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Integrating the culturo-techno-contextual approach into science teacher education: Microteaching practices on socioscientific issues

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ABSTRACT

The Culturo-Techno-Contextual Approach (CTCA) offers an innovative model in science education by integrating cultural heritage, technology mediation, and local context. This study aims to examine the processes through which pre-service science teachers (PSTs) integrate CTCA into the teaching of socioscientific issues (SSIs) and their microteaching practices during this process. The study was designed as a case study, and the data collection tools consisted of the CTCA-based lesson plans, microteaching video recordings, and PSTs' views on lesson plan preparation and practices. The results of the study revealed that the PSTs prepared strong lesson plans in terms of local context and technology use. They demonstrated strong performance in the dimensions of technology use and digital summary message delivery in microteaching. The results indicate that CTCA offers an effective framework for teaching SSIs in science teacher education; however, skills related to developing cultural context, conceptual clarification, and discussion management need to be supported.

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Introduction

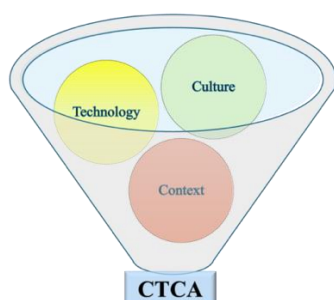
The rapid changes, dilemmas, and complex global challenges in contemporary society necessitate that individuals possess 21st-century skills, such as collaboration, communication, and particularly critical thinking (Adam et al., 2026). In addition to critical thinking skills, recent research has emphasised the necessity of 21st-century competencies, including problem-solving, information literacy, and digital literacy, alongside the continuously evolving requirement for digital competence (Silber-Varod et al., 2019). Globally, the disconnect between scientific content and real-world context in science education affects students' academic achievement and critical thinking skills (Adam et al., 2025). To address these challenges and integrate students' daily lives, cultural heritage, and technological competencies into science education, Okebukola introduced the Culturo-Techno-Contextual Approach (CTCA) in 2015 (Okebukola, 2020).

Culturo-Techno-Contextual Approach: Components and Implementation Steps

The CTCA fuses three core pillars: the culture in which students are immersed, the technology with which teachers and students increasingly interact, and the local context that reflects the unique identity of each educational institution (Okebukola, 2020; Figure 1).

Figure 1

Components of the culturo-techno-contextual approach



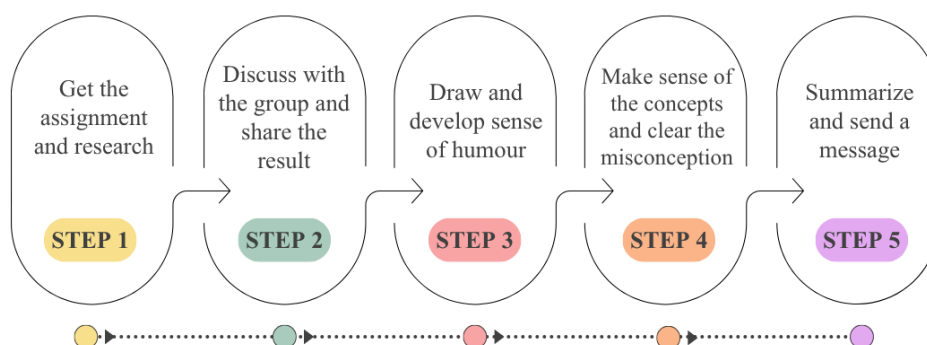
Note. Okebukola, 2020

The CTCA is grounded in Kwame Nkrumah's ethnophilosophy for the cultural component, Martin Heidegger's technophilosophy for technology, and Michael Williams' contextualism for the context (Onowugbeda et al., 2024b). The cultural component represents the indigenous knowledge inherent to individuals. Here, indigenous knowledge refers to how individuals acquire understanding of the world order and evaluate how to use this knowledge to enhance their quality of life. With the emergence of the COVID-19 pandemic, technology-integrated courses have gained prominence across all educational levels, from primary school to university (Crompton et al., 2021; Ives, 2021). The technology component has emerged from the increasing prevalence of technology-enhanced interactive lessons that prioritize such integration in science education (Ademola et al., 2022). Meanwhile, the context component provides a framework that allows for the consideration of the specific circumstances and conditions in which individuals are situated.

In the implementation of CTCA, two types of interaction from Vygotsky's social constructivism theory feature prominently: acquiring knowledge about local/cultural practices related to the concept at hand and facilitating group interaction with peers. Building upon these two core interactions, Okebukola (2020) proposed a five-step implementation process for CTCA within the classroom environment (Figure 2).

Figure 2

The diagram of implementation steps of CTCA



Note. Okebukola, 2020

In the first step of this process, a pre-class assignment is given regarding local practices related to the subject matter and resources accessible via the internet. In the second step, group work is conducted based on the assignment from the first step, and students are encouraged to present their findings. In the third step, the lesson progresses by having students draw examples related to the topic from their immediate environment (context) and incorporating a humorous perspective (e.g., cartoons). The fourth step encompasses cultural practices and web resources shared within the classroom. In the final step, a concise summary of the content is sent to the students through online channels.

Grounded in theoretical foundations such as Vygotsky's social constructivist theory and Ausubel's meaningful learning theory, the CTCA is well suited to teaching socioscientific issues (SSIs) that are particularly controversial and involve social dimensions (Tekin & Aslan, 2025). The imperative for technology integration, particularly in the aftermath of the COVID-19 pandemic and the February 2023 Kahramanmaraş earthquakes in Türkiye, has further underscored the significance of CTCA's technological component in science courses. Furthermore, in Türkiye, a nation with a multicultural structure characterised by diverse demographic and cultural traits across seven distinct geographical regions, this approach, grounded in local knowledge and cultural practices, holds substantial potential for fostering diversity in science education.

To illustrate, a topic such as biodiversity carries markedly different local/cultural characteristics depending on the region in which it is taught: in one locality, this might involve traditional ecological practices or culturally significant endemic species, while in another, it might draw on region-specific agricultural or fishing practices tied to local biodiversity. The technological characteristics of the same topic might, in turn, involve the use of citizen-science mobile applications for species identification or region-specific biodiversity-monitoring platforms. A particularly illustrative case from the region in which the present study was conducted is Tuz Gölü (Salt Lake) in Aksaray, a nationally significant saline lake and protected wetland whose shrinking water levels have become a pressing local socioscientific concern. Its local/cultural dimension encompasses the region's long-standing salt-harvesting tradition, the lake's role in regional tourism, and its ecological significance as a breeding ground for flamingos, while its technological dimension can be approached through satellite-based remote sensing and geographic information system (GIS) mapping used to monitor the lake's shrinkage over time. This context-sensitive, technology-integrated structure is what allows CTCA to be adapted flexibly across topics and regions, a flexibility further elaborated in the Procedure section.

