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Research Article

School teachers' perceived knowledge and affordances for using technology in teaching

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ABSTRACT

Teachers' knowledge about technology and teaching with technology is decisive for how affordances of technology integration are taken up. Two questionnaires were administered in 21 high schools in Kazakhstan: one about types of teacher knowledge based on technological pedagogical content knowledge framework and one about affordances of technology integration. The analyses show a relatively high level of all types of teacher knowledge and a large variation in perceived affordances, with relatively low scores for support from the school leader and time available to design and plan technology integration in class. Furthermore, different types of knowledge were related to different affordances, which means that a focus on a high level of all types of teacher's knowledge of technology might help best to benefit from most of the affordances. Limitations and directions for future research are discussed.

Keywords: teaching with technology, affordances, knowledge, teachers, secondary education

INTRODUCTION

Teachers' knowledge and beliefs about technology-enhanced teaching and learning are conditional on how teachers use technology in teaching and school (Lucas et al., 2021; Quast et al., 2023). In teacher education programs, technology receives little attention, neither how it can be used in secondary education nor as support of pedagogy in teacher education itself (Ata et al., 2021; Barbour & Hodges, 2024; Hathaway et al., 2023). This is also the case in Kazakhstan (Orakova et al., 2024; Shumeiko et al., 2024), which is the context of the current study. This means that most learning how to teach with technology in secondary education is done during school practice, after student teachers have graduated and entered the profession. Continuous professional development (CPD) programs can support the development of in-service teachers' competencies to use technology to support the learning of their students (Elsayary, 2023; Koh et al., 2017). Moreover, support from the leadership and technical support are also affordances in school that positively affect teachers' integration of technology in teaching (Ertmer et al., 2012; Mirzajani et al., 2016). Finally, positive attitudes or beliefs about using technology in teaching can also be seen as an affordance of technology integration in class (Balta et al., 2023; Beardsley et al., 2021; Sergeeva et al., 2024). Yet insights are

Table 1. Overview of competence areas & competences in *DigCompEdu* framework

Competence areas	Competences
Professional engagement: Using digital technologies for communication, collaboration, & professional development	Organizational communication Professional collaboration Reflective practice Digital continuous professional development
Digital resources: Sourcing, creating, & sharing digital resources	Selecting Creating & modifying Managing, protecting, & sharing
Teaching and learning: Managing & orchestrating use of digital technologies in teaching & learning	Teaching Guidance Collaborative learning Self-regulated learning
Assessment: Using digital technologies & strategies to enhance assessment	Assessment strategies Analyzing evidence Feedback & planning
Empowering learners: Using digital technologies to enhance inclusion, personalization, & learners' active engagement	Accessibility and inclusion Differentiation & personalization Actively engaging learners
Facilitating learners' digital competence: Enabling learners to use digital technologies creatively & responsibly for information, communication, content creation, well-being, & problem-solving	Information & media literacy Communication Content creation Responsible use Problem-solving

needed into what kinds of teachers' knowledge relate to the affordances of technology use in teaching and increase the chances that affordances are taken up. Then we can better understand what kind of knowledge teacher education programs and professional development programs should be heading for. The aim of the current study was therefore to get insight into in-service teachers' knowledge and beliefs about technology use and how these were related to affordances.

LITERATURE REVIEW

Teachers' Digital Competences

Teachers' perceptions of their digital competence relate to the perception of their own abilities and knowledge of digital-related content and are assumed to be needed to master technology (Durocher & Potvin, 2020; Rubach & Lazarides, 2023). These perceptions can be differentiated into basic and professional, job-specific digital competence beliefs (Krumsvik, 2014). The European framework for the digital competence of educators (*DigCompEdu*) (Redecker & Punie, 2017) provides 22 teacher competences in the six areas:

(1) professional engagement,

(2) digital resources,

(3) teaching and learning,

(4) assessment,

(5) empowering learners, and

(6) facilitating learners' digital competence (see **Table 1**).

Several studies used *DigCompEdu* and assessed teachers' competence to use technology in school (e.g., Grodek-Szostak et al., 2021; Lucas et al., 2021; Quast et al., 2023). Lucas et al. (2021) have shown that teachers reported the highest proficiency in 'digital resources', whereas, in the study by Grodek-Szostak et al. (2021), teachers reported the lowest proficiency in 'digital resources'. Results by Quast et al. (2023) indicate that teachers felt least competent in the competence area 'assessment'. Even though studies used the same theoretical framework, the different ways to measure the construct hamper the comparison of results and lead to contradicting evidence.

