistry content and the frequency of ICT use?

3. Method

A quantitative research approach and a descriptive research method were used to examine the overall TPACK status of chemistry teachers and the association of teacher-perceived TPACK levels with age, gender, level of education, time teaching chemistry, and frequency of ICT use.

3. 1. Sample

The survey used a representative sample: 261 teachers participated, 246 (94.25%) women and 15 (5.75%) men. Their ages ranged from 24 to 66 years, with mean age *M* = 45.30; *SD* = 9.72. Ten percent of primary and secondary schools in Slovenia were selected, equally represented from all 12 statistical regions, from a list published on the website of the Ministry of Education. The participants were teachers teaching chemistry at different levels of education. Sample included 18 (6.90%) secondary school chemistry teachers, 68 (26.05%) primary school chemistry teachers, 44 (16.86%) science teachers and 131 (50.19%) classroom teachers. They have been teaching chemistry for between 1 and 45 years, with an average of *M* = 18.10 and *SD* = 10.80.

3. 2. Instruments

We used two measuring instruments to collect the data:

1) The ICTCHEM questionnaire on the use of ICT for teaching chemistry.
2) The Technology Pedagogical Content Knowledge Questionnaire (TPACK) to measure the level of teachers' perception of TPACK.[43]

The ICTCHEM questionnaire on the use of ICT for teaching chemistry was developed for the survey. Sensitivity was ensured by a multilevel or multiple-choice scale, and the objectivity of the performance was ensured by standardized instructions.

The questionnaire consists of questions to determine the following variables (gender, age, level of education, years of teaching chemistry). In addition, it contains a question on the frequency of use of ICT in teaching chemistry. For this question, a 5-point scale was used: '1 – never', '2 – rarely (up to 25% of teaching hours)', '3 – occasionally (25% to 50% of teaching hours)', '4 – often (50% to 75% of teaching hours)', and '5 – very often (75% to 100% of teaching hours)'.

To measure teachers' perceptions of TPACK levels, we used the TPACK questionnaire.[43] The questionnaire contains 33 items that include four factors: design (10 items), exertion (12 items), ethics (6 items), and proficiency (5 items).

The design factor covers items 1–10, which include an analysis of the current situation prior to the teaching process, the selection of methods, techniques and technologies, and the preparation of activities, materials, and instruments to be used in the teaching process (e.g., I can plan the teaching and learning process according to available technological resources.).

The exertion factor includes items 11–22 on implementing ICT-enhanced teaching and assessment plans (e.g., I can use technology to evaluate students' achievement in related content areas).

The ethics factor includes items 23–28 on ethical behavior in the use of ICT (e.g., I can behave ethically regarding the appropriate use of technology in educational environments.).

The proficiency factor includes items 29–33 related to the teacher's ability to integrate ICT into the teaching and learning process by demonstrating effective use of ICT. This factor refers to maintaining the teacher's capacity to integrate technological knowledge with content and pedagogical knowledge to become an expert in the teaching profession, to put forward proposals for solving problems related to the subject area, the teaching process and technology, and to choose the most appropriate one among these proposed solutions (e.g., I can use technology to find solutions to problems (structuring, updating and relating the content to real life, etc.)).

For each item, the teachers chose the most appropriate answer according to a 5-point Likert scale: '1 – strongly disagree', '2 – disagree', '3 – neither agree nor disagree', '4 – agree', '5 – strongly agree'.

There are three levels of TPACK perception: a low level of TPACK perception has an arithmetic mean between 1.00 and 2.33; an intermediate level of TPACK perception has an arithmetic mean between 2.34 and 3.67; and an advanced level of TPACK perception has an arithmetic mean between 3.68 and 5.00.[21] In the study by Kabakçı Yurdakul et al.,[43] the Cronbach alpha reliability coefficient is 0.95 for the overall questionnaire, 0.92 for the design, 0.91 for the exertion, 0.86 for the ethics and 0.85 for the proficiency factor. In our study, the Cronbach alpha reliability coefficient for the whole questionnaire is 0.96; for the design factor, the Cronbach alpha reliability coefficient is 0.90; for the exertion factor, 0.92; for the ethics factor, 0.83; and for the proficiency factor, 0.85. Cronbach alpha reliability index values above 0.70 are acceptable, and values above 0.80 are defined as reliable.[44] In our study, we obtained similar Cronbach alpha reliability index values as in the original study. The calculated values indicate that the questionnaire is reliable.