An Integrated Theoretical Framework

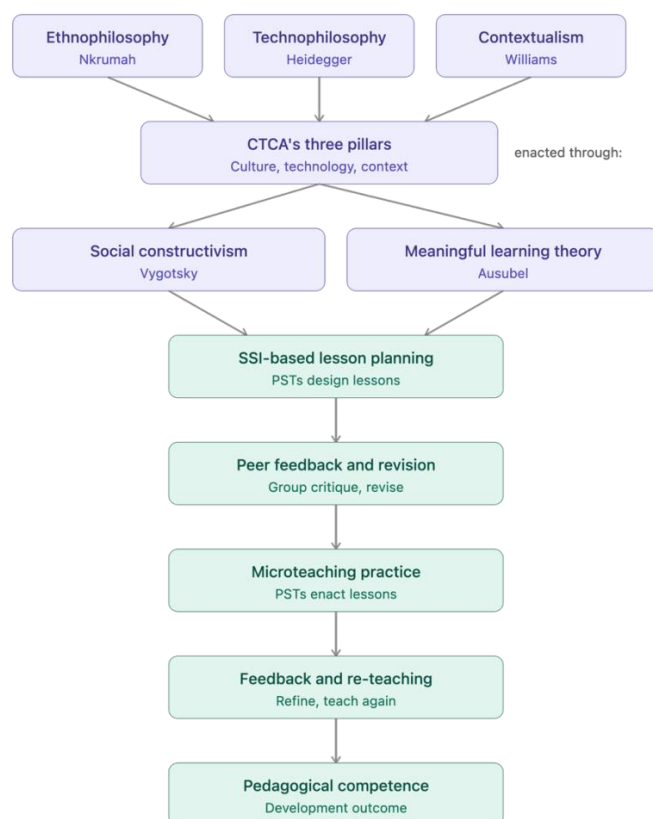
CTCA draws on five perspectives (ethnophilosophy, technophilosophy, contextualism, social constructivism, and meaningful learning theory), which converge into a coherent rationale operating at two levels. First, ethnophilosophy, technophilosophy, and contextualism justify why culture, technology, and context belong together as one structure rather than separate add-ons, each addressing a condition of science learning (indigenous knowledge, technological mediation, local relevance) that alone would leave the others unaddressed. Second, social constructivism and meaningful learning theory explain how learning proceeds once these pillars are enacted: the former through interaction, acquiring local knowledge and peer collaboration, the latter through grounding instruction in learners' existing cultural and technological frames, producing more durable understanding (Ausubel, 1968). The first level thus establishes what CTCA integrates and why; the second, how that integration becomes learning, and it is this process-oriented level that most directly grounds CTCA's suitability for SSIs, which, being controversial and inherently social, are learned through the same socially mediated processes CTCA structures.

Just as CTCA structures student learning around social interaction and meaningful content, the process examined here structures PSTs' own professional learning similarly: they construct understanding through group-based lesson planning, act on peer and instructor feedback, and refine

practice through microteaching and reteaching, a cycle that is itself socially constructed and meaningful in Vygotskian and Ausubelian terms, now applied to pedagogical rather than content knowledge. This reflexive extension connects CTCA's theoretical foundations to the practice-based, socially mediated account of teacher learning developed below (Grossman et al., 2009; Lave & Wenger, 1991; Shulman, 1987), summarised as the conceptual pathway in Figure 3.

Figure 3

An integrated theoretical framework linking CTCA's philosophical and learning-theoretical foundations



This diagram clarifies the study's logic at every stage: the philosophical pillars justify CTCA's content structure, the learning theories explain how that structure produces understanding, and this mechanism, reapplied to PSTs' own planning and teaching cycle, explains how CTCA is expected to develop their pedagogical competence, the study's outcome of interest. The following section situates CTCA relative to other instructional frameworks in science teacher education.

Situating CTCA within Related Instructional Frameworks

CTCA's structure invites comparison with other frameworks in science teacher education, clarifying both its overlaps and its distinctiveness. Its cultural pillar shares affinities with Culturally Responsive Teaching (CRT), which similarly centres on students' cultural backgrounds as pedagogical resources (Gay, 2010; Ladson-Billings, 1995); unlike CRT, however, CTCA treats culture as one of three interdependent components coordinated with technology and context within a specified sequence of steps. A similar relationship holds with place-based education, which grounds learning in the ecological, social, and historical particulars of students' local environment (Smith, 2002); CTCA's

context pillar overlaps with this orientation, but place-based education specifies neither a structured technology role nor a stepwise sequence. CTCA's technology pillar resonates with Technological Pedagogical Content Knowledge (TPACK), which theorises integrating technology with pedagogy and content (Mishra & Koehler, 2006); whereas TPACK offers a general account of what teachers need to know, CTCA offers a more prescriptive, step-based procedure within a specific cultural and contextual frame.

More broadly, transforming subject matter into a teachable, learner-adapted form, central to Shulman's (1986) construct of Pedagogical Content Knowledge (PCK) and to the pedagogical reasoning discussed below, is precisely the task CTCA structures for PSTs designing lessons around locally and technologically situated SSI content. CTCA also shares features with Inquiry-Based Science Education, particularly its emphasis on investigation and evidence-based reasoning (Minner et al., 2010), but differs in anchoring inquiry in local/cultural material and technology from the outset, rather than treating context as incidental. In relation to SSI pedagogy, the broader field within which this study is situated, CTCA functions less as a competing framework than as a structured instructional vehicle: where SSI pedagogy establishes why controversial issues merit dedicated attention, CTCA offers one systematic answer to how they might be planned and taught, treating local and technological relevance as integral. CTCA thus does not replace these frameworks so much as recombine elements of each —culture, technology, and context— into a single, sequenced structure whose distinctiveness lies in this integration and whose implementation by prospective teachers has not previously been examined within CTCA research or these adjacent literatures.

Rationale and Aim of the Present Study

Recent studies have indicated that CTCA significantly enhances academic achievement, critical thinking, and knowledge retention across science education (Adam et al., 2025; Adam et al., 2026; Olusegun et al., 2024; Onowugbeda et al., 2024a), with positive effects reported across diverse content areas, including genetics (Adebayo et al., 2022), nutrition and metabolism (Adam et al., 2025), ecology (Ademola et al., 2022), and STEM more broadly (Oladejo et al., 2025). Together, this work shows a consistent pattern: positive effects appear robust across content domains, suggesting CTCA's benefits are not narrowly topic dependent. At the same time, this literature shares a methodological limitation: each study evaluates CTCA as a fixed treatment, designed and delivered by a researcher or teacher and assessed through its effects on students, with implementation itself held constant rather than examined. Consequently, this literature offers limited insight into how PSTs interpret CTCA's implementation steps, what decisions they make when translating its cultural and technological components into a lesson, and where they encounter difficulty. Although CTCA is relatively recent, research on its adaptation for teaching SSIs has gained momentum, emphasising the need to conceptualise its implementation steps and developing concrete examples. In Türkiye, this approach was first addressed by Tekin and Aslan (2025), who used artificial intelligence to exemplify SSIs and detailed CTCA's implementation steps, though again through a researcher-constructed example rather than one designed by prospective teachers themselves.

This gap is consequential given the instructional role SSI-based materials already play in science classrooms. Teachers frequently use such materials to engage students in discussion and decision-making around controversial scientific issues (Kokolaki & Stavrou, 2023), such discussions are typically structured around risk-benefit analysis (Schenk et al., 2021), ethical reflection (Nadlir et al., 2025), and multiple perspectives (Kristensen & Knain, 2024). Because CTCA lesson planning is inherently linked to these same concerns, it may serve as a novel example of how pre-service teachers develop and implement SSI-based materials, provided the planning process itself, not only its rationale, is examined. This is consistent with the teacher education literature, which treats lesson planning as a core professional competence (Zaragoza et al., 2023) and high-quality lesson plans as foundational to high-quality instruction (Großmann & Krüger, 2024). Engaging with CTCA holistically, its planning and implementation dimensions alike, therefore stands to contribute

significantly to pre-service teachers' professional development, and to the design and implementation of SSI-based lesson plans within the CTCA framework as a means of fostering a high-quality learning environment in terms of cultural sensitivity, technology integration and pedagogical design skills (Okebukola, 2020).

This shift, from CTCA's effects on student learning to a professional competency developed during teacher preparation, is a change in the theoretical object, not merely of population. Investigating CTCA with students addresses instructional effectiveness: does the approach improve outcomes for those who receive it? Investigating it with pre-service teachers addresses a different question, one of pedagogical reasoning and professional formation (Shulman, 1987). Where a student encounters CTCA as a finished product, a PST must first comprehend its theoretical commitments — Nkrumah's ethnophilosophy, Heidegger's philosophy of technology, Williams' contextualism — and transform the approach into a coherent, teachable design, a task Shulman (1987) calls pedagogical reasoning: transforming subject matter into forms pedagogically powerful and adapted to learners. This cannot be inferred from studies of CTCA's effects on students, however positive, since it concerns a distinct capacity: designing for CTCA rather than merely learning through it.