The findings mentioned above about the relatively low scores of teachers on various digital competences are confirmed in other studies, both in Kazakhstan (Orakova et al., 2024; Shumeiko et al., 2024) and elsewhere

(Barbour & Hodges, 2024; Hathaway et al., 2023). These studies show that primary and secondary school teachers show a higher proficiency in general and subject-specific pedagogies compared to digital pedagogy and the use of digital resources. More attention to teachers' digital competences in initial teacher education programs or CPD could help to further develop these competences. Yet stand-alone courses that primarily focus on the development of *technological knowledge* (*TK*) and skills do not help to integrate content, pedagogical and technology knowledge of teachers (Admiraal et al., 2017; Mishra & Koehler, 2006).

Many of the studies that have been conducted to examine the development of teachers' technological competences have been carried out in an information and communication technologies (ICT) course (Balta & Guvercin, 2015; Chai et al., 2010; Koh & Divaharan, 2011; Pamuk, 2011) rather than in technology-infused methods courses.

Admiraal et al. (2017) evaluated the implementation of two technology-infused courses of one teacher education program. In line with studies on the development of pre-service teachers' technological, pedagogical, and *content knowledge* (*CK*) (Wetzel et al., 2014), two important enablers were distinguished:

(1) teaching practice to enact what was learned in teacher education institution as well as to receive feedback from students on this enactment and

(2) modelling of teacher educators and teachers in school.

The authors also conclude that both enablers require further development of knowledge and skills of both teacher educators and cooperating schoolteachers.

ElSayary (2023) investigated the impact of an upskilling training program on developing teachers' digital competence. The program consisted of a 10-week training session using a blended approach. The author found that the upskilling training program efficiently developed teachers' skills in using technology in digital citizenship, communication and collaboration, critical thinking, problem-solving, decision-making, creativity, and innovation. Teachers also showed a positive attitude towards using technology that supports collaboration, learning, and productivity. In sum, teachers developed their digital competences. The main explanation the author gives for these effects was that the training program met the needs of the teachers. The author concluded that an increase in teachers' digital competence will also support the development of the students' digital competences.

Affordances to Integrate Technology in Teaching

The extensive and frequent use of technology does not imply that teachers integrate the technology into their educational practices. Affordances and barriers of pre-service teachers and in-service teachers to *integrate* technology in their teaching are studied extensively. Tondeur et al. (2008, 2021) provide an overview of affordances of teachers' integration of technology in teaching, which is corroborated by many other studies on both affordances and barriers of technology-integrated teaching practices (see e.g., Abel et al., 2022; Admiraal et al., 2013; Dinc, 2019; Francom, 2020; Scherer et al., 2023). A model that brings most of the affordances and barriers together is the will, skill, and tool (WST) model of Knezek and Christensen (2008) or the extended WST model, which is the will, experience, skill, and tool model of Farjon et al. (2019). As this model is about pre-service teachers' affordances and barriers to integrate technology in their classrooms, we suggest adding support and facilitation to this model, which is a factor commonly found in technology integration of in-service teachers (Abel et al., 2022; Admiraal et al., 2013; Dinc, 2019).

Will refers to the attitude towards and the belief in the use of technology, including positive attitudes towards the use of technology in teaching practices, the belief that technology can be supportive of the learning process of students, the belief that teaching practices can be changed and students are able to learn from technology-integrated practices, and positive attitudes towards changing ones' own teaching practice in general. This construct is widely recognized as a necessary condition for successful technology integration', which means that a positive attitude and the lack of a negative attitude both affect whether and how teachers integrate technology.

Experience refers the quantity and quality of first-hand experiences with the integration of technology into teaching, including training programs to increase their competences, previous positive and negative teaching experiences, and learning themselves with support of technology. Sufficient learning experience with teaching with technology is necessary for teachers to integrate technology successfully.

Skills refers to teachers' knowledge, ability, and readiness to use technology and is universally acknowledged as being a prerequisite to successful technology integration. It includes the basic skills in and knowledge of various technologies and how to use them to achieve both personal and educational goals.

