INDONESIAN JOURNAL OF CURRICULUM
AND EDUCATIONAL TECHNOLOGY STUDIES
2025, Vol. 13, No. 2, 115-12, DOI: https://doi.org/10.15294/ijcets.v13i2.35379

Integrated TPACK–CRT Learning Design for Elementary Schools: Empirical Study and Conceptual Framework Development

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Abstract

21st-century learning demands integration between technology, pedagogy, content, and cultural context to make the learning process more meaningful, reflective, and inclusive. This research aims to analyze the needs of elementary school students and the readiness of teachers in implementing TPACK-CRT-based learning and to develop a conceptual design for TPACK-CRT learning as an integrative framework. The research uses a quantitative approach with a conceptual qualitative approach, involving 40 elementary school students and 3 teachers. Data was collected through questionnaires and the synthesis of TPACK and CRT theories, which were then analyzed using descriptive analysis and conceptual framework building. The results show that both student needs and teacher readiness are in the high category, but there are differences in orientation: students demand more contextual use of technology, while teachers show higher readiness in pedagogical and affective aspects. Based on the synthesis results, a conceptual design for TPACK-CRT learning was produced, consisting of four main phases: contextual orientation, meaningful technology integration, cultural interaction and collaboration, and humanistic reflection and relevance. This research contributes to strengthening the theoretical framework of TPACK-CRT integration and provides practical guidance.

ARTICLE HISTORY
Received 21 October 2025
Accepted 20 November 2025

KEY WORDS
Conceptual Framework; CRT; Elementary School Learning Design; TPACK.

INTRODUCTION

21st-century learning demands a process of technological mastery, while simultaneously bringing meaning, interactivity, and contextualization to learning, aligning it with students' lives and cultures. Ideally, learning takes place in an innovative, student-centered climate that effectively utilizes technology to reinforce conceptual understanding (Schmid et al., 2022; Wiklund-Engblom et al., 2025). In this context, the teacher's ability to integrate technological, pedagogical, and content aspects, as emphasized in the Technological Pedagogical and Content Knowledge (TPACK) framework, becomes crucial for making learning more student-centered and enhancing their understanding (Jiménez Sierra et al., 2023; Yue et al., 2024). Nevertheless, Alkubaisi (2025) emphasizes that mastering TPACK alone is not enough, teachers also need to understand students' context, including their culture and readiness.

Cheng et al.'s (2021) research highlights that integrating technology with culturally relevant teaching is crucial for creating an adaptive and meaningful classroom environment for students. Culturally responsive approaches like Culturally Responsive Teaching (CRT) emphasize cultural relevance and empathy in the learning process, which supports increased student engagement and strengthens teacher-student relationships (Abacioglu et al., 2020; Calibara, 2025). Empirical research shows that implementing CRT in primary education can improve inclusivity and lear-

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ning outcomes, while also supporting students' social and emotional development (Galenzoga, 2025; Niman, 2025; Rentzi, 2024). Therefore, the integration of TPACK and CRT is key to creating learning that is not only culturally responsive but also pedagogically and technologically effective, making learning in the 21st century adaptive, contextual, inclusive, and meaningful.

Although there is extensive literature examining the importance of TPACK mastery and the application of CRT in 21st-century learning, teachers still face difficulties in accurately implementing cultural contexts in the classroom (Candra & Wahzudik, 2024; Okta & Putra, 2025). Additionally, field practices often still utilize teacher-centered methods with limited ability to integrate technology in primary schools (Kibirige, 2023; Mu, 2023; Pappa et al., 2024). In fact, even some teachers who have attempted to implement TPACK and CRT still do so partially, where technology is more often used as an instructional aid rather than a means of active learning, and the application of CRT is not yet fully culturally contextual (Cheng et al., 2021).This condition indicates a gap between theory and practice in the field, necessitating the development of a study that empirically and adaptively integrates TPACK and CRT.

Several studies related to TPACK and CRT have been conducted extensively, but the integration of both within a single conceptual learning design is still rare. For example, Filina et al. (2024) focused on the application of TPACK in digital learning but did not discuss integration with CRT. Studies related to Culturally Responsive Pedagogical Knowledge (CRPK) emphasize pedagogy and cultural relevance more but are less flexible in accommodating TPACK integration (Ogodo, 2024). Haga (2024) conceptually examined the TPACCK model to emphasize the importance of the cultural dimension in TPACK, but did not yet present an adaptive, contextual, and culturally responsive learning design. Building on previous research findings, the empirical, adaptive, contextual, and culturally responsive development of a conceptual learning design integrating TPACK and CRT is crucial to bridge the existing gap between theory and practice, particularly at the elementary school level.

The development of the TPACK-CRT learning design needs to be based on the results of student needs analysis and teacher readiness to identify the needs for technology integration, culturally responsive learning needs, and the needs for innovative conceptual learning design (Jabareen, 2009). Subsequently, a synthesis of TPACK theory (Mishra & Koehler, 2006) and CRT (Gay, 2010). was carried out to build a conceptual model that is adaptive, inclusive, and contextual. The design was then validated based on theoretical relevance, resulting in a conceptual learning framework and phase design that integrates the dimensions of technology, pedagogy, content, and student culture. This conceptual design offers novelty through the combination of empirical and theoretical foundations, relevance to real-world practice, support for 21st-century learning, and the provision of practical guidance previously unavailable (Abacioglu et al., 2020; Gay, 2018; Schmid et al., 2022).