This distinction also carries methodological consequences that separate the present study from prior CTCA research. The iterative structure adopted here, in which PSTs plan, receive peer feedback, revise, microteach, and are given the chance to reteach, reflects a practice-based approach to teacher preparation in which core practices are rehearsed and refined under supervision before independent enactment (Grossman et al., 2009), with no analogue in single-session, researcher-delivered CTCA interventions. Moreover, because PSTs are simultaneously being socialised into the professional identity of a science teacher, their engagement with CTCA is bound up with a trajectory of increasing participation in teaching practice itself (Lave & Wenger, 1991), rather than a one-off encounter with a novel method. Findings on how PSTs plan and enact CTCA-based lessons therefore cannot be assumed to mirror findings on how school students respond to CTCA instruction; the two literatures address related but theoretically distinct phenomena. In this respect, the study is the first to jointly examine PSTs' performance and perspectives in planning and microteaching SSI-content lessons based on the CTCA, thereby highlighting the reflections of this approach within the teacher education context. In line with this aim, the study addressed the following research questions:

- What is PSTs' performance in preparing CTCA-based lesson plans?
- What are PSTs' perspectives on planning CTCA-based lessons?
- What is PSTs' performance in integrating CTCA into microteaching practices?
- What are the perspectives of PSTs on microteaching CTCA-based lesson plans?

Method

Design

This study employs a qualitative case study design to explore PSTs' perspectives on their microteaching within the framework of a CTCA to SSIs. Case study methodology is defined as a research approach that facilitates an intensive investigation of an uncontrollable phenomenon, specifically addressing the “how” and “why” questions (Yıldırım & Şimşek, 2021). The study was conducted in three main stages: informing participants about the CTCA, preparing CTCA-based lesson plans, and microteaching. These stages enabled the process to progress within its natural setting and allowed PSTs' perspectives regarding lesson planning and microteaching to be directly reflected in the study. Since the CTCA is still a relatively new approach, this design was chosen to provide a clearer understanding of its implementation process in the literature.

Participants

The study was conducted with the participation of 34 PSTs (26 female, 8 male) enrolled in the third year of the Science Teacher Education Program at a university located in central Türkiye. The participants consisted of students enrolled in a one academic semester course taught by the researcher. To enable possible classroom observations, participants were selected using a convenience sampling method. Most of the participants graduated from public high schools and came from middle- to lower-middle socioeconomic backgrounds. Participation in the study was entirely voluntary. During the lesson planning and microteaching processes, the PSTs worked in groups of three to four members. Participants were anonymised using codes such as PST1, PST2, and so forth throughout the reporting of the findings.

Data Collection Tools

In this study, lesson plans created by PSTs, microteaching video recordings, and interview form focused on lesson plan and microteaching experiences served as data collection tools. Participants structured their lesson plans following the CTCA steps outlined in Figure 2 (An example lesson plan is provided in the appendix). Following the planning phase, participants performed 10 to 15-minute microteaching sessions aligned with their respective designs. To explore the PSTs' perspectives during lesson planning and microteaching, a semi-structured interview form was developed. This form was designed in alignment with the implementation steps proposed by Okebukola (2020) and was structured into two sections focusing on lesson planning and the microteaching process, respectively. To ensure the validity of the instrument, expert opinions were sought from three faculty members. Two experts specialize in science education, while the third is an expert in the field of educational measurement and evaluation. Reflecting the experts' feedback on the evolving nature of the CTCA, an additional item was incorporated to elicit suggestions for refining the CTCA implementation steps within the lesson preparation process. After this revision, the instrument was re-evaluated by the experts, and the final form was finalized once the experts reached consensus.

Procedure

Ethical approval for this study was obtained from the Aksaray University Ethics Committee (No: 2025-41; Date: 21.01.2025). The research was conducted over a 12-week period during the spring semester of the 2024-2025 academic year, within the scope of a course taught by the researcher. During the first week, information was provided regarding the course content, weekly syllabus, the working procedures for the PSTs, and the academic resources available for their use. In the second week, PSTs were informed about critical considerations for selecting topics within the framework of the CTCA, specifically focusing on local relevance and technological integration. Based on these criteria, they selected topics from the science curriculum (Ministry of National Education [MoNE], 2024) and established work plans in groups of three to four. The topics (SSIs) and learning outcomes determined by each group are presented in Table 1.

Table 1

SSIs and learning outcomes determined by PSTs

Groups and PSTs	Topic (SSIs)	Grade	Learning outcomes
G1 (PST1-PST3)	Cardiovascular health	7	FB.7.3.2.3. Gathering information on what needs to be done to maintain a healthy cardiovascular system
G2 (PST4-PST6)	Biodiversity	6	FB.6.7.1.1 Being able to question the importance of biodiversity for wildlife
G3 (PST7-PST9)	Acidic and basic materials	8	FB.8.5.4.3. The ability to use inferential reasoning based on the 'pH' values relating to the acidity and basicity of substances

G4 (PST10-PST12)	Climate change	8	FB.8.1.2.1. The ability to compare climate and weather events
G5 (PST13-PST15)	Biodiversity	6	FB.6.7.1.1 Being able to question the importance of biodiversity for wildlife
G6 (PST16-PST17)	Household waste and recycling	5	FB.5.7.1.1. The ability to classify recyclable and non-recyclable materials in household waste
G7 (PST18-PST21)	Efficient use of resources	7	FB.7.7.2.1 The ability to question the importance of using resources efficiently
G8 (PST22-PST24)	Environmental concerns	6	FB.6.7.2.2. The ability to solve problems relating to the environment in their immediate surroundings or within the country
G9 (PST25-PST28)	Environmental adaptation	8	FB.8.3.4.2. The ability to draw scientific conclusions regarding the adaptation of living organisms to their environment
G10 (PST29-PST31)	Biodiversity	6	FB.6.7.1.2. The ability to predict factors threatening biodiversity based on research data
G11 (PST32-PST34)	Biodiversity	6	FB.6.7.1.2. The ability to predict factors threatening biodiversity based on research data

The notation 'FB.6.7.1.2' specifies the grade level, unit, and topic of the learning outcome.

In the third week, the local/cultural and technological characteristics of the topics selected by the groups were identified. During this phase, an in-class brainstorming session was conducted in which classmates provided insights into the local features of their respective regions related to the chosen topics. In the same week, each group shared their assignment prompts designed for the first step of the CTCA (Step 1: Get the assignment and research). During the fourth and fifth weeks, the PSTs prepared lesson plans based on the CTCA, considering the critical considerations and suggestions provided by their peers. In the sixth week, these lesson plans were reviewed by other groups. During this stage, feedback regarding the alignment of the learning outcomes with the nature of the CTCA, the correct implementation of the CTCA steps, and the aspects of the lesson plans requiring improvement was presented to the respective groups. In the seventh week, each group updated their lesson plans in accordance with the suggestions provided and shared the final versions with the researcher. Additionally, during this week, the PSTs shared their views on the lesson plan preparation process with the researcher via online platforms. Weeks 8 through 12 encompassed the groups' microteaching processes. Adhering to the previously scheduled dates, three groups conducted microteaching each week, with the final two groups completing their sessions in the last week. During this process, groups performed a 10–15-minute presentation of their lesson plans. These teaching sessions were video recorded. The microteaching videos were subsequently reviewed by the instructor and students to provide feedback. PSTs provided feedback through peer assessment forms. The lesson plans and videos were evaluated using the 'CTCA-Based Lesson Evaluation Rubric' developed by the researcher. Following the feedback, participants were provided with the opportunity to reteach after revising their plans, and the microteaching process was concluded with the last set of feedback (Applebee, 1976; McKnight, 1971). Following the conclusion of the microteaching cycle, participants from each group provided their feedback regarding the process through online platforms. The overall research process is summarized in Figure 4.