Tools refers to the accessibility of technology and familiarity of technology use and can be understood as another prerequisite to successful technology integration. The lack of access to different technologies is a more fundamental prerequisite than the other constructs as without technology it can also not be integrated in education.

Finally, *Support and facilitation* of teachers' technology integration is added to the previous models, including time to prepare lessons and design materials, support from leaderships and colleagues, and an innovative school culture in which technology-integration and trial-out new practices is appreciated.

This Study

Prior to designing CPD programs for in-service teachers on technology-enhanced teaching and learning, it should be clear what knowledge teachers have related to technology-enhanced teaching and learning and how this knowledge is related to perceived affordances of integrating technology in teaching. The following three research questions directed the current study:

1. What is the level of technology knowledge of Kazakh school teachers?
2. Which affordances to integrate technology in teaching practice do Kazakh school teachers perceive?
3. How is teachers' *TK* related to the affordances they perceive to integrate technology in their teaching?

METHODS

Participants

Invitations were sent to teachers from 21 high schools in 21 different cities in Kazakhstan. These schools are in four geographic regions of Kazakhstan, that is, east, west, north, and south. In total, the participants returned 322 responses through Google Forms. After data cleaning, the final sample was reduced to 309 with the deletion of eight cases with random responses (i.e., the same responses to all 34 items) and five cases with missing values greater than 10.0% of the items. Of the 309 teachers, 159 were male (51.5%) and 150 were female (48.5%). Teachers' ages varied between 20 and 64 with a mean of 33 years and their experience varied between zero and 42 with an average of 10 years. Of the 309 teachers, 112 (36.3%) taught natural sciences (physics, mathematics, etc.) and 197 (63.7%) taught a school subject related to social sciences (language, history, etc.). Moreover, 281 (90.9%) teachers were Kazakh, and the rest were teachers from other nationalities such as Russian, Turkish, and Uzbek. All teachers joined the study voluntarily.

Measures

Two questionnaires have been administered to measure Affordances for using technology in teaching and Teacher knowledge. Both surveys were translated to Kazakh. The translated versions were revised by two English language instructors from SDU University. The issues in both translations were resolved among the translators.

Consent was obtained from teachers. The participating teachers completed both surveys online through a Google Form, which took them about 15-20 minutes to complete the surveys. Brief instructions on how to complete surveys were given to the teachers before the survey administration. Teachers were also informed of the research purposes and confidentiality of data. Teachers were told to answer faithfully according to their real situations and there were no right or wrong answers.

Barriers to technology integration

Barriers to technology integration (BTI) questionnaire developed by Francom (2020) was used to measure the *Affordances for using technology in teaching*. BTI consists of 18 items and participants respond by indicating the amount of agreement to the items with a Likert format of one to five, where one is strongly disagree and five is strongly agree. BTI includes negatively worded items that were reverse coded before data analysis. BTI has been validated through data collected from 1906 teachers from a rural north-midwestern US state

(Francom, 2020). BTI assesses the multifaceted landscape of technological integration in education across five dimensions. First, the dimension of *access to technology tools and resources (ATTR)* gauges the reliability of internet connections, accessibility of social websites for both educators and students, and the availability of high-quality educational technologies. The second dimension, *technology training and support (TTS)* evaluates the frequency and relevance of training received by educators and the effectiveness of support when facing technological challenges. Third, *administrative support (AS)* explores the encouragement from school leaders to use technology and the bureaucratic processes involved in gaining approval for new technologies or teaching methods. Fourth, the dimension of *time to plan and prepare for tech integration (TPPTI)* examines the adequacy of time for educators to thoughtfully incorporate technology into lessons. Fifth, *beliefs on the importance and usefulness of technology tools and resources (BIUTTR)* delves into educators' confidence in finding and using technological resources, perceptions of technology's impact on student learning, and views on its incorporation into the learning experience, providing a comprehensive overview of the technological environment in education. Some sample survey items include, "at my school, I have access to the best educational technologies", "when I have a problem with a technological tool or resource, I receive quick and effective assistance", and "I have enough time to plan and prepare lessons that use technology".