The *KMO* test value in Kabakçı Yurdakul et al.[43] is 0.96, while in our study, it is 0.94, indicating that the data are suitable for factor analysis. The *KMO* test value, which can be between 0 and 1, is interpreted as normal if it is between 0.50 and 0.70, as good if it is between 0.70 and 0.80, as very good if it is between 0.80 and 0.90, and as excellent if it is above 0.90.[45] Since the *KMO* test value is very high (close to 1), it is interpreted as excellent, which means that the data are very suitable for pooling into factors. In our study, as in the study by Kabakçı Yurdakul et al.,[43] the four-factor structure of the TPACK questionnaire was validated by confirmatory factor analysis (*CFA*). We used the method of principal axes and Warimax rotation.

3. 3. Data Collection

The survey was conducted from 21 August to 16 October 2021. Questionnaires were sent to a selected sample of primary and secondary school teachers. Participants completed the measuring instruments in digital format. Anonymity was ensured by encrypting the measuring instruments.

For the first research question, the data were analysed using descriptive statistics and the results are presented in terms of relative frequencies (*f* %).

For the second research question, a chi-square test was used to determine whether age, gender, teaching at different levels of education, time spent teaching chemistry, and frequency of ICT use were statistically significantly related to the teacher's perceived level of TPACK, also for the individual TPACK factor (design, exertion, ethics, proficiency). To measure the effect size of the chi-square test, we used Cramar's *V*. To determine whether the correlation was highly proportional or inversely proportional, we used Kendall's τ coefficients. Associations between results are given at the 5% risk level.[44]

The age of teachers was divided into five parts according to the life stages published in the study:[46] late adolescence (17–25 years), early adulthood (26–35 years), late adulthood (36–45 years), early elderly (46–55 years) and late elderly (56–66 years).

The years of chemistry content teaching were divided into five parts according to the periods published in the study:[19] 1–5 years, 6–10 years, 11–15 years, 16–20 years, and 21 years and older.

The teaching of chemistry content was divided into four levels according to the level of education, depending on the grade or year taught by the teacher, to cover the vertical from the beginning of primary school to the end of secondary school: (Primary School – Classroom (Grades 1–5), Primary School – Science (Grades 6–7), Primary School – Chemistry (Grades 8–9), and Secondary School – Chemistry (Grades 1–4)).

4. Results and Discussion

4.1. Perceived Level of TPACK of Teachers Teaching Chemistry Content

Teachers teaching chemistry content perceive a high level of TPACK according to the value of the arithmetic mean (*M* = 3.68; *SD* = 0.60), which coincides with the results of other research.[2,4,19–22] The majority of teachers teaching chemistry content perceive a high level of TPACK, while the least number of teachers teaching chemistry content perceive a low level of TPACK (Figure 2).

For the design factor, teachers teaching chemistry content perceive a high level of TPACK according to the value of the arithmetic mean (*M* = 4.35; *SD* = 0.63) which is consistent with other research.[4,19,21,22] Most of the teachers teaching chemistry content perceive a high level of TPACK, while the least number of teachers who teach chemistry content perceive a low level of TPACK (Figure 3).

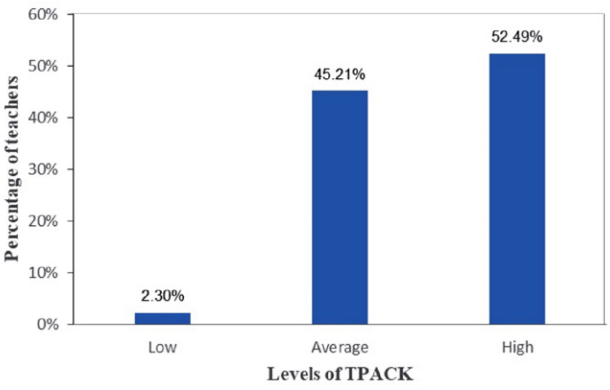

Figure 2: Percentage of teachers teaching chemistry according to each TPACK perception level for the whole TPACK questionnaire (*N* = 261).