Figure 4*12-week research process*

Data Analysis

The 'CTCA-Based Lesson Evaluation Rubric', developed by the researcher, was used to evaluate the PSTs' lesson plans and microteaching videos. This rubric was developed specifically for this study rather than adapted from an existing instrument, drawing on the relevant literature to inform its criteria. Developed based on the relevant literature, this rubric is a four-level analytic rubric consisting of eight criteria in total: three criteria under the section 'Inclusion of the Basic Components of CTCA' and five criteria under the section 'Alignment with the CTCA Implementation Process' (Adam et al., 2026; Okebukola, 2020; Okyere Darko & Ekwam, 2025). The full wording of each criterion, together with its descriptor at each of the four performance levels, is provided in Appendix Table 4. The evaluation levels were structured as 'Successful (4)', 'Acceptable (3)', 'Needs improvement (2)', and 'Insufficient (1)', according to the extent to which the relevant criteria were reflected in the lesson plans and microteaching practices. Since an equal-interval scoring structure was assumed across the rubric levels, an arithmetic interpretation was used in evaluating the scores (Moskal, 2002). Accordingly, the score intervals were calculated using the formula 'score interval coefficient = (highest score – lowest score) / number of levels' (Kan, 2016). Based on this calculation, the mean scores obtained from the rubric were interpreted as follows: 1.00–1.75 = weak relationship with CTCA, 1.76–2.50 = moderate level, 2.51–3.25 = acceptable level of CTCA implementation, and 3.26–4.00 = full alignment with CTCA. To establish content validity, an initial draft of the rubric was reviewed by two faculty members in the field of science education, who provided written and verbal feedback on the clarity and appropriateness of each criterion rather than completing a structured validation form; this feedback led to revisions in the wording of several criteria, after which the researcher and the two experts reached consensus on the final version. The rubric was not piloted with a separate sample prior to the main data collection, a limitation addressed in the Discussion section. The data obtained from the rubric were subjected to descriptive analysis, and the groups' levels of lesson planning and implementation were evaluated based on their mean scores.

The data obtained through the interview form were analysed using content analysis, a qualitative analysis methods. In content analysis, similar units of data are coded and grouped into categories and themes to facilitate interpretation (Yıldırım & Şimşek, 2021). Patton's (2002) inductive content analysis model was applied during the analysis process. Analysis was conducted manually using word-processing and spreadsheet tools. Responses provided by the participants to the open-ended questions were coded at the level of meaning units, through an inductive, line-by-line reading of the transcripts in which codes were generated directly from participants' own expressions rather

than from a predetermined coding scheme; subsequently, conceptually similar codes were grouped into categories, and categories were organized into themes (Elo & Kyngäs, 2008). The resulting themes represented broader patterns across participants' planning and microteaching experiences. The entire analysis process was conducted by the researcher. Additionally, to ensure the reliability of the research data, a faculty member expert in the field of science education accompanied the author during the analysis. In this process, ideas were exchanged with the expert regarding the categorization of PSTs' opinions; disagreements in coding were resolved through discussion between the researcher and the expert until consensus was reached, and necessary revisions were made (Cohen et al., 2007).

For inter-coder reliability, Miles and Huberman's (1994) reliability formula ($\text{reliability} = \frac{\text{agreement}}{\text{agreement} + \text{disagreement}} \times 100$) was used and the inter-coder agreement rate was calculated as 90%. Several additional strategies were employed to strengthen the trustworthiness of the qualitative findings, following Lincoln and Guba's (1985) criteria. Credibility was supported through methodological triangulation, in which the interview findings were examined alongside evidence from the CTCA-Based Lesson Evaluation Rubric scores and the microteaching video recordings, allowing convergence across these three data sources to be considered. The science education expert who supported the coding process also engaged in ongoing reflective discussions with the researcher throughout the analysis, serving a peer-debriefing function by prompting the researcher to justify and reconsider interpretive decisions. Dependability and confirmability were further supported through a written audit trail documenting coding decisions and their rationale throughout the analysis process. Finally, transferability was supported through the thick description provided throughout the Method section, including detailed information on participants' backgrounds, the 12-week research procedure, and the specific topics, grade levels, and learning outcomes addressed by each group (Table 1), allowing readers to judge the applicability of the findings to their own contexts.

Given the researcher's multiple roles as course instructor, CTCA intervention designer, rubric evaluator, interviewer, and data analyst, several procedures were implemented to manage the potential power imbalance these multiple roles could create and to minimise researcher bias. First, participants were informed, both verbally and in the written consent form, that their participation in the study was entirely voluntary and would not influence their course grade in any way; consistent with this, rubric scores assigned to lesson plans and microteaching performances were used solely for research purposes and did not contribute to participants' course assessment, which was conducted independently through separate course requirements. Second, to reduce participants' potential reluctance to express critical views given the researcher's authority as their instructor, feedback on the lesson planning and microteaching processes was collected through an anonymous online survey (Google Forms) that did not record participants' identities, and this data collection took place after course grades had been finalised. Third, to minimise researcher bias during coding, interpretation, and reporting, the analytical procedures described above, including a second coder for inter-coder reliability, ongoing peer debriefing with the science education expert, methodological triangulation across data sources, and a written audit trail, were employed throughout the analysis.

Results

Pre-service Science Teachers' Performance in Preparing CTCA-Based Lesson Plans

The results regarding the lesson plans prepared by PSTs and analysed using the CTCA-Based Lesson Evaluation Rubric are presented in Table 2.

Table 2*PSTs' performance in preparing CTCA-based lesson plans*

Group	SSI	Score									Evaluation
		C1	C2	C3	C4	C5	C6	C7	C8	M	
G1	Cardiovascular health	3	3	3	4	4	3	3	4	3.38	Successful
G2	Biodiversity	3	3	3	3	3	3	2	3	2.99	Acceptable
G3	Acidic and basic materials	2	4	2	3	3	3	3	2	2.75	Acceptable
G4	Climate change	4	4	4	4	4	4	4	3	3.88	Successful
G5	Biodiversity	3	4	4	3	3	4	3	4	3.50	Successful
G6	Household waste and recycling	3	3	3	2	3	3	3	3	2.88	Acceptable
G7	Efficient use of resources	3	4	4	4	4	4	3	4	3.75	Successful
G8	Environmental concerns	2	3	3	2	3	3	3	3	2.75	Acceptable
G9	Environmental adaptation	2	3	3	3	3	3	3	3	2.88	Acceptable
G10	Biodiversity	3	3	4	3	3	3	3	3	3.13	Acceptable
G11	Biodiversity	3	3	4	3	3	3	3	3	3.13	Acceptable
M		2.82	3.36	3.36	3.09	3.27	3.27	3.00	3.18	3.17	

Note. C1: Cultural Context, C2: Technology Mediation, C3: Local Context, C4: Pre-Lesson Preparation, C5: Group Discussion and Sharing, C6: Drawing–Humour–Concretization, C7: Conceptual Clarification, C8: Digital Summary Message; M: Mean