The urgency of this research lies in the need to present learning that not only focuses on technological mastery but also fosters sensitivity to students' cultural diversity in the context of 21st-century learning. Meanwhile, teaching practices in elementary schools still show a gap between 21st-century demands and actual implementation, where the integration between technological, pedagogical, content, and cultural context aspects has not yet been optimal. Therefore, this study aims to analyze students' needs and teachers' readiness for TPACK and CRT-based learning, as well as develop a conceptual learning design for elementary schools that integrates the TPACK framework and the CRT approach. Theoretically, the results of this study are expected to expand understanding of TPACK-CRT integration as a 21st-century conceptual learning design, while practically guiding teachers in designing learning that is adaptive, inclusive, and relevant to students' cultural contexts.

THEORETICAL FRAMEWORK

This research uses a theoretical foundation that serves as the basis for developing a learning design integrating TPACK and CRT in the context of elementary school learning. The TPACK

framework was first introduced by Mishra and Koehler (2006) as a development of the Pedagogical Content Knowledge (PCK) concept proposed by Shulman (1986). Shulman (1986) discussed the basic conceptual framework of PCK, which was the initial foundation for the emergence of the TPACK model, emphasizing the importance of blending content knowledge and pedagogical knowledge in effective teaching practice. Subsequently, Mishra & Koehler (2006) developed the TPACK concept as an extension of PCK by adding the dimension of technological expertise. TPACK explains teacher competence in integrating three main knowledge domains: Technological Knowledge, Pedagogical Knowledge, and Content Knowledge, to create effective technology-based learning. These three domains intersect and form new knowledge components, namely Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Pedagogical Content Knowledge (PCK). Ultimately, these three components combine to form Technological Pedagogical Content Knowledge (TPACK) as the core of a teacher's ability to design, implement, and evaluate pedagogically integrated technology learning (Koehler et al., 2013). The intersection of three components that combine to form TPCK is shown in Figure 1.

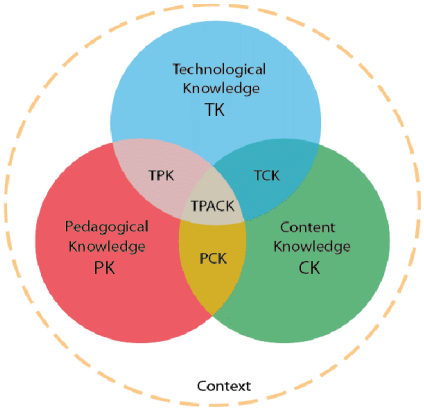

Figure 1 The TPACK framework (graphic adapted from http://tpack.org)

Along with the development of Mishra (2019) research, he proposed expanding the TPACK framework by adding the Contextual Knowledge (XK) domain, which includes teachers' knowledge of school policies, classroom culture, socioeconomic background, and available technological situations. This expansion makes TPACK a holistic model of teacher knowledge because it requires integration between technology, pedagogy, and content within the social and cultural context of learning. However, the TPACK framework, with the addition of the Contextual Knowledge (XK) domain by Mishra (2019) has not explicitly guided teachers to understand and integrate local cultural contexts or local wisdom values into learning. In fact, TPACK is an important foundation for ensuring that technology use is not merely technical, but truly strengthens the quality, meaning, and relevance of the learning process (Schmid et al., 2022; Yue et al., 2024). Therefore, a conceptual learning design is needed that integrates TPACK with the CRT approach to be more adaptable to the characteristics of elementary school students.

CRT can be understood as a learning approach that places students' culture at the core of designing and implementing the learning process, making learning relevant, inclusive, and meaningful for all students (Gay, 2018). In practice, Gay (2018) emphasizes that implementing CRT involves utilizing students' diverse cultural knowledge, prior experiences, frames of reference, and performance styles to make learning experiences more relevant and effective. Ladson-Billings (1995) identified three main dimensions of Culturally Relevant Pedagogy, which were later widely adapted in the CRT concept: academic success, cultural competence, and critical consciousness. These three dimensions are an important foundation for implementing CRT, as they emphasize that academic success must be accompanied by cultural emphasis and critical awareness of social justice. Additionally, the CRT indicators were developed based on the framework by Gay (2010), which emphasizes three main dimensions: cultural relevance, caring and empathy,

and empowerment as pedagogical principles to ensure meaningfulness and equity in learning. Studies show that CRT can create inclusive learning, rooted in students' cultural identities, and relevant to their life contexts through culturally sensitive teacher strategies (Samuels, 2025; Ulbricht et al., 2024).

Theoretically, this research is based on the integration of two main frameworks: CRT and Technological TPACK. CRT provides a pedagogical foundation that emphasizes cultural relevance, inclusivity, and the strengthening of student identity, while TPACK offers a conceptual structure for harmoniously integrating technology, pedagogy, and content. The integration of the two resulted in a new conceptual framework called the TPACK–CRT framework, which bridges 21st-century learning theory and practice. This framework confirms that the use of technology in the conceptual design of learning is not only oriented toward digital innovation, but also toward cultural sensitivity and the social context of students.