Teacher knowledge

Teacher knowledge (originally called *technological pedagogical content knowledge* [*TPACK*] *for meaningful learning*) questionnaire comprised 36 items and seven dimensions. It was developed by Koh and Chai (2014) and was validated through the data from 102 teachers in Singapore. Participants respond by indicating the amount of agreement to the items with a Likert format of one to five, where one is strongly disagree and five is strongly agree. Unlike BTI, *teacher knowledge* questionnaire did not comprise any negatively worded items. *Teacher knowledge* questionnaire encompasses a comprehensive assessment of teachers' competencies across multiple dimensions. First, *CK* evaluates teachers' familiarity, depth, and confidence in their teaching subject, addressing misconceptions and learning difficulties. Second, *pedagogical knowledge (PK)* focuses on teaching strategies, including the ability to challenge students, guide learning strategies, and facilitate reflective activities. Third, *TK* evaluates technical skills, problem-solving abilities, and awareness of new technologies. Fourth, *pedagogical content knowledge (PCK)* assesses the integration of pedagogy and *CK* without relying on technology. Fifth, *technological pedagogical knowledge (TPK)* examines the use of technology to enhance pedagogical practices. Sixth, *technological content knowledge (TCK)* assesses knowledge of subject-specific technologies. Seventh, *TPACK* integrates technology, pedagogy, and *CK*, evaluating teachers' ability to design student-centered lessons that effectively blend content, technology, and pedagogy while utilizing appropriate ICT tools.

Data Analysis

Data were first screened to identify cases that needed to be removed and mean imputation was performed for missing values of no greater than 10.0% of the data. Excel and Jamovi 2.4.8 were used for data analysis. Internal consistency tests (Cronbach's alpha) were first conducted to ensure the reliability of the measurement instruments. The descriptive statistics and Cronbach's alpha are presented in **Table 2**.

Both descriptive and inferential statistics were then computed to analyze the data. Firstly, means, standard deviations, and normality (Shapiro-Wilk's test on normality) were calculated to describe the data. Then, correlations between the subscales of both questionnaires and the correlation between age and all subscales were also analyzed. Because of non-normal distribution of data Mann Whitney U test and Kruskal Wallis test were performed to ascertain whether there were significant differences in *affordances for using technology in teaching* and *teacher knowledge* between male and female teachers, between teachers teaching social and natural sciences lessons, and between teachers that differ in work experience (i.e., zero-three years, four-10 years, and over 10 years), nationality (Kazakh or not), or geographic regions of Kazakhstan they work in. Finally, we tested the hypothesis that there is an interaction between *affordances for using technology in teaching* and *Teacher* knowledge related to technology through structural equation modeling (SEM) analysis.

Table 2. Descriptive statistics of *affordances & teacher knowledge*

	n	Mean	Standard deviation	Shapiro-Wilk W	Shapiro-Wilk p	Cronbach's alpha
Affordances for using technology in teaching						
ATTR	309	4.04	0.680	0.919	<0.001	0.727
TTS	309	4.01	0.626	0.916	<0.001	0.778
AS	309	2.95	0.613	0.862	<0.001	0.664
TPPTI	309	3.24	0.613	0.711	<0.001	0.131
BIUTTR	309	4.22	0.569	0.872	<0.001	0.741
Teacher knowledge						
CK	309	4.29	0.551	0.822	<0.001	0.905
PK	309	4.13	0.513	0.870	<0.001	0.903
PCK	309	3.98	0.629	0.853	<0.001	0.890
TK	309	4.10	0.528	0.913	<0.001	0.816
TPK	309	4.19	0.506	0.880	<0.001	0.908
TCK	309	4.17	0.591	0.877	<0.001	0.874
TPCK	309	3.89	0.681	0.909	<0.001	0.922

Table 3. Fit indices

	SRMR	RMSEA	CFI	TLI	NNFI	RNI	NFI	RFI	IFI	PNFI
Expected values	≤0.08	≤0.08	≥0.90	≥0.90	near 1.00	NA	near 1.00	NA	near 1.00	>0.50
Observed values	0.07	0.06	0.99	0.99	0.99	0.99	0.99	0.98	0.99	0.88

Note. There are no widely accepted cutoff values for RNI & RFI & for expected values see Hair et al. (2010), Hu and Bentler (1999), Kelley and Lai (2011), & Kline (2023)

RESULTS

Teachers' Level of Technology Knowledge & Perceived Affordances

For a concise and informative summary of our dataset's main characteristics, we first present the descriptive statistics, per subscale (number of valid scores, mean, standard deviation, Shapiro-Wilk W's normality statistics, and Cronbach's alpha, see **Table 2**). The first five scales are the dimensions of *affordances for using technology in teaching*, the other seven subscales are the dimensions of *teacher knowledge*.