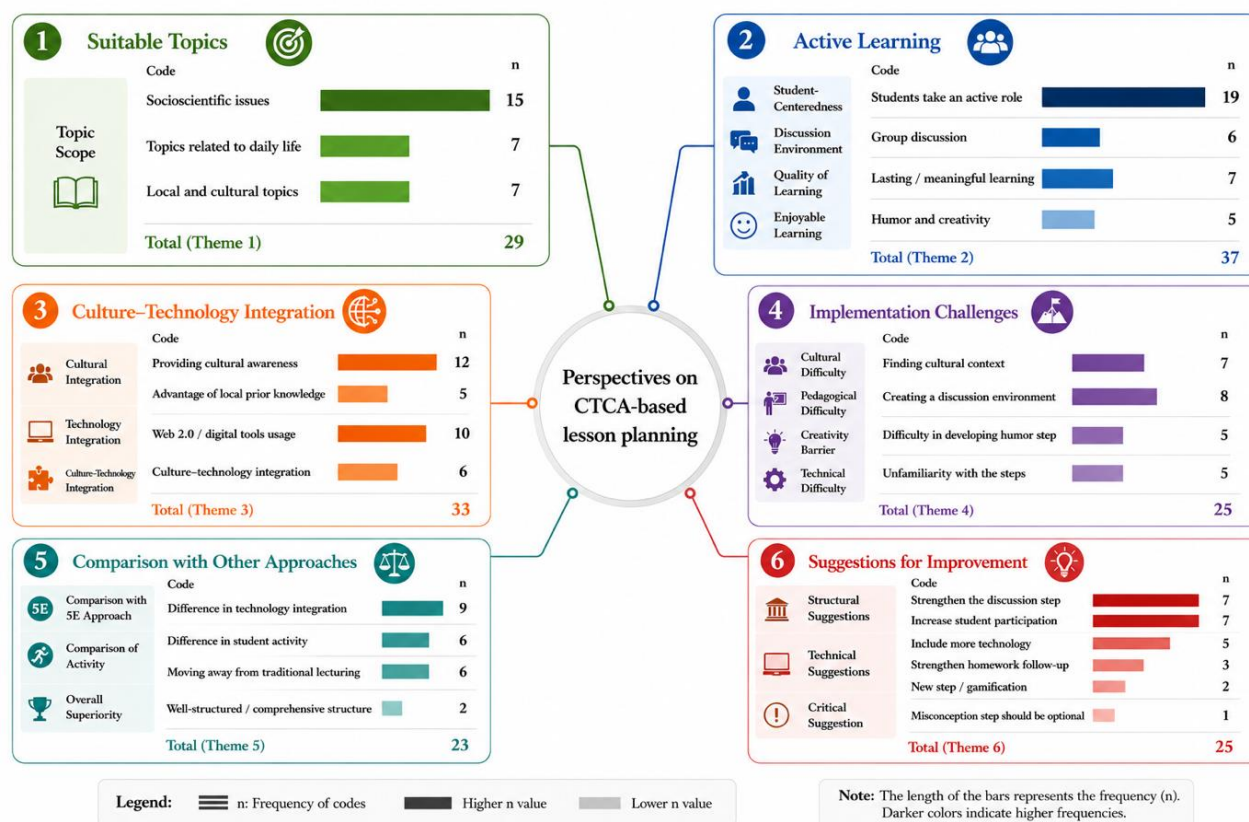
As shown in Table 2, most PSTs incorporated the CTCA implementation steps into their lesson plans. In this respect, it can be stated that they prepared lesson plans at acceptable and successful levels. The highest-scoring dimensions were local context with concrete events, natural areas, local species, or local practices ($M=3.36$) and integrated the use of technology ($M=3.36$) into their practice. G4 and G7 stood out in this regard. However, the limited reflection of the cultural context in the lesson plans ($M=2.82$) and the lack of explicit identification of misconceptions ($M=3.00$) were aspects that needed improvement in the PSTs' lesson plans.

Pre-service Science Teachers' Perspectives on the CTCA-Based Lesson Planning Process

This section presents the findings obtained from PSTs' perspectives on the CTCA-based lesson planning process (Figure 5). To enhance readability, the analysis results are presented in a summarised form in this section. Detailed codes, categories, themes, and illustrative statements are presented in Appendix Table 5.

Figure 5

Findings on PSTs' perspectives on CTCA-based lesson planning (Summary representation)



According to Figure 5, the PSTs emphasised the importance of identifying appropriate topics during the lesson planning process, highlighted the contribution of the CTCA to active learning, and foregrounded the cultural-technological integration embedded in this approach. They also compared the CTCA with other instructional approaches, reported implementation challenges, and offered suggestions for improvement.

In this process, they identified SSIs ($n=15$), topics related to daily life ($n=7$), and local/cultural topics ($n=7$) as the most suitable topics for CTCA-based lesson planning. The PSTs also stated that the CTCA could contribute to active learning by functioning as a student-centred approach in terms of enabling students to take active roles ($n=19$), enhancing the quality of learning through meaningful and lasting learning ($n=7$), and providing a discussion environment through group discussion ($n=6$). According to them, given its inherent nature, the CTCA can support students in achieving culture-technology integration by fostering cultural awareness ($n=12$) and enhancing the use of digital tools ($n=10$). The PSTs also distinguished this approach from other instructional approaches in terms of its distinctive emphasis on technology integration ($n=9$), student activeness ($n=6$), and its shift away from traditional instruction ($n=6$). Nevertheless, for the PSTs, providing a cultural context related to the topic addressed ($n=7$), creating a discussion environment ($n=8$), developing humour ($n=5$), and their limited familiarity with the CTCA steps ($n=5$) may pose challenges in implementation. To overcome some of these challenges, they suggested that the approach could be improved through structural recommendations, such as strengthening the discussion step ($n=7$) and increasing student participation ($n=7$), as well as technical recommendations, such as placing greater emphasis on technology ($n=5$) and strengthening homework follow-up ($n=3$). The following quotations illustrate the PSTs' perspectives:

"The CTCA can be widely used in science education because socioscientific and environmental issues may vary across regions and cultures." (PST1, Suitable topics)

"In the discussion stage, students actively participate in the lesson and are able to express their ideas freely." (PST5, Active learning)

"I was greatly impressed by the open-ended nature of the 'draw and develop humor' step, as it allows students to use their creativity effectively." (PST22, Active learning)

"Since the topic was related to my own hometown, I was able to make more connections and interpretations." (PST1, Culture–technology integration)

"Cultural approaches and technology are integrated; in this context, our past and future are blended together." (PST30, Culture–technology integration)

"While the 5E model is more related to question–answer activities and preparing presentations, the CTCA values students' own cultures and is more closely associated with technology." (PST8, Comparison with other approaches)

"Throughout my education so far, I have become more aware of how negatively traditional instruction can affect students." (PST21, Comparison with other approaches)

"The discussion section is challenging; because it is difficult to receive feedback from the class, this section may remain insufficient." (PST26, Implementation challenges)

"Since it was an approach, we had not encountered before, I had difficulty understanding its stages." (PST3, Implementation challenges)

"By assigning the homework earlier, a richer discussion environment could have been created; the lesson could also take place outside the classroom." (PST33, Suggestions for improvement)

"Making the misconception step compulsory for every topic implies that there should be misconceptions in every topic." (PST22, Suggestions for improvement)

Pre-service Science Teachers' Performance in Incorporating CTCA into Their Microteaching Practices

The data obtained from the video analysis of PSTs' microteaching practices are presented below (Table 3).