METHOD

This research uses a quantitative approach and a conceptual qualitative approach. The quantitative approach is used to answer research questions related to finding student needs and teacher readiness for TPACK-CRT-based learning. The conceptual qualitative approach is used to answer the second research question regarding the development of a conceptual design for integrated TACK-CRT learning. This approach ensures that the developed learning design is evidence-based, practically relevant, and can serve as a reference for further research. To address the first research question regarding student needs and teacher readiness for TPACK-CRT-based learning, the research subjects were selected from a school that had implemented technology and the CRT approach. A total of 40 elementary school students and 3 elementary school teachers were identified as meeting the inclusion criteria, namely: (1) active in the learning process, (2) involved in learning that utilizes technology or digital media, and (3) participated in learning that considers cultural context. The instrument used for data collection was a 1–4 Likert scale questionnaire developed based on TPACK and CRT indicators (Gay, 2018; Mishra & Koehler, 2006). The items measured students' learning needs and teachers' readiness in terms of technological integration, pedagogical and content knowledge, and cultural responsiveness. The collected data were analyzed using descriptive statistics, including means, percentages, and the interpretation of needs and readiness categories (Arikunto, 2014). The obtained questionnaire data were analyzed using the following formula.

$$\textbf{Level of Need/Readiness} = (\textbf{Total Score}\ )/(\textbf{Maximum Score}\ ) \times 10$$

The calculation results were then interpreted based on categories of need levels as shown in Table 1.

Table 1 Need and Readiness Categories

Percentage Range	Category
81–100%	High
61–80%	Medium
≤ 60%	Low

Next, the second research question develops a conceptual learning design that integrates TPACK-CRT. The data source consists of scientific literature data related to TPACK and CRT theory (Gay, 2018; Mishra & Koehler, 2006). This research uses conceptual framework building based on Jabareen's (2009) stages. The analysis procedure consists of eight stages from Jabareen's (2009), including (1) mapping the selected data sources, (2) extensive reading and categorizing, (3) identifying and naming concepts, (4) deconstructing and categorizing, (5) integrating concepts, (6) synthesizing into a theoretical framework, (7) validating the framework, and (8) re-

thinking the framework. The output of this phase is a conceptual design for TPACK-CRT learning that can be used for further testing. As for the breakdown of each procedure in this phase, it can be seen in Table 2.

Table 2 Procedure Conceptual Framework Building

Procedure	Description of Procedure	Output
Mapping the selected data sources	Collecting and reading TPACK & CRT literature, as well as needs and readiness maps	List of theoretical sources, needs, and readiness
Extensive reading & categorizing	In-depth reading of literature and needs mapping	Initial categories of the TPACK-CRT concept
Identifying & naming concepts	Determining the core concepts of both theories	List of key concepts
Deconstructing & categorizing	Analyzing the relationship and differences in conceptual structure between TPACK and CRT to find conceptual common ground	Structured concept category
Integrating concepts	Synthesizing theory and analyzing the points of convergence between TPACK and CRT as the basis for forming integrative principles	Integrative TPACK–CRT Principle
Synthesizing into a theoretical framework	Developing the TPACK-CRT framework & the four phases of learning	Conceptual framework
Validating the framework	Checking the suitability of the framework with the literature Framework reflection and refinement	Validated conceptual framework
Rethinking the framework	Reflection & framework refinement	Final conceptual framework

RESULT AND DISCUSSION

The results of the analysis of the first objective in this study provide an empirical overview of students' needs and elementary school teachers' readiness to integrate TPACK and CRT into their teaching practices. Overall, the findings indicate potential synergy between students' learning needs and teachers' implementation capacity, serving as a basis for developing an integrated TPACK-CRT learning design. Analysis of the second objective revealed conceptual overlaps between the TPACK framework and CRT principles, which can be used as a foundation for integration in learning design. The findings are detailed as follows.

A. Student Needs and Teacher Readiness in the Implementation of TPACK-CRT

Multimodal lAn analysis of elementary school students' needs was conducted to identify the extent to which students require learning that integrates Technological TPACK, CRT, and innovative learning design. Data was collected using a 1–4 Likert scale questionnaire with statements representing the need indicators for each of the three aspects. The results of the data analysis on student needs are presented in Table 3.

Table 3 Student Needs Analysis

Needs Aspect	Key Indicators	Average Score (1-4)	Percentage	Category
TPACK	TK	3.5	87%	High
	PK	3.3	82%	High
	CK	3.5	87%	High
	PCK	3.7	92%	High
	TCK	3.7	92%	High
	TPK	3.6	90%	High
Total TPACK Score		3.5	87%	High
CRT	Cultural Relevance	3.3	82%	High
	Caring and Empathy	3.3	82%	High
	Empowerment	3.6	90%	High
Total CRT Score		3.4	85%	High
Total TPCK-CRT Score		3.4	85%	High

Based on the analysis results in Table 3, the overall need level of elementary school students in implementing TPACK-CRT-based learning is in the High category with an average score of 3.4 or 85%. The TPACK aspect is in the High category with an average score of 3.5 or 87%. Meanwhile, the CRT aspect is in the High category with an average score of 3.4 or 85%. This finding indicates that students have a strong need for learning experiences that integrate technology with cultural contexts close to their lives. Studies show that when technology-based learning, such as TPACK, is not accompanied by the integration of students' culture and identity, engagement and meaningful learning become limited (Macann & Yadav, 2023). Additionally, other research reveals that combining technology like TPACK with culturally responsive teaching (CRT) results in higher effectiveness in increasing motivation and participation of elementary school students (Harahap et al., 2024).