Table 2 indicates that teachers have, in general, the lowest score on *AS* (mean [M]=2.95) followed by *TPPTI* (M=3.24). The highest mean score was in *CK* (M=4.29), and then in *TPK* (M=4.19). The level of the seven dimensions of *teacher knowledge* was similar. Because of the low internal consistency coefficient, one item of *ATTR* and one item of *BIUTTR* were deleted to improve the reliability of the scales. TPPTI was not included in further analyses because of its low reliability. This process does not compromise the data's integrity. Instead, it strengthens the validity of our conclusions by ensuring that the scales used in our analyses accurately reflect the constructs they are intended to measure. The removal of poorly performing items is a corrective measure that enhances the scales' ability to produce reliable and consistent results, thereby increasing the credibility and generalizability of our findings.

Structural Equation Modeling Analyses

To explore the relationship between *affordances for using technology in teaching* and *teacher knowledge*, we conducted a SEM analysis (Kline, 2023) for three dimensions of affordances and four dimensions of *teacher knowledge*. We will rely on the following fit indices (Hu & Bentler, 1999; Kelley & Lai, 2011): standardized root mean square residual (SRMR), root mean square error of approximation (RMSEA), comparative fit index (CFI), Tucker-Lewis index (TLI), Bentler-Bonett non-normed fit index (NNFI), relative non-centrality index (RNI), Bentler-Bonett normed fit index (NFI), Bollen's relative fit index (RFI), Bollen's incremental fit index (IFI), and Parsimony normed fit index (PNFI) to complement Chi-square test in assessing model fit. These indices provide a more comprehensive view of model fit. As seen in **Table 3**, all additional fit indices indicated that the measurement model was good.

Measurement model

A measurement model in SEM serves as the foundation for assessing the quality of measurement of latent constructs and provides a basis for testing hypotheses about the relationships between these constructs

Table 4. Measurement model for SEM analyses

Latent	Observed	Estimate	SE	β	z	p
TK (exogenous 1)	TK1	1.000	0.000	0.822		
	TK2	1.006	0.037	0.827	27.08	<0.001
	TK3	0.878	0.043	0.722	20.58	<0.001
	TK4	0.943	0.039	0.775	23.92	<0.001
	TK5	0.530	0.059	0.436	9.03	<0.001
	TK6	1.009	0.042	0.829	24.24	<0.001
	TK7	0.998	0.037	0.820	26.71	<0.001
TPK (exogenous 2)	TPK1	1.000	0.000	0.921		
	TPK2	0.993	0.019	0.915	51.06	<0.001
	TPK3	0.989	0.021	0.911	47.24	<0.001
	TPK4	1.032	0.023	0.951	45.36	<0.001
	TPK5	0.894	0.028	0.823	31.91	<0.001
TCK (exogenous 3)	TCK1	1.000	0.000	0.889		
	TCK2	1.043	0.021	0.927	48.96	<0.001
	TCK3	1.054	0.021	0.937	49.40	<0.001
TPCK (exogenous 4)	TPCK1	1.000	0.000	0.897		
	TPCK2	1.050	0.019	0.942	56.10	<0.001
	TPCK3	1.045	0.021	0.937	50.08	<0.001
	TPCK4	1.038	0.019	0.931	54.43	<0.001
	TPCK5	0.950	0.022	0.853	44.10	<0.001
ATTR (exogenous 1)	ATTR1	1.000	0.000	0.681		
	ATTR3	1.119	0.113	0.762	9.91	<0.001
	ATTR4	1.079	0.102	0.734	10.63	<0.001
	ATTR5	1.063	0.110	0.724	9.63	<0.001
TTS (exogenous 2)	TTS1	1.000	0.000	0.794		
	TTS2	1.051	0.074	0.834	14.14	<0.001
	TTS3	1.028	0.071	0.816	14.43	<0.001
BIUTTR (exogenous 4)	BIUTTR2	1.000	0.000	0.715		
	BIUTTR3	1.010	0.086	0.722	11.72	<0.001
	BIUTTR4	1.331	0.111	0.952	11.96	<0.001