Within the design factor, the item 'I can use technology to appropriately design materials to the needs for an effective teaching and learning process (e.g., PowerPoint presentations)' has the highest arithmetic mean (*M* = 4.36; *SD* = 0.75), followed by the item 'I can plan the teaching and learning process according to available technological resources' with the second highest arithmetic mean (*M* = 4.18; *SD* = 0.64).

Within the design factor, the item 'I can develop appropriate assessment tools by using technology' has the lowest arithmetic mean (*M* = 3.51; *SD* = 0.95), followed by the item 'I can optimise the duration of the lesson by using technologies (educational software, virtual labs, etc.)' with the second lowest arithmetic mean (*M* = 3.58; *SD* = 0.89), with the third lowest arithmetic mean (*M* = 3.67; *SD* = 0.83) for the item 'I can combine appropriate methods, techniques and technologies by evaluating their attributes in order to present the content effectively.'

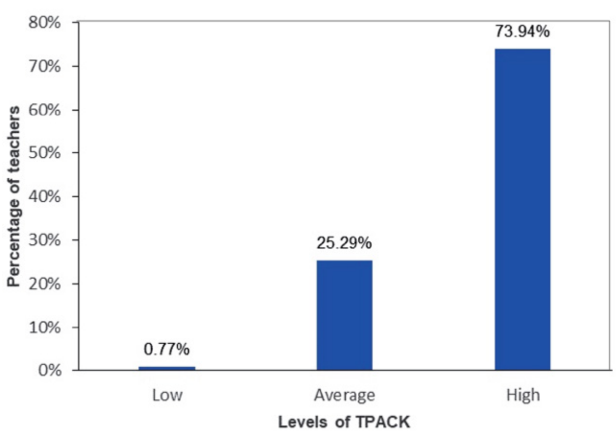

Figure 3: Percentage of teachers teaching chemistry according to each TPACK perception level for the design factor (*N* = 261).

For the exertion factor, teachers teaching chemistry content perceive a high level of TPACK according to the value of the arithmetic mean (*M* = 3.72; *SD* = 0.62), which is consistent with other researchers.[4,19,21,22] Most of the teachers teaching chemistry content perceive a high level of TPACK, while the least number of teachers teaching chemistry content perceive a low level of TPACK (Figure 4).

Within the exertion factor, the item 'I can implement effective classroom management in the teaching and learning process in which technology is used' has the highest arithmetic mean (*M* = 4.11; *SD* = 0.73), followed by the statement 'I can use technology to keep my content knowledge updated' with the second highest arithmetic mean (*M* = 4.00; *SD* = 0.76).

Within the exertion factor, the item with the lowest arithmetic mean (*M* = 2.90; *SD* = 1.20) is 'I can use innovative technologies (Facebook, blogs, Twitter, podcasting, etc.) to support the teaching and learning process', followed by the second lowest (*M* = 3.49; *SD* = 1.00) item 'I can guide students in the process of designing technology-based products (presentations, games, films, etc.)', followed by the third lowest (*M* = 3.53; *SD* = 0.90) item 'I can use technology for evaluating students' achievement in related content areas.'

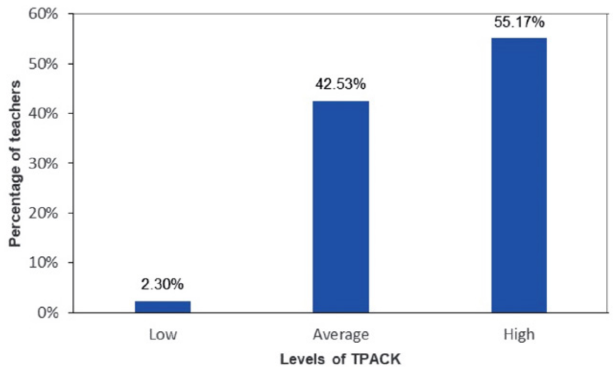

Figure 4: Percentage of teachers teaching chemistry according to each TPACK perception level for the exertion factor (*N* = 261).