However, this need must align with teachers' readiness to implement TPACK-CRT-based learning. An analysis of elementary school teachers' readiness to implement TPACK-CRT-based learning was conducted to obtain an empirical overview of the extent to which teachers possess the ability and readiness to integrate technology, pedagogy, content, and cultural diversity values into their teaching practices. The data obtained were then analyzed descriptively to determine the level of teacher readiness in each aspect. The results of the analysis of teacher readiness in the context of TPACK-CRT implementation are presented in Table 4.

Based on the analysis results in Table 4, the overall readiness level of elementary school teachers in implementing TPACK-CRT-based learning falls into the High category with an average score of 3.4 or 86%. The TPACK aspect is in the High category with an average score of 3.3 or 83%. Meanwhile, the CRT aspect is in the High category with an average score of 3.6 or 91%. This finding indicates that conceptually, teachers have a good understanding of the integration of technology, pedagogy, and content, and demonstrate awareness of the importance of cultural relevance in learning.

Although the level of teacher readiness in implementing TPACK-CRT-based learning is considered high, this condition is not yet fully reflected in systematic and meaningful teaching practices. This aligns with previous research findings indicating that the utilization of technology and cultural responsiveness principles in primary schools is often still separate and instrumental, not yet integrated into reflective and value-oriented learning designs (Cheng et al., 2021; Kibirige,

Ta2023). This readiness needs to be followed up by developing a TPACK-CRT-based learning design that can guide teachers in systematically integrating technology, pedagogy, and cultural context (Çam & Koç, 2024; Chuang et al., 2020).

Table 4 Student Needs Analysis

Needs Aspect	Key Indicators	Average Score (1-4)	Percentage	Category
TPACK	TK	3	75%	Medium
	PK	4	100%	High
	CK	3.5	87%	High
	PCK	3	75%	Medium
	TCK	3	75%	Medium
	TPK	3.5	87%	High
Total TPACK Score		3.3	83%	High
CRT	Cultural Relevance	3	75%	Medium
	Caring and Empathy	4	100%	High
	Empowerment	4	100%	High
Total CRT Score		3.6	91%	High
Total TPCK-CRT Score		3.4	85%	High

The comparison between student needs and teacher readiness was mapped to assess the alignment of learning needs with the capacity to implement TPACK-CRT-based learning. The comparison between student needs and teacher readiness in the context of TPACK-CRT integration is shown in Figure 2.

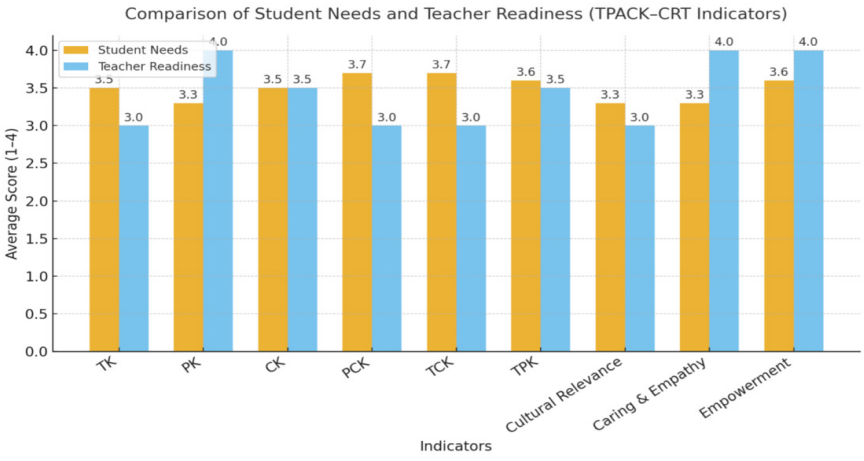

Figure 2. Comparison of Needs and Readiness

Overall, both are in the high category, with a tendency that students' needs are slightly higher than teachers' readiness. In the TPACK aspect, differences are seen in the Technological Knowledge dimension, where students' needs are greater in utilizing technology compared to teachers' readiness to meaningfully integrate technology into learning. Meanwhile, in the CRT aspect, teachers' readiness appears higher than students' needs, particularly in terms of caring and empathy toward cultural diversity in the classroom.

This condition indicates an orientation gap between teachers and students: teachers tend

to emphasize the social and affective dimensions of learning, while students show a higher need for the contextual and relevant use of technology in their cultural reality. This finding aligns with the research results of Macann & Yadav (2023), which confirm that integrating technology without cultural meaning tends to limit student engagement and the formation of learning identity. In line with this, Chuang et al. (2020) also highlighted the importance of developing learning designs that not only emphasize technological aspects but also reflectively connect digital experiences with students' socio-cultural contexts. Therefore, teachers need to be facilitated to integrate technology meaningfully through a pedagogical approach grounded in the values of cultural responsiveness.

B. Development of a Conceptual Design for Integrating TPACK and CRT

The findings regarding student needs and teacher readiness indicate the potential for developing innovative and contextual learning designs. Students' need for technology and cultural integration is supported by teachers' readiness in pedagogical and content aspects, although further strengthening is needed in the technology and cultural sensitivity dimensions. This result serves as an empirical basis for developing a TPACK-CRT-based conceptual framework for learning in the next phase.