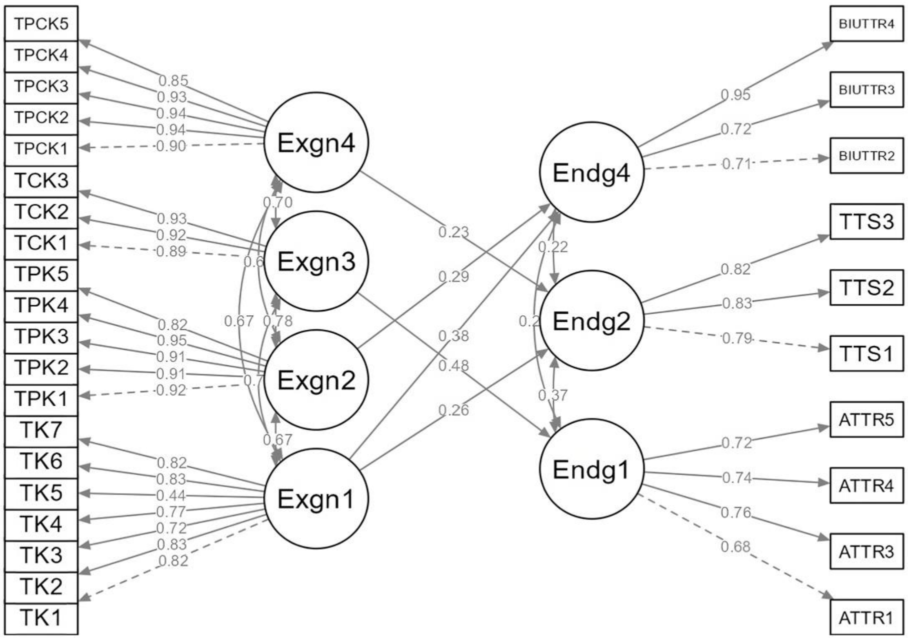

Figure 1. Visualization of developed model (https://www.jamovi.org/)

(Fornell & Larcker, 1981). In **Table 4**, the standardized regression coefficients (b) for each observed variable are significant (p<0.001).

Indices in **Figure 1** indicate weak relationships between the latent constructs. We have deleted the relationships with a b-coefficient lower than 0.2.

Table 5. Reliability indices

Variable	α	ω_1	ω_2	ω_3	AVE
TK	0.829	0.844	0.844	0.878	0.576
TPK	0.913	0.901	0.901	0.908	0.819
TCK	0.878	0.868	0.868	0.868	0.842
TPCK	0.923	0.922	0.922	0.940	0.833
ATTR	0.743	0.761	0.761	0.773	0.527
TTS	0.774	0.783	0.783	0.798	0.664
BIUTTR	0.750	0.765	0.765	0.779	0.647

As **Figure 1** illustrates, *TPCK* (Exgn4) was positively related to *TTS* (Endg2, b=0.23, p=0.002), *TCK* (Exgn3) was positively related to *ATTR* (Endg1, b=0.48, p<0.001), *TPK* (Exgn2) was positively related to *BIUTTR* (Endg4, b=0.29, p≤.001), and *TK* (Excn1) was positively related to both *BIUTTR* (Endg4, b=0.38, p≤0.001), and *TTS* (Endg2, b=0.26, p=0.001).

Model validation

Two reliability indices were calculated to establish the consistency of the model. Cronbach's alpha coefficient indicates the extent to which the items within a scale are correlated with each other. Omega is used to assess the extent to which the items in a measure are measuring the same underlying construct. To increase the reliability coefficients one item was extracted from each of the endogenous1 (*ATTR1*), endogenous3 (*TTS1*), and endogenous4 (*BIUTTR2*) variables. These were negatively worded items and research has indicated that these kinds of items may load on a separate factor, forming a measurement artifact (Miller & Cleary, 1993). Convergent validity is evaluated by examining the outer loadings of the indicators to determine the average variance extracted (AVE) from each construct. The external loads should exceed 0.708 so that AVE>0.500 indicates good convergent validity (Hair Jr. et al., 2017). In general, Cronbach's alpha and omega coefficients of 0.70 or higher are considered acceptable for research purposes (Awang, 2015; Cheung et al., 2023; Hair Jr. et al., 2017). All variables have acceptable values (see **Table 5**).