Table 3

PSTs' performance in incorporating CTCA into their microteaching practices

Group	SSI	Score									Evaluation
		C1	C2	C3	C4	C5	C6	C7	C8	M	
G1	Cardiovascular health	2	3	3	3	3	3	2	3	2.75	Acceptable
G2	Biodiversity	4	4	3	3	3	4	3	4	3.50	Successful
G3	Acidic and basic materials	4	4	3	4	3	4	3	4	3.63	Successful
G4	Climate change	4	4	4	4	3	4	3	4	3.75	Successful
G5	Biodiversity	3	4	3	3	3	3	3	3	3.13	Acceptable
G6	Household waste and recycling	3	4	4	3	4	3	3	3	3.38	Successful
G7	Efficient use of resources	3	4	3	4	4	4	3	3	3.50	Successful
G8	Environmental concerns	2	4	3	3	3	3	3	3	3.00	Acceptable
G9	Environmental adaptation	2	3	3	3	3	4	3	4	3.13	Acceptable
G10	Biodiversity	3	4	4	3	3	3	3	4	3.38	Successful
G11	Biodiversity	3	4	3	3	4	3	3	4	3.38	Successful
M		3.00	3.82	3.27	3.27	3.27	3.46	2.91	3.55	3.32	

Note. C1: Cultural Context, C2: Technology Mediation, C3: Local Context, C4: Pre-Lesson Preparation, C5: Group Discussion and Sharing, C6: Drawing–Humour–Concretization, C7: Conceptual Clarification, C8: Digital Summary Message; M: Mean

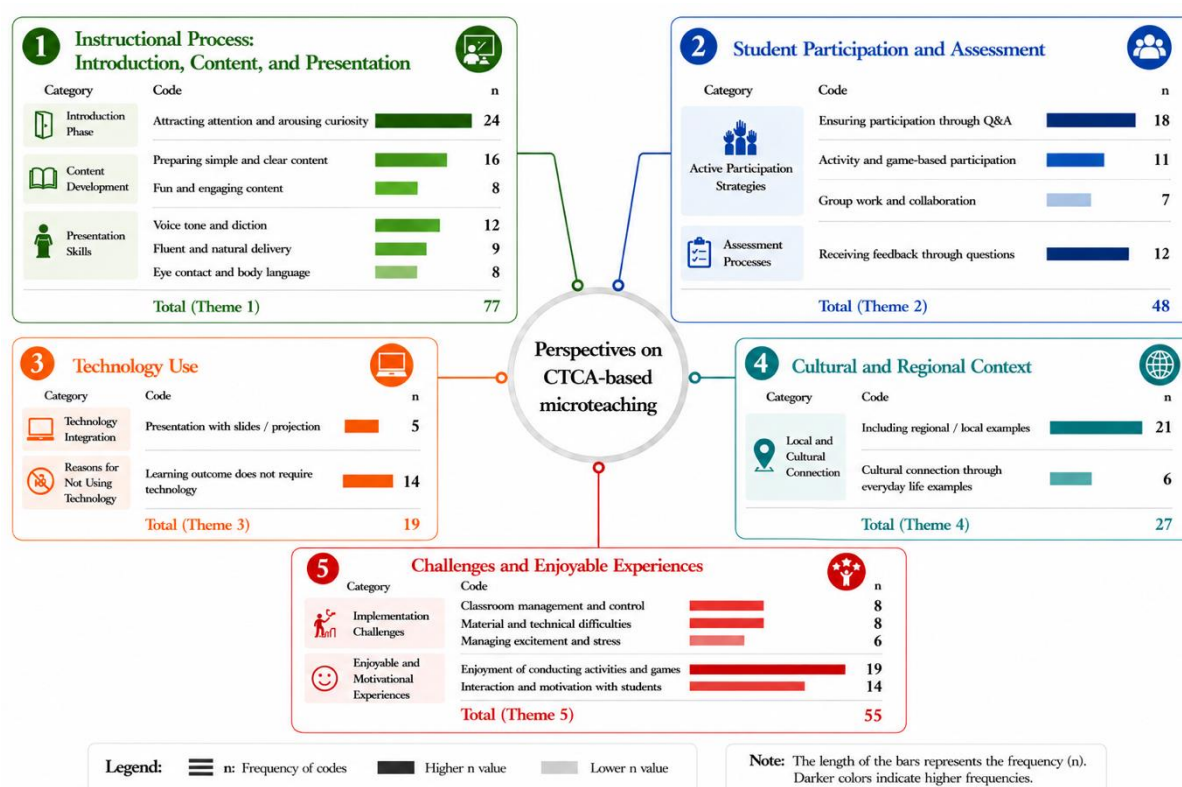
According to Table 3, in general, PSTs incorporated CTCA into their microteaching practices at successful and acceptable levels. The areas in which the PSTs were most successful in their microteaching practices were the use of technology ($M=3.82$) and the delivery of digital summary messages ($M=3.55$). The groups that stood out in the microteaching practices were G4 and G3. However, the PSTs demonstrated an acceptable level of performance in conceptual clarification ($M=2.91$) and establishing a cultural context ($M=3.00$) in their practices.

Pre-service Science Teachers' Perspectives on CTCA-Based Microteaching Practices

This section presents the findings obtained from PSTs' perspectives on CTCA-based microteaching practices (Figure 6). To enhance readability, the analysis results are presented in a summarised form in this section. Detailed codes, categories, themes, and illustrative statements are presented in Appendix Table 6).

Figure 6

Findings on PSTs' perspectives on CTCA-based microteaching practices (Summarized representation)



According to Figure 6, the PSTs evaluated CTCA-based microteaching practices through the themes of instructional process, student participation and assessment, technology use, establishing cultural and regional contexts, and challenges and enjoyable experiences.

The PSTs stated that, during the practices, they experienced the instructional process primarily in terms of the introduction stage, particularly through attracting attention and arousing curiosity ($n=24$); content development, through preparing clear and comprehensible content ($n=16$); and presentation skills, through tone of voice and diction ($n=12$). In addition, during the microteaching process, they experienced student participation by promoting active involvement through question-and-answer techniques ($n=18$) and activity- and game-based practices ($n=11$), as well as assessment by obtaining feedback through questions ($n=12$). The PSTs stated that they achieved technology integration through the technological materials they used, such as slides and videos ($n=9$); however,

they also noted that they did not use technological support when the learning outcome did not require it (n=14). In addition, their emphasis on incorporating regional/local examples into their microteaching practices (n=21) indicates that this approach was the most prominent factor in their use of local and regional contexts. During the practices, difficulties related to classroom control and classroom management (n=8), as well as material preparation and technical issues (n=8), were reported by the pre-service teachers. However, the enjoyment of engaging their classmates in activities and games (n=19), the interaction established with their peers (n=14), and the opportunity to experience the teaching profession (n=2) emerged as motivating factors. The following quotations illustrate the PSTs' perspectives:

"In the introduction, I asked questions that would arouse students' curiosity and checked their readiness." (PST29, Instructional process)

"We paid attention to making it easy, understandable, and clear." (PST6, Instructional process)

"We wanted to design an activity that students would be willing to participate in; there were no passive students." (PST5, Student participation and assessment)

"To make the lesson more engaging, we watched videos related to the topic." (PST34, Technology use)

"Technology was not highly relevant to my learning outcome; I used it only for research purposes." (PST7, Technology use)

"While preparing our slides, we selected visuals from our city so that students could more easily relate to them, as they reflected the environment in which they live." (PST32, Cultural and regional context)

"There were not many aspects that challenged me, but classroom control was difficult." (PST7, Challenges and enjoyable experiences)

"Even though it lasted only 10 minutes, experiencing teaching made me very happy." (PST21, Challenges and enjoyable experiences)

Discussion

Pre-service Science Teachers' Performance in Preparing CTCA-Based Lesson Plans

In this study, PSTs' performance in preparing CTCA-based lesson plans was evaluated, and it was found that most of the groups prepared lesson plans at acceptable and successful levels. Lesson planning is emphasised as one of the fundamental components of teachers' professional competence and draws attention to the integration of pre-service teachers' content knowledge and pedagogical knowledge (Großmann & Krüger, 2024; Kinskey & Zeidler, 2021). Consistent with this, Kinskey and Zeidler (2021) revealed that, in SSI-based lesson plans, PSTs had difficulty simultaneously designing both the subject content and the management of the discussion environment.