Based on the identification of student needs and teacher readiness in TPACK learning related to technology integration, pedagogy, and/or CRT related to cultural context, this research develops a conceptual design framework that integrates TPACK-CRT. This framework was developed based on the conceptual framework analysis stages by Jabareen (2009). The results of the TPACK-CRT learning conceptual design framework development procedure broadly include: (1) a comprehensive description of TPACK and CRT theory as a conceptual basis, (2) a map of the relationships and conceptual intersections of TPACK-CRT highlighting integration potential, (3) TPACK-CRT integrative principles, and (4) the TPACK-CRT learning design conceptual framework. The detailed results of the development stages can be seen in Figure 3

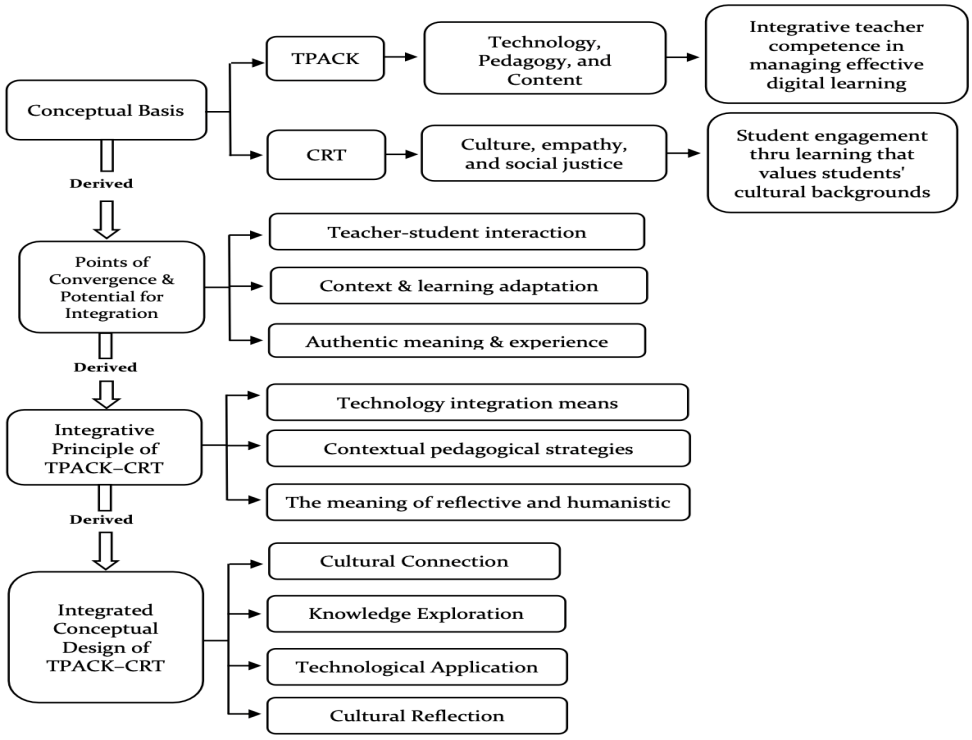

Figure 3 Output derived from the procedure of developing the conceptual design framework of TPACK–CRT-based learning.

The development of the TPACK–CRT conceptual design is based on two main frameworks: Technological Pedagogical Content Knowledge (TPACK) and Culturally Responsive Teaching (CRT). TPACK emphasizes teachers' integrative competence in connecting technology, pedagogy, and content to make digital learning effective and meaningful (Mishra, 2019; Mishra & Koehler, 2006). Meanwhile, CRT focuses on cultural relevance, empathy, and social justice by placing students' cultures at the center of learning to make it more inclusive and contextual (Gay, 2018; Ladson-Billings, 1995). Both complement each other; TPACK strengthens the technological and pedagogical aspects, while CRT adds cultural and humanistic dimensions. Therefore, integrating the two has the potential to produce digital learning that is effective, reflective, and relevant to students' life contexts.

After synthesizing TPACK and CRT theories to understand their respective characteristics and contributions, the next step is to analyze their points of convergence and potential for integration in the context of basic learning. First, this analysis highlights that Pedagogical Knowledge within TPACK has a strong overlap with CRT principles in the aspect of empathetic teacher–student interaction that values cultural diversity, aligning with the views of Gay (2018) and Hammond (2015), who emphasize that a positive relationship between teachers and students is the main foundation for culturally responsive learning. Second, Content Knowledge relates to efforts of contextualizing and adapting learning, in which instructional materials are developed to be relevant to students' experiences, values, and cultural identities, as suggested by Ladson-Billings (1995), that cultural relevance in content strengthens the meaning of learning and increases students' sense of belonging to knowledge. Third, Technological Knowledge supports the formation of authentic meaning and experiences through the use of digital technology as a medium for expressing cultural identity and facilitating cross-context collaboration, as stated by Cheng et al. (2021) and Macann & Yadav (2023) that technology can function as a space for cultural representation and self-reflection when consciously integrated into learning. Thus, these three areas teacher-student interaction, learning context and adaptation, and authentic meaning and experience become a conceptual meeting point that strengthens the foundation for the integration of TPACK-CRT in the next stage.