For the ethics factor, teachers teaching chemistry content perceive an average level of TPACK according to the value of the arithmetic mean (*M* = 3.66; *SD* = 0.70), which does not coincide with other research in which teachers perceived a high level of TPACK.[4,19,21,22] Most teachers teaching chemistry content perceive a high level of TPACK, while the least of the teachers teaching chemistry content perceive a low level of TPACK (Figure 5).

Within the ethics factor, the item 'I can behave ethically regarding the appropriate use of technology in educational environments' has the highest arithmetic mean (*M* = 4.00; *SD* = 0.80), followed by the item 'I can behave ethically in acquiring and using special/private information which will be used in teaching a subject area – via technology (audio records, video records, documents etc.)' with the second-highest arithmetic mean (*M* = 3.91; *SD* = 0.88).

Within the ethics factor, the item 'I can provide each student equal access to technology' has the lowest arithmetic mean (*M* = 3.13; *SD* = 1.16), followed by the second lowest arithmetic mean (*M* = 3.60; *SD* = 1.06) for 'I can follow the teaching profession's codes of ethics in online educational environments (WebCT, Moodle, etc.)' followed by the third lowest arithmetic mean (*M* = 3.62; *SD* = 0.92) item 'I can use technology in every phase of the teaching and learning process by considering the copyright issues (e.g., license).'

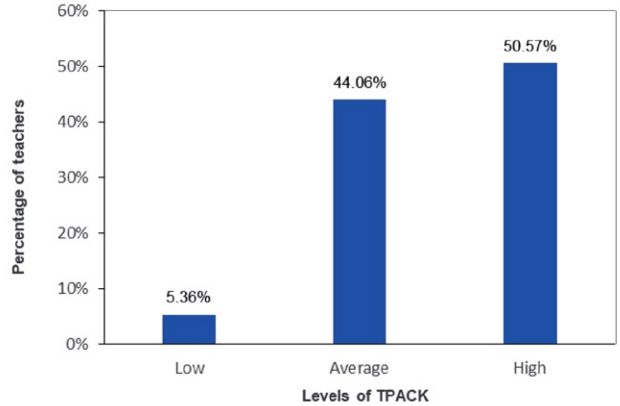

Figure 5: Percentage of teachers teaching chemistry according to each TPACK perception level for the ethics factor (*N* = 261).

For the proficiency factor, teachers teaching chemistry content perceive an intermediate level of TPACK according to the value of the arithmetic mean (*M* = 2.98, *SD* = 0.80), which is consistent with the research of Çoklar and Özbek[19] and Şentürk et al.,[22] but not consistent with the research of Arslan[4] and Kabakçı Yurdakul,[21] in which teachers perceived an advanced level of TPACK. Most teachers teaching chemistry content perceive an average level of TPACK, while the least number of teachers teaching chemistry content perceive a low level of TPACK (Figure 6).

Within the proficiency factor, the item 'I can use technology to find solutions to problems (structuring, updating and relating the content to real life, etc.)' has the highest arithmetic mean (*M* = 3.55; *SD* = 0.90), followed by the item 'I can cooperate with other disciplines regarding the use of technology to solve problems encountered in the process of presenting content' with the second-highest arithmetic mean (*M* = 3.44; *SD* = 0.99).

Within the proficiency factor, the item 'I can become a leader in spreading the use of technological innovations in my future teaching community' has the lowest arithmetic mean (*M* = 2.46; *SD* = 1.13), followed by the second lowest arithmetic mean (*M* = 2.70; *SD* = 1.04) for 'I can troubleshoot problems that could be encountered with online educational environments (WebCT, Moodle, etc.)' and with the third lowest arithmetic mean (*M* = 2.75; *SD* = 0.98) the statement 'I can troubleshoot any kind of problem that may occur while using technology in any phase of the teaching-learning process.'

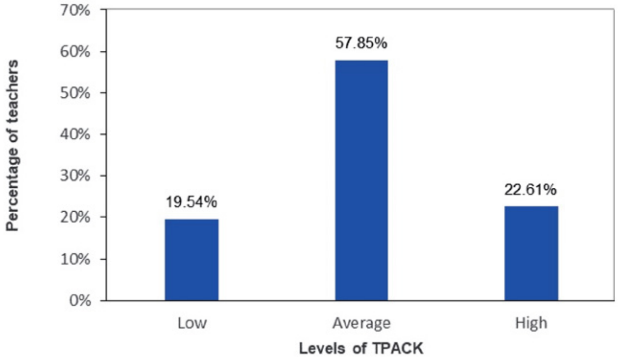

Figure 6: Percentage of teachers teaching chemistry according to each TPACK perception level for the proficiency factor ($N = 261$).

The highest arithmetic mean ($M = 4.36$, $SD = 0.75$) of all the items in the questionnaire is 'I can use technology to appropriately design materials to the needs for an effective teaching and learning process (e.g. PowerPoint presentations)', which is from the design factor, while Arslan had the highest value of arithmetic mean for the statement from the ethics factor in his study 'I can behave ethically regarding the appropriate use of technology in educational environments', which otherwise had the highest arithmetic mean within the ethics factor in our study.[4]

The lowest arithmetic mean ($M = 2.46$, $SD = 1.13$) is for the statement 'I can become a leader in spreading the use of technological innovations in my future teaching community', which is from the proficiency factor; had the lowest arithmetic mean value for the proficiency factor item 'I can troubleshoot problems that could be encountered with online educational environments (WebCT, Moodle, etc.)',[4] which has the second lowest arithmetic mean of all the items in our study.

According to the value of the arithmetic mean, teachers teaching chemistry content perceive a high level of TPACK for the design and exertion factor, while they perceive an average level of TPACK for the ethics and proficiency factor (Figure 7).

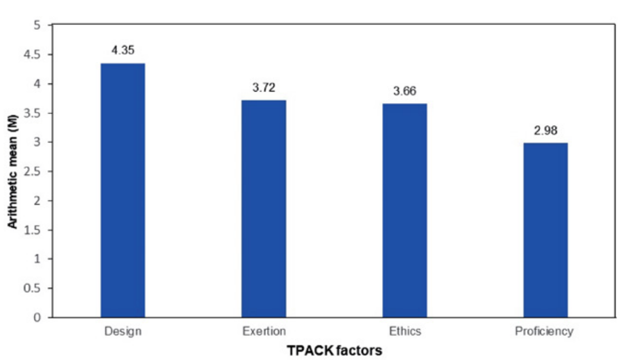

Figure 7: Arithmetic mean value for each factor of the TPVZ questionnaire.

Unlike the research in which teachers perceived a high level of TPACK,[4,19,21,22] in our study, teachers teaching chemistry content perceived an average level of TPACK in the ethics factor. Similarly, in the proficiency factor, teachers teaching chemistry content perceived an average level, which coincides with the findings of Kabakçı Yurdakul[21] and Çoklar and Özbek,[19] but not with those of Arslan[4] and Kabakçı Yurdakul.[21] For this reason, in the organization of TPACK training, we would devote more hours to proficiency in ethical behavior in the use of ICT, in which we would present the recommendations of the code of ethics for teachers in online educational environments. Therefore, more in-service teacher training hours should be devoted to the topics covered in the ethics and proficiency factor, as chemistry teachers perceived both factors as having an average level of TPVZ. We would also devote more TPACK training hours to the effective use of ICT in the classroom and, by presenting concrete examples of good practice, train teachers to link technological knowledge with content and pedagogical knowledge so that they become experts in the teaching profession, are able to put forward problem-solving proposals, and can become leaders in spreading the use of technological innovations in their teaching community.

4. 2. Relation of Demographic Variables to the Perceived Level of TPACK Relation of Age of Teachers to Perceived TPACK Level

The correlation between the age of the teachers teaching chemistry and the perceived level of TPACK is statistically significant ($\chi2(8, N = 261) = 26.29$, $p = 0.001$, $V = 0.21$). Teachers' age is strongly correlated with teachers' perceived TPACK level. The direction of the association is inversely proportional because Kendall's τ coefficient is negative ($\tau = -0.21$), implying that in our study, as in the findings of other researchers,[23,24,26,27] older teachers perceive a lower level of TPACK.

Teachers who perceive a low level of TPACK have a mean age of 54 years ($M = 53.80$; $SD = 4.71$), those who perceive an average level have a mean age of 47 years ($M = 47.20$; $SD = 9.35$), and those who perceive an advanced level have a mean age of 43 years ($M = 43.30$; $SD = 9.71$).

For the design factor ($\chi2(8, N = 261) = 7.10$, $p = 0.53$), exertion ($\chi2(8, N = 261) = 14.80$, $p = 0.063$) and ethics ($\chi2(8, N = 261) = 13.18$, $p = 0.45$), the correlation between the age of the teachers teaching chemistry content and the perceived level of TPACK is not statistically significant.

In the proficiency factor ($\chi2(8, N = 261) = 18.30$, $p = 0.00100$, $V = 0.23$), the correlation between the age of teachers teaching chemistry content and the perceived level of TPACK is statistically significant. Age is strongly correlated with the perceived level of TPACK. The direction of the association is inversely proportional because Kendall's τ coefficient is negative ($\tau = -0.23$).

We suggest more training for older teachers on integrating TPACK in the classroom, encouraging them to use ICT more often, overcoming barriers (e.g., fear of change, use of novelty) and developing their competencies to troubleshoot problems with online environments to become more flexible in implementing change.

The correlation of teachers' gender with perceived TPACK levels

The gender of the teacher teaching chemistry content is not related to the teacher's perceived level of TPACK ($\chi2$ (2, N = 261) = 0.63, p = 0.73), which is consistent with the results of other research.[4,20,28–31]

For the design ($\chi2$(2, N = 261) = 0.14, p = 0.69), exertion ($\chi2$(2, N = 261) = 1.01, p = 0.60), ethics ($\chi2$(2, N = 261) = 0.90, p = 0.64) and proficiency factor ($\chi2$(2, N = 261) = 3.54, p = 0.17), the correlation of teacher gender with teacher perceived levels of TPACK is also not statistically significant.

Therefore, there is no need to differentiate between male and female teachers when designing in-service teacher training programmes that would support their development of TPACK because they have the same perceived level of TPACK.

The correlation of teaching at different levels of education with the perceived level of TPACK

Teaching at different levels of education is not related to teachers' perceived levels of TPACK ($\chi2$ (6, N = 261) = 2,68, p = 0,85), which is consistent with the other research.[34,38] Also for the design ($\chi2$(6, N = 261) = 3.59, p = 0.73), exertion ($\chi2$(6, N = 261) = 3.04, p = 0.80), ethics ($\chi2$(6, N = 261) = 3.58, p = 0.73), and proficiency factor ($\chi2$(6, N = 261) = 12.10, p = 0.060), teaching at different educational levels is not related to teachers' perceived level of TPACK. Thus, teachers at varying levels of education (e.g., as a secondary school chemistry teacher, or as a primary school chemistry teacher, or as a science or classroom teacher) do not differ in their perceived level of TPACK.

The correlation of years of experience in teaching chemistry with perceived levels of TPACK

The experience in teaching chemistry is statistically significantly related to the teacher's perceived TPACK level $\chi2$(8, N = 261) = 17.91, p = 0.02, V = 0.17). It is also moderately strongly related to the teacher's perceived TPACK level.

In the proficiency factor ($\chi2$(8, N = 261) = 29.30, p = 0.001, V = 0.23), years of experience in teaching chemistry is statistically significantly related to the teacher's perceived level of TPACK. The correlation is strong. For the design factor ($\chi2$(8, N =261) = 9.05, p = 0.34), exertion ($\chi2$(8, N =261) = 9.84, p = 0.28) and ethics ($\chi2$(10, N =261) = 14.02, p = 0.081), the correlation of time spent teaching chemistry content with the teacher's perceived level of TPACK is not statistically significant.

Teachers perceiving a low TPACK level have been teaching chemistry for an average of 25 years (M = 25.20; SD = 8.98), those perceiving an average level of TPACK teach for an average of 20 years (M = 20.40; SD = 11.10), and those who perceive a high level of TPACK teach chemistry for an average of 16 years (M = 15.80; SD = 10.10).

The more years a teacher has been teaching chemistry, the lower their TPACK perception. In their research,[26,30,35,36] the same findings were reached, that less experienced teachers tend to perceive their TPACK level significantly higher than more experienced teachers. This finding can be supported by the fact that less experienced teachers are also younger teachers who have been introduced to ICT in childhood, and their ICT training was also different and also use it more frequently in their daily lives, which allows them to integrate it more easily into their classrooms.[24] Teachers who have been teaching chemistry for a longer period should be encouraged to attend in-service teacher training that would support their development of TPACK in teaching and suggested integrating more ICT in their lessons, which could help them improve their perception of TPACK and better adapt to modern educational trends.

The correlation of frequency of ICT use with perceived TPACK levels

The frequency of ICT use is statistically significantly related to the teacher's perceived level of TPACK ($\chi2$(8, N = 261) = 44.55, p = 0.00100, V = 0.32). The frequency of ICT use is strongly related to the teacher's perceived level of TPACK. Kendall's τ coefficient is positive (τ = 0.28), meaning teachers who use ICT more frequently perceive a higher level of TPACK.

In the design ($\chi2$(8, N = 261) = 39.41, p = 0.00100, V = 0.42), exertion ($\chi2$(8, N = 261) = 23.54, p = 0.00300, V = 0.26), ethics ($\chi2$(8, N = 261) = 30.77, p = 0.00100, V = 0.32) and proficiency factors ($\chi2$(8, N = 261) = 34.01, p = 0.00100, V = 0.26), a statistically significant association of the frequency of ICT use with the teacher's perceived level of TPACK exists. For all factors, the frequency of ICT use is strongly correlated with the perceived level of TPACK.

Teachers who use ICT more frequently perceive higher levels of TPACK, which is consistent with the results of other research.[2,4,21,37] Teachers who use ICT frequently also have more opportunities to collaborate with other teachers and exchange teaching ideas. This can help them to develop their TPACK as they can learn new ideas and examples of good use for teaching, which allows them to create more effective and engaging lessons for their students. By gaining new knowledge and experience and by continuously improving their ICT use, teachers' perception of the level of TPACK can increase over time.

5. Conclusions and Implications for Planning of In-service Teacher Training in Chemistry Education

The aims of our study were to investigate how teachers teaching chemistry at different levels of education perceive their level of TPACK and to examine the factors that influence it.

It was found that teachers teaching chemistry content perceive a high level of TPACK. There is a statistically significant relationship between age, time teaching chemistry content and frequency of ICT use with teachers' perceived TPACK, while there is no statistically significant relation between teacher gender and teaching at different levels of education with teachers' perceived level of TPACK. Therefore, when designing training to stimulate the development of teachers' TPACK in chemistry education, it is not necessary to design specific adjustments to the training according to teachers' gender. Given the different levels of education, adjustments in promoting the development of teachers' TPACK are not really necessary in terms of technological and pedagogical knowledge. It is important to adapt in-service teacher training in a way that empowers teachers of a particular level of chemistry education in the use of ICT in a way that is most supportive of the acquisition of chemistry knowledge of the level of education at which teachers are teaching.

The survey results suggest that it makes sense to encourage more intensive in-service teacher training that would support the development of TPACK for older teachers or those teachers who have been teaching chemistry for a longer period because they perceive a lower level of TPACK than younger teachers or those teachers who have been teaching chemistry for a shorter period. At the same time, it is important to continuously involve teachers in training sessions that promote the use of ICT and empower teachers with innovations, as research shows that teachers who use ICT more often perceive a higher level of TPACK. It would be better for these teachers to be involved in longer training sessions in which they actively experiment with the use of TPACK, get ongoing feedback and try things out again in practice.

The results of the research on teachers' perception of TPACK levels within the factor (design, exertion, ethics and proficiency) suggest that in-service teacher training in TPACK planning needs to include content and process skills that enable the development of appropriate assessment tools (e.g., quizzes, online surveys, online tests, etc.) through ICT and to present ways to use ICT to optimize the duration of a lesson (e.g. use of videos, animations, interactive multimedia, etc.) and to show, through concrete examples, how to combine appropriate teaching methods with the use of ICT to enable teachers to present the content effectively (e.g., use of multimedia, interactive assignments, interactive textbooks, etc.).