The result showing that the strongest performance in the lesson plans was achieved in the dimensions of associating the local context with concrete events, natural areas, or local species, and using technology is noteworthy. Yemini et al. (2025) emphasise the importance of cultural and shared spaces in the context of place-based education. In this context, 'place' does not refer only to a geographical location but also includes the knowledge, skills, and mutual communication of local communities. The locality emphasised in the present study can be evaluated within this framework. In this study, the fact that G4, which focused on climate change, and G7, which focused on the efficient use of resources, stood out as the groups that strongly reflected the local context in their lesson plans may point to a pattern within this sample whereby socioscientific and environment-based topics align more easily with CTCA; given that only two groups addressed such topics, however, this observation should be treated as tentative rather than conclusive. This result is consistent with researchers who argue that SSI teaching can be structured through topics that are most suitable for cultural contexts (Wagner et al., 2026). However, the literature emphasises that technology use should not be limited merely to the diversity of tools and that it is important to integrate technology for pedagogical purposes. Dinçer (2024) states that science teachers may experience shortcomings in technology integration, particularly in terms of design and competence, and that effective integration requires

practice-based, student-centred, technology-supported teacher education. In the present study, the high level of technology-supported implementation in the lesson plans and the fact that these practices were carried out with PSTs are promising in terms of addressing the shortcomings identified in the literature in their future professional lives.

On the other hand, the identification of the reflection of cultural context in lesson plans as the weakest dimension is a result that requires attention. Ellerbrock et al. (2016) emphasize that pre-service teachers are not sufficiently prepared in undergraduate programs to develop cultural awareness and that this deficiency is directly reflected in their lesson plans. Similarly, Halpern and Ozfidan (2024) examined the impact of cultural competence factors in teacher education programs and revealed that the ability to incorporate cultural content into the planning process requires experience and guidance. Wagner et al. (2026), in their study with high school students, investigated how students drew on their cultural repertoires and epistemic science knowledge when responding to a SSI. Their findings showed that integrating biological knowledge with cultural knowledge fosters a critical stance toward knowledge claims, supports the use of pluralistic knowledge among culturally and linguistically diverse students, and promotes critical engagement with SSIs in high school biology. These results, which support the findings of the present study, indicate that the cultural context dimension should be addressed more systematically and sustainably in teacher education programs.

Pre-service Science Teachers' Perspectives on the Process of Preparing CTCA-Based Lesson Plans

The PSTs' views indicate that SSIs and topics connected to daily life were perceived as the most suitable content areas for CTCA. Kinskey and Zeidler (2021) revealed that pre-service teachers' topic selection in SSI-based lessons is directly influenced by their content knowledge and perceptions of pedagogical feasibility. In the present study, PSTs' emphasis on SSIs may stem from the potential of these topics to align with students' cultural and regional experiences. Although the existing literature on CTCA has generally focused on biology achievement, the study by Onowugbeda et al. (2026) presents findings on the effect of CTCA on students' achievement in genetics, a SSI. The study emphasises the value of context-orientated and technology-supported instruction for high school students in the topic of genetics. They recommend that teachers who aim to improve learning outcomes in genetics integrate CTCA into their lessons. Therefore, considering its alignment in terms of both cultural context and content, developing CTCA-based practices that incorporate different SSIs may provide an important integration in science education.

The emphasis on a structure that foregrounds students' active roles indicates that PSTs position CTCA beyond traditional transmission-based models. Minken et al. (2021) emphasise that SSI-based lesson plans strengthen teachers' pedagogical content knowledge and that student-centred activities enhance the quality of learning. In the teaching of SSIs, student involvement, dialogue, and active participation are strongly emphasised (Chen & Xiao, 2021). The systematic review by Högström et al. (2025) shows that group discussions are the most prominent method for teaching SSIs. In the present study, PSTs' strong emphasis on students' active roles during the lesson planning process may be an important indicator of their potential to reflect this experience in their own classrooms.

The emphasis on the potential contribution of CTCA to culture–technology integration is highly consistent with the nature of CTCA. Lee (2018) provided examples through three cases to illustrate how technology, science, and culture can be brought together. According to Lee, culture plays a powerful role in advancing technology and fostering the interaction between technology and science.

Among the difficulties experienced in relation to the CTCA implementation process in lesson plans, creating a discussion environment and establishing a cultural context came to the fore. It is therefore expected that these results align with the finding that the cultural context dimension had the lowest score in PSTs' performance in preparing CTCA-based lesson plans. Zhang and Hsu (2025) emphasise that teachers do not feel sufficiently prepared to manage controversial issues and need

structured professional development support to overcome this difficulty. This emphasis indicates that there is still a need for culture-orientated practices such as CTCA, which may be valuable for PSTs' future professional lives.

PSTs also experienced some difficulties during the lesson plan preparation process. These difficulties included identifying a cultural context, creating a discussion environment, developing humour, and not being sufficiently familiar with the CTCA steps. Cultural context was an important determining factor within the scope of this study. The other difficulties experienced by the PSTs appear to be mostly related to the CTCA implementation process. Since the PSTs were still planning lessons based on theoretical knowledge at this stage and had not yet moved on to implementation, the absence of a clear process for constructing these components may have led to this result.

Pre-service Science Teachers' Performance in Incorporating CTCA into Their Microteaching Practices

The analysis of the microteaching videos revealed that PSTs generally incorporated CTCA into their practices at successful and acceptable levels. When compared with their performance in preparing lesson plans, implementation appears to have slightly exceeded the planning level. This result is consistent with studies arguing that microteaching serves as a strong bridge in transferring theoretical knowledge into practice. Iliasova et al. (2025) showed that microteaching enables teachers to develop multidimensional skills such as classroom management, instructional delivery, and reflective practice together.

It is noteworthy that the strongest performance in microteaching was observed in the dimensions of technology use and digital summary message delivery. The systematic review by Basilotta-Gómez-Pablos et al. (2022) on teachers' digital competence indicates that teachers generally have low to moderate levels of digital competence. The study particularly draws attention to teachers' lack of competence in evaluating educational practices. To address this deficiency, it recommends designing more practical and personalised training programmes that respond to teachers' needs in the digital age. The rapid development of artificial intelligence today also suggests that PSTs may be using these technologies more frequently than in-service teachers. In the present study, the high level of technological competence may stem from PSTs' existing familiarity with technological tools in their daily lives.

The relatively lower performance in the dimensions of conceptual clarification and establishing a cultural context is consistent with the findings on lesson plan preparation. This situation indicates that these skills require not only technical knowledge related to the planning process but also experience and guided practice. Since CTCA is a relatively new approach, it remains an area in which both the researcher and the PSTs have had limited practice. Conducting multiple practices, especially for conceptual clarification, anticipating possible misconceptions in advance, or preparing for misconceptions encountered in previous experiences may be important.

Pre-service Science Teachers' Perspectives on the CTCA-Based Microteaching Process

The PSTs evaluated the microteaching process under the themes of instructional aspects, participation, technology, cultural context, challenges, and enjoyable experiences. The fact that attracting attention and arousing curiosity were the most frequently mentioned instructional experiences indicates that PSTs were aware of the decisive role of an effective introduction phase in motivation. This result is consistent with studies showing that microteaching provides PSTs with opportunities to make their pedagogical choices consciously. Lewis (2024) revealed that microteaching enables PSTs to experience teaching "like a real teacher" and that this experience supports the development of professional identity.

The prominence of the question-and-answer technique and activities/games in the dimension of student participation shows that CTCA's emphasis on active learning was transferred into practice.

Jeon (2025) states that microteaching not only supports individual development but also promotes collaborative learning through structured peer interaction. Therefore, consistent with the participatory design of the microteaching process itself, experiencing CTCA foregrounded student participation for this group of PSTs.

A noteworthy pattern in technology use is that PSTs adopted technological support when required by the learning outcome. Petko et al. (2024), by relating the TPACK framework to contextual factors, show that PSTs' technology choices reflect their pedagogical intentions. In the dimension of cultural and regional context, the inclusion of regional/local examples emerged as the most distinctive feature of the implementation. This result is consistent with studies emphasising that cultural context helps students make sense of science concepts and that local knowledge strengthens learning. Although PSTs demonstrated a relatively low level of cultural context integration during the lesson plan preparation, the level of use of this component increased during implementation. Their increased attention to cultural context during the post-planning implementation process may have contributed to this change in their views.