The synthesis from the previous stage identified three intersection areas between TPACK and CRT. These areas teacher–student interaction, learning context and adaptation, and authentic meaning and experience were then developed into three integrative principles for the conceptual design of TPACK-CRT-based learning. First, technology integration means the purposeful use of digital tools to support learning that values students' cultural backgrounds and promotes meaningful interaction between teachers and students. This finding aligns with Ladson-Billings (1995) and Gay (2018), who emphasize that social relationships based on empathy and respect for cultural identity are at the core of culturally responsive pedagogy. Second, contextual pedagogical strategies refer to adapting learning content, methods, and technology to align with students' local cultural contexts, languages, and lived experiences. This is reinforced by Cheng et al. (2021), who highlight the importance of designing technology-based learning that considers the socio-cultural context to be more meaningful. Third, the meaning of reflective and humanistic highlights the importance of designing learning experiences that are authentic, reflective, and connected to students' cultural identities. This view is supported by Macann & Yadav (2023), who assert that technology in learning should expand the meaning and expression of culture, not merely be an instructional aid. Overall, these three principles are intertwined and form the TPACK-CRT conceptual framework, which emphasizes the integration of technology, pedagogy, content, and cultural relevance as the foundation for 21st-century learning.

Based on the integrative principles identified in the previous stage, a four-phase integrated conceptual design of TPACK–CRT-based learning was developed. These phases operationalize the principles of meaningful technology integration, contextual pedagogical strategies, and reflective–humanistic learning into a coherent learning framework. The first phase, Cultural Connection, is grounded in the integrative principle of contextual pedagogical strategies, which empha-

size the importance of recognizing students' social and cultural backgrounds as the foundation of learning. This aligns with the findings of Banner (2016) and Semião et al. (2023), which emphasize that understanding students' socio-cultural backgrounds is the starting point for fair and meaningful learning. The second phase, Knowledge Exploration, reflects the principle of meaningful technology integration, wherein learning activities guide students to explore academic concepts while connecting them to culturally relevant content. This is supported by research by (Eppard et al., 2021), which found that integrating culturally relevant technology increases student engagement and strengthens personal connections to the subject matter.

The third phase, Technological Application, emerges from the integration of contextual pedagogical strategies with technological knowledge, emphasizing the use of technology as a tool for constructing and expressing culturally grounded understanding. Empirical evidence suggests that engaging students in cross-cultural digital collaboration fosters deeper empathy, stimulates creative problem-solving, and strengthens global competence within virtual learning contexts (Deng et al., 2021; Fischer, 2024; Hackett et al., 2023). The fourth phase, Cultural Reflection, is rooted in the principle of reflective and humanistic learning, highlighting the importance of examining values, cultural awareness, and personal meaning at the end of the learning cycle. Consistent with the findings of Alsaleh (2024) reflecting on technology and culture-based learning experiences helps students build self-awareness and internalize humanistic values within a digital context. Thus, these four phases form a systematic framework for integrating technology, pedagogy, content, and cultural context into elementary school learning practices. This finding is supported by previous research that developed technology-based ethnomathematics media, showing that integrating cultural contexts and digital innovation can increase the relevance of learning and encourage student engagement in understanding academic concepts meaningfully (Rachman et al., 2025; Rachman et al., 2025; Rachman et al., 2025).

This research has several constraints and limitations. Theoretical studies still dominate the synthesis conducted, and the empirical data used come from a limited number of subjects, so the findings cannot yet be widely generalized. However, these limitations are minimized through in-depth analysis and theoretical triangulation to ensure conceptual consistency. Additionally, the still conceptual integration of TPACK and CRT presents its own challenges. Still, the results provide constructive direction for the development of implementable models, such as teacher training modules or TPACK–CRT-based learning materials.

Theoretically, this research contributes to strengthening a learning framework that synergistically integrates technology, pedagogy, content, and cultural responsiveness. From a practical standpoint, the research findings guide teachers in designing adaptive, inclusive, and meaningful learning that aligns with students' cultural contexts. Meanwhile, methodologically, this research demonstrates the advantages of combining empirical and conceptual approaches as a strategy for developing learning designs relevant to the needs of 21st-century education.

CONCLUSION

This research achieved two main objectives. First, the results of the empirical analysis indicate a gap but also potential synergy between students' needs and teachers' readiness in implementing TPACK-CRT, where students demand more contextual use of technology while teachers are more pedagogically and affectively prepared. Second, this research formulates a TPACK-CRT-based conceptual learning design that includes four main phases contextual orientation, meaningful technology integration, cultural interaction and collaboration, and reflection and humanistic relevance—as a systematic guide in realizing integrative, inclusive, and meaning-oriented learning.

Further research is suggested to expand the number and variety of subjects to make the empirical results more representative, and to test the effectiveness of the TPACK-CRT conceptual design through real-world implementation in the classroom. Additionally, the development of a

mentoring model for teachers needs to be undertaken to ensure the consistent and contextual application of the principles of technology integration and cultural responsiveness, in accordance with the needs of elementary schools.