DISCUSSION

This questionnaire study was about schoolteachers in Kazakhstan and their perceptions of their knowledge of technology and factors that either hinder or support their technology integration in their teaching in school. The schoolteachers perceived their knowledge of the content as the highest, whereas pedagogical *CK*, with or without *TK* received the lowest scores. In general, the differences between various types of knowledge were minimal. Concerning the factors that potentially influence the integration of technology in schoolteachers' teaching, both the support from the administrative staff and the availability of time to prepare for the integration of technology in teaching were perceived to be present at a relatively low level. Yet teachers' beliefs about the importance and usefulness of technological tools and resources for teaching and learning received a relatively high score. Finally, beliefs on the importance and usefulness of technology were positively related to knowledge about both technology and technology and pedagogy. *TTS* were related to both *TK* and *TPACK*, and access to technology was related to technological *CK*.

Technological Knowledge of Kazakh School Teachers

The differences between the various types of *TK* of Kazakh school teachers are quite small. In general, the teachers perceived their knowledge of technology, pedagogy, and content and their combinations at a high level. This relatively high level of knowledge beliefs is partly confirmed in previous work, showing high scores on teachers' competence beliefs in finding relevant digital resources (Lucas et al., 2021), although relatively low scores are reported as well by Grodek-Szostak et al. (2021). Yet the various types of *TK* showed different relationships with the factors that support the integration of technology in teaching. The more teachers knew of subject-specific technologies, the more they were able to access technology tools and resources. Probably, the tools and resources that are available for Kazakh teachers are mainly about the school subjects they teach. This would align with the conclusion from Orakova et al. (2024), who found that Kazakh school teachers command pedagogical competences more than generic technology competences.

Furthermore, the more teachers knew how to support their pedagogy with technology and about technology in general, the more positive their beliefs about the importance and usefulness of technology for teaching. Finally, the more teachers knew about technology in general and about combining technology, content, and pedagogy, the more positive they were about receiving *TTS*. It might be that teachers with *TK* see training and support to be quickly updated about the newest technologies (cf., Clark & Zhang, 2018), and teachers who combined all three types of knowledge might be more interested in solutions for complex teaching practices in which technology knowledge should be combined with knowledge about content and pedagogies. In sum, all types of *TK* appeared to be important for factors that support the integration of technology in teaching.

Factors That Support Technology Integration in Teaching

Both support from school leaders and the availability of enough time to integrate technology into teaching were the factors that received the lowest scores among the Kazakh teachers. As the other factors were less related to the teachers' school environment, it seems that teachers felt less supported in school, compared to the availability of tools, training, and support outside school or their attitudes toward the use of teaching. School environment variables are found to be important for teachers' use of technology in class and for their professional development in teaching with technology (Masoumi & Noroozi, 2023. These school environment variables relate to, for example, *AS* teachers receive (Chang et al., 2008), and technical support and tool availability (Ertmer et al., 2012; Mirzajani et al., 2016).

Unfortunately, both *AS* and *TPPTI* were left out of the final model, which means that we could not examine the relationships between these two factors and the various types of knowledge. However, their importance for technology integration in teaching practices is well established in previous research. Therefore, we suggest extending the Support and facilitation construct with a broader School environment construct and adding it to the WEST model of Farjon et al. (2019).

Limitations & Directions for Future Research

Due to the current study's focus on teacher knowledge and factors that potentially support technology integration in teaching, no information has been included about other teacher characteristics that are found to influence these factors, such as teachers' competence beliefs or self-efficacy (Quast et al., 2023), teachers' professional development in technology integration (Koh et al., 2017) and teachers' attitudes towards technology integration in class (Beardsley et al., 2021). A more comprehensive questionnaire study could provide insights into the relative importance of the type of teacher knowledge for both internal (teacher) and external (school) factors that influence technology integration in class.

A second limitation of the current study is the lack of the outcome variable, teaching with technology. The addition of technology-enhanced teaching as a variable to the model with both internal and external factors would also provide insights into the relationship between the factors and the perceived (measured in a questionnaire) or actual (measured in observations) integration of technology in teaching.

CONCLUSIONS

This study about teacher *TK* and factors that support teaching with technology in school showed that various types of teacher technology knowledge were related to these supportive factors. It also shows that, in general, Kazakh teachers have a relatively high level of technology knowledge, which might mean that increasing support in school and teachers' professional development will positively affect teachers' integration of technology in their teaching practice.

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Data availability: Data generated or analyzed during this study are available from the authors on request.

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