The difficulties related to classroom management and material preparation may have resulted from PSTs' first experience with the CTCA process. In addition, because the SSIs addressed in the microteaching process can involve dilemmas and conflicting perspectives, they may have caused PSTs to experience challenges in classroom management. Consistent with this, Namdar and Tuskan's (2018) study, which examined science teachers' views on argumentation, also reported that teachers most frequently experienced difficulty in maintaining classroom control during this process. Since CTCA may include argumentation or other discussion-based processes, particularly in the group discussion stage, such difficulties can be expected. In addition, the fact that most PSTs described microteaching as an enjoyable and motivating experience suggests that, for these participants, this process was experienced as relevant not only to technical skill acquisition but also to their sense of professional development.

Taken together, the patterns observed across both lesson planning and microteaching, the finding that technology integration appeared stronger than cultural integration may reflect a difference in what each pillar demands of PSTs, in Heidegger's and Nkrumah's terms respectively. Enacting CTCA's technology pillar largely involves selecting and deploying discrete, visible tools, slides, videos, digital summary messages whose presence or absence is comparatively easy to identify, plan for, and assess. Enacting the cultural pillar, by contrast, requires PSTs to draw on Nkrumah's notion of indigenous knowledge: understanding how a local community makes sense of the world and translating that understanding into instructional content. This is a more interpretive, epistemically demanding task, and one for which PSTs, as digital natives already fluent with technological tools in their daily lives, may simply have had a shorter distance to travel than they did in developing the deeper local knowledge cultural integration requires. Read this way, the pattern may say less about CTCA's inherent structure than about the differing knowledge bases PSTs brought into the course, an institutional and generational factor the present design cannot fully disentangle from CTCA's own demands.

The comparatively weak performance in conceptual clarification is, we suggest, consistent with Shulman's (1987) account of pedagogical content knowledge and pedagogical reasoning. Anticipating and addressing misconceptions is arguably the most demanding component of pedagogical reasoning, requiring not only subject matter knowledge but also an internalised model of how learners are likely to misunderstand a concept, a form of knowledge typically built through repeated classroom experience rather than a single planning cycle. Viewed through Lave and Wenger's (1991) concept of legitimate peripheral participation, PSTs at this stage of their professional trajectory remain peripheral to the practice community of experienced science teachers; the iterative planning–feedback–microteaching–reteaching cycle adopted here, while consistent with Grossman et al.'s (2009) practice-based model of rehearsing core practices under supervision, may simply require more cycles or more targeted feedback specifically on anticipating misconceptions before this particular practice is reliably enacted.

An alternative explanation worth considering is that the CTCA-Based Lesson Evaluation Rubric itself may have made technology integration more visible, and therefore easier to reward, than cultural integration; criteria tied to concrete artefacts (e.g., digital tools used) may be more straightforward to score consistently than criteria requiring judgement about the depth or authenticity of cultural engagement. If so, part of this difference may reflect the operationalisation of the rubric rather than PSTs' underlying capacities, a possibility we could not fully rule out in the present design.

Theoretical and Practical Implications

Theoretically, these interpretations carry two broader implications. For CTCA research, they suggest the approach's three pillars should not be treated as developmentally equivalent when studied with novice implementers: rather than reporting a single aggregate effectiveness score, future CTCA studies would benefit from examining implementation at the level of individual pillars, particularly when the focus shifts from student outcomes to teachers' own enactment. For teacher education research more broadly, these findings suggest that practice-based cycles such as planning, peer feedback, microteaching, and reteaching, may suffice for developing visible, tool-based components of an approach; however, they may not be adequate within a single semester, for fostering more experience-dependent capacities, such as anticipating misconceptions or engaging authentically with cultural knowledge, central to Shulman's (1987) account of pedagogical reasoning.

Practically, these findings point to several concrete considerations for CTCA-based teacher preparation. Programmes may wish to allocate disproportionately more time and iterative practice to cultural integration and conceptual clarification specifically, rather than assuming a single planning–microteaching cycle develops all CTCA components at a similar pace. For cultural integration, the approach could include structured guidance or checklists to help PSTs research and translate local/indigenous knowledge into instructional content, addressing the more interpretive demands this pillar involves. For conceptual clarification, the process could include a dedicated misconception-anticipation step, in which PSTs identify likely student misunderstandings for their specific topic before finalising their lesson plans, rather than leaving this implicit in general planning. Programmes might also consider extending CTCA-based preparation across more than one semester or linking it across multiple courses to allow PSTs more than a single iterative cycle for the components that seem to require more sustained development.

Limitations

Several methodological choices shape how these findings should be interpreted and to what extent they can be transferred beyond the present context. Participants were selected via convenience sampling from a single course, which means those who volunteered may have differed systematically, for instance in motivation or confidence, from PSTs who did not; the reported patterns should therefore be understood as characteristic of this, self-selected group rather than of PSTs in general. The study was further situated within a single institutional context, whose regional culture, curricular structure, and available resources shaped both the SSIs PSTs selected (Table 1) and the forms cultural and technological integration could take; findings regarding, for instance, the relative ease of technology integration may be specific to an institution where PSTs already had strong digital access and fluency, and could differ in contexts with more limited technological infrastructure. The relatively small participant group, 34 PSTs organised into 11 groups, allowed for close, detailed engagement with each group's lesson plans, microteaching performance, and reflections, but also means that patterns observed for one or two standout groups (e.g., G4, G7) cannot be assumed to generalise even within the sample, let alone beyond it. As discussed above, the researcher's multiple roles as course instructor, intervention designer, evaluator, interviewer, and data analyst, while addressed through several procedural safeguards (see Method), remains a source of potential influence that these safeguards may not have fully offset; participants' willingness to voice criticism, for example, may still

have been shaped by their ongoing relationship with the researcher as their instructor. Finally, the qualitative case study design itself was chosen to provide an in-depth, contextually grounded account of an emerging instructional approach, a choice that trades statistical generalisability for interpretive depth; the findings are accordingly best read as an analytic account of how CTCA was taken up in one setting, offering transferable insights for similar contexts rather than claims about CTCA's effectiveness that would require experimental or comparative designs to establish.

These limitations point to several directions for future research. Multi-institutional studies, conducted across universities with differing regional cultures, curricula, and levels of technological infrastructure, would help clarify which of the present findings reflect features of CTCA itself and which reflect this particular institutional context. Comparative designs, contrasting CTCA-based preparation with alternative instructional approaches or with a no-intervention control group, would help isolate the specific contribution of CTCA relative to PSTs' general professional development over the same period. Longitudinal investigations, following PSTs from initial CTCA training into their early in-service teaching, would help determine whether the practice-based competencies observed here, and the gaps identified in conceptual clarification and cultural integration, persist, develop further, or fade once PSTs leave the structured, supervised context of teacher preparation.

Conclusion

The results of the study suggest that, within this educational context, a holistic and practice-based programme design may support the sustainable implementation of CTCA in teacher education. The experiences PSTs reported in relation to local context, technology integration, and active learning suggest that this approach shows considerable potential for engaging PSTs with SSI-based instruction. However, the shortcomings observed in areas such as conceptual clarification and discussion management indicate that CTCA-specific pedagogical skills may require more explicit attention in teacher education at both theoretical and practical levels.

Given that SSIs are directly related to students' daily lives, CTCA appears, based on this study, to offer a promising framework for PSTs to draw on in their future classrooms. The findings suggest that CTCA-based teacher education may support aspects of PSTs' professional development, particularly by encouraging them to relate scientific knowledge to technology and local context and to support students' active participation, patterns that emerged consistently across both planning and enactment. At the same time, cultural context integration and conceptual learning emerged as areas requiring more sustained attention within teacher education programmes, rather than outcomes this single practice cycle appears to have fully achieved. Because it was a qualitative case