REFERENCES

Abacioglu, C. S., Volman, M., & Fischer, A. H. (2020). Teachers' multicultural attitudes and perspective taking abilities as factors in culturally responsive teaching. *British Journal of Educational Psychology,* 90(3), 736–752. https://doi.org/10.1111/bjep.12328

Alkubaisi, M. (2025). Exploring teachers' perceptions of integrating artificial intelligence (AI) in STEM education using the TPACK framework: an exploratory case study. *Discover Artificial Intelligence,* 5(1), 266. https://doi.org/10.1007/s44163-025-00522-3

Alsaleh, A. (2024). The impact of technological advancement on culture and society. *Scientific Reports,* 14(1), 32140. https://doi.org/10.1038/s41598-024-83995-z

Arikunto, S. (2014). *Prosedur Penelitian Suatu Pendekatan Praktik*. Rineka Cipta. https://cir.nii.ac.jp/crid/1130000795354347648

Banner, I. (2016). Valuing difference in students' culture and experience in school science lessons. *Cultural Studies of Science Education*, 11(4), 1071–1079. https://doi.org/10.1007/s11422-016-9729-5

Calibara, F. C. (2025). Exploring the impact of culturally responsive teaching: Enhancing equity, engagement, and social-emotional development in diverse educational settings. *International Journal of Scientific Research and Engineering Development*, 8(2), 352–358. https://www.ijsred.com/volume8/issue2/IJSRED-V8I2P36.pdf

Çam, Ş. S., & Koç, G. (2024). Professional Development Program to Develop Teacher Educators' Technological Pedagogical Content Knowledge. *SAGE Open*, 14(2). https://doi.org/10.1177/21582440241242841

Candra, G. E., & Wahzudik, N. (2024). Teachers' interpretation of the Merdeka curriculum as a policy innovation: A phenomenological exploration. *Indonesian Journal of Curriculum and Educational Technology Studies*, 12(1). https://doi.org/10.15294/ijcets.v12i1.16283

Cheng, M.-M., Lacaste, A. V, Saranza, C., & Chuang, H.-H. (2021). Culturally Responsive Teaching in Technology-Supported Learning Environments in Marine Education for Sustainable Development. *Sustainability,* 13(24), 13922. https://doi.org/10.3390/su132413922

Chuang, H., Shih, C., & Cheng, M. (2020). Teachers' perceptions of culturally responsive teaching in technology-supported learning environments. *British Journal of Educational Technology*, 51(6), 2442–2460. https://doi.org/10.1111/bjet.12921

Deng, L., Shen, Y. W., & Chan, J. W. W. (2021). Supporting cross-cultural pedagogy with online tools: Pedagogical design and student perceptions. *TechTrends*, 65(5), 760–770. https://doi.org/10.1007/s11528-021-00633-5

Eppard, J., Kaviani, A., Bowles, M., & Johnson, J. (2021). EdTech Culturation: Integrating A Culturally Relevant Pedagogy into Educational Technology. Electronic Journal of E-Learning, 19(6), pp516-530. https://doi.org/10.34190/ejel.19.6.2065

Filina, N. Z., Sari, S. M., & Zahraini, Z. (2024). The utilization of Technological Pedagogical Content Knowledge (TPACK) in elementary school learning. International Journal of Business, Law, and Education, 5(1), 260–266. https://doi.org/10.56442/ijble.v5i1.371

Fischer, L. (2024). Cross-cultural perspectives on online collaborative learning in Germany. International Journal of Online and Distance Learning, 5(1), 49–59. https://doi.org/10.47604/ijodl.2439

Galenzoga, K. (2025). Culturally responsive teaching: A view on classroom pedagogy. https://doi.org/10.5281/ZENODO.15765263

Gay, G. (2010). *Culturally Responsive Teaching: Theory, Research, and Practice*. Teachers College Press.

Gay, G. (2018). *Culturally Responsive Teaching: Theory, Research, and Practice*. Teachers College Press.

Hackett, S., Janssen, J., Beach, P., Perreault, M., Beelen, J., & van Tartwijk, J. (2023). The effectiveness of Collaborative Online International Learning (COIL) on intercultural competence development in higher education. *Int. J. Educ. Technol. High. Educ.*, 20(1), 5. https://doi.org/10.1186/s41239-022-00373-3

Haga, S. (2024). From knowledge to inclusion: Culturally responsive TPACK (TPACCK). *Res. Pract. Technol. Enhanc. Learn.*, 20, 3. https://doi.org/10.58459/rptel.2025.20003

Hammond, Z. L. (2015). *Culturally responsive teaching and the brain*. Corwin Press. https://us.corwin.com/books/cultural-responsv-teaching-brain-241754

Harahap, Y. S., Siregar, N., & Amin, T. S. (2024). Integrasi Culturally Responsive Teaching dalam Pembelajaran Bahasa Inggris berbasis T-PACK. *Joe*, 6(4), 21541–21547. https://doi.org/10.31004/joe.v6i4.6141

Jabareen, Y. (2009). Building a conceptual framework: Philosophy, definitions, and procedure. *Int. J. Qual. Methods,* 8(4), 49–62. https://doi.org/10.1177/160940690900800406

Jiménez Sierra, Á. A., Ortega Iglesias, J. M., Cabero-Almenara, J., & Palacios-Rodríguez, A. (2023). Development of the teacher's technological pedagogical content knowledge (TPACK) from the Lesson Study: A systematic review. *Front. Educ.*, 8(1078913). https://doi.org/10.3389/feduc.2023.1078913

Kibirige, I. (2023). Primary teachers' challenges in implementing ICT in science, technology, engineering, and mathematics (STEM) in the post-pandemic era in Uganda. *Educ. Sci. (Basel)*, 13(4), 382. https://doi.org/10.3390/educsci13040382

Koehler, M. J., Mishra, P., & Cain, W. (2013). What is technological pedagogical content knowledge (TPACK)? *Journal of Education*, 193(3), 13–19. https://doi.org/10.1177/002205741319300303