As part of the support of the development of teachers' TPACK, in-service teacher training that would support their development of TPACK should include content and process skills that enable the use of innovative ICT (e.g., Facebook, blogs, Twitter, podcasts, etc.) to support the teaching and learning process, and teachers should be provided with guidelines to help them guide students in making products using ICT (e.g. presentations, games, films, etc.). In addition, in-service teacher training that would support their development of TPACK should present teachers with effective and field-tested ways of using ICT to assess pupils' achievement in related content areas and demonstrate appropriate teaching approaches and methods that consider individual differences between pupils when using ICT.

As the majority of teachers in the survey perceived an average level of TPACK in the ethics factor, to improve the situation in in-service teacher training that would support their development of TPACK, we would add to the content design guidelines for teachers on how to guide students to valid and reliable electronic resources, present rules of ethical behavior when using ICT in the educational environment and when obtaining specific/personal information to be used in teaching the subject area using ICT (audio recordings, video recordings, documents, etc.). We would detail the recommendations of the code of ethics for teachers in online educational environments (WebCT, Moodle, etc.) and demonstrate through concrete examples how to use ICT in all phases of the teaching and learning process, considering the relevant copyright (e.g., permissions for use).

Most teachers perceived an average level of TPACK in the proficiency factor of the research, and in-service teacher training that would support their development of TPACK would therefore include content and process skills that enable teachers to be able to troubleshoot problems that might arise when using online learning environments or that might arise during the use of ICT at any stage of the teaching or learning process. Also, more hours of training, with the demonstration of concrete and proven examples of good practice and testing what has been learnt in practice, would enable teachers to link technological knowledge with content and pedagogical knowledge so that they become experts in the teaching profession, able to use ICT to put forward proposals to find solutions to problems (structuring, updating and linking learning content to everyday life, etc.), to be able to collaborate with other disciplines in the use of ICT to solve the problems encountered in using online environments, and to be trained to become leaders in spreading the use of technological innovations in their teaching community.

The research also has the limitation that it was based on self-reported data derived from teachers' perceptions. To overcome this limitation, further research could test the TPACK of teachers teaching chemistry content in real situations where they could demonstrate their knowledge of specific subject areas. Therefore, to refine the design of the training further, further research would include a TPACK test consisting of practical tasks in the field of chemistry to test the TPACK of teachers teaching chemistry in real-life situations. One possibility is to have external assessors or students assess their TPACK as it is demonstrated in classroom work.

In conclusion, we suggest that changes in teaching approaches are inevitable, and therefore, we recommend that teachers teaching chemistry content should be prepared to adapt their teaching style to new challenges and to attend training courses, as improving technological pedagogical content knowledge is a process that requires time, openness to learning and adaptation. However, we recommend that the organizers of in-service teacher training courses that would support their development of TPACK in chemistry content areas check the teacher's perception of the level of TPACK with the TPACK questionnaire and the technological pedagogical content knowledge with the TPACK test prior to the training and plan the training in detail based on the results of the survey, which show the gaps in teachers' knowledge and indicates their needs.

6. References

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Povzetek

V raziskavi smo preverjali, kako učitelji, ki poučujejo kemijske vsebine na različnih ravneh izobraževanja, zaznajo lastno raven tehnološko vsebinsko pedagoškega znanja ter preučili povezavo zaznane učiteljeve ravni tehnološko pedagoško vsebinskega znanja s starostjo, s spolom, s poučevanjem na različnih ravneh izobraževanja, s časom poučevanja kemijskih vsebin in s pogostostjo uporabe informacijsko-komunikacijske tehnologije. V raziskavi je sodelovalo 261 učiteljev od tega 246 žensk in 15 moških iz vse Slovenije, ki poučujejo kemijske vsebine v povprečju 18 let na različnih ravneh izobraževanja s povprečno starostjo 45 let. Rezultati so pokazali, da zaznajo učitelji, ki poučujejo kemijske vsebine, visoko raven tehnološko pedagoško vsebinskega znanja. Med starostjo, časom poučevanja kemijskih vsebin in pogostostjo uporabe informacijsko-komunikacijske tehnologije je statistično pomembna povezanost z zaznano ravnjo tehnološko pedagoško vsebinskega znanja. Na osnovi rezultatov raziskave so bile pripravljene smernice za načrtovanje strokovnega izobraževanja učiteljev, ki poučujejo kemijske vsebine.