Ladson-Billings, G. (1995). Toward a theory of culturally relevant pedagogy. *Am. Educ. Res. J.*, 32(3), 465–491. https://doi.org/10.3102/00028312032003465

Macann, V., & Yadav, A. (2023). Culturally responsive-sustaining computational thinking: Enactment in elementary classrooms. *J. Comput. Sci. Integr.*, 6(1), 7. https://doi.org/10.26716/jcsi.2023.12.22.51

Mishra, P. (2019). Considering contextual knowledge: The TPACK diagram gets an upgrade. *J. Digit. Learn. Teach. Educ.*, 35(2), 76–78. https://doi.org/10.1080/21532974.2019.1588611

Mishra, P., & Koehler, M. J. (2006). Technological Pedagogical Content Knowledge: A framework for teacher knowledge. *Teach. Coll. Rec.*, 108(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

Mu, S. (2023). Research on the integration of information technology and primary teaching in the digital age. *Journal of Education, Humanities and Social Sciences*, 13, 74–79. https://doi.org/10.54097/ehss.v13i.7857

Niman, E. M. (2025). Embedding local culture in social studies: pathways to strengthen social-emotional learning in primary education. *Front. Educ.*, 10(1655528). https://doi.org/10.3389/feduc.2025.1655528

Ogodo, J. A. (2024). Culturally responsive pedagogical knowledge: An integrative teacher knowledge base for diversified STEM classrooms. *Educ. Sci. (Basel)*, 14(2), 124. https://doi.org/10.3390/educsci14020124

Okta, S. L., & Putra, D. (2025). Adaptation of independent learning curriculum by elementary school teachers: Case study in the Indonesia–Malaysia border region. *Ijeer*, 5(2), 65–70. https://doi.org/10.46336/ijeer.v5i2.936

Pappa, C. I., Georgiou, D., & Pittich, D. (2024). Technology education in primary schools: addressing teachers' perceptions, perceived barriers, and needs. *Int. J. Technol. Des. Educ.*, 34(2), 485–503. https://doi.org/10.1007/s10798-023-09828-8

Rachman, K., Mas'ud, A. I., Vesya, S. R., Arbiyanti, A. P., & Rasyid, I. (2025). Development of Digital Puzzle Based on Indonesian Traditional Houses as Virtual Manipulative Learning Media for Plane Geometry. *Unnes Journal of Mathematics Education*, 14(2), 167–178. https://doi.org/10.15294/ujme.v14i2.29951

Rachman, K., Pangestika, C., Vesya, S. R., & Arbiyanti, A. P. (2025). Development of Android-based applications integrated with Tari Piring culture as ethnomathematics learning media for elementary school students. U*nion: Jurnal Ilmiah Pendidikan Matematika*, 13(1), 200–212. https://doi.org/10.30738/union.v13i1.19217

Rachman, K., Rasyid, I., Arbiyanti, A. P., & Vesya, S. R. (2025). Integration of Kaliurang Local Culture into Augmented Reality for Spatial Geometry Learning Media Development. *SAKAGURU: Journal of Pedagogy and Creative Teacher*, 2(1). https://doi.org/10.70211/sakaguru.v2i1.203

Rentzi, A. (2024). Social justice in education: Creating an inclusive culture at schools through critical multicultural theory. *European Journal of Education and Pedagogy*, 5(1), 94–97. https://doi.org/10.24018/ejedu.2024.5.1.802

Samuels, A. J. (2025). Exploring culturally responsive pedagogy: Teachers' perspectives on fostering equitable and inclusive classrooms. https://files.eric.ed.gov/fulltext/EJ1166706.pdf

Schmid, R., Pauli, C., Stebler, R., Reusser, K., & Petko, D. (2022). Implementation of technology-supported

personalized learning—its impact on instructional quality. *J. Educ. Res.*, 115(3), 187–198. https://doi.org/10.1080/00220671.2022.2089086

Semião, D., Mogarro, M. J., Pinto, F. B., Martins, M. J. D., Santos, N., Sousa, O., Marchão, A., Freire, I. P., Lord, L., & Tinoca, L. (2023). Teachers' Perspectives on Students' Cultural Diversity: A Systematic Literature Review. *Education Sciences,* 13(12), 1215. https://doi.org/10.3390/educsci13121215

Shulman, L. S. (1986). Those who understand: Knowledge growth in teaching. *Educ. Res.*, 15(2), 4–14. https://doi.org/10.3102/0013189x015002004

Ulbricht, J., Schachner, M. K., Civitillo, S., & Juang, L. (2024). Fostering culturally responsive teaching through the identity project intervention: A qualitative quasi-experiment with pre-service teachers. Identity (Mahwah, N.J.), 1–24. https://doi.org/10.1080/15283488.2024.2361890

Wiklund-Engblom, A., Bergström, P., & Lindfors, M. (2025). Exploring Teaching Practices in an Innovative Learning Environment: A Pragmatic View on the Student-Centred Ideal in Future Classrooms. *Postdigital Science and Education*, 1–21.

Yue, M., Jong, M. S.-Y., & Ng, D. T. K. (2024). Understanding K–12 teachers' technological pedagogical content knowledge readiness and attitudes toward artificial intelligence education. *Educ. Inf. Technol.*, 29(15), 19505–19536. https://doi.org/10.1007/s10639-024-12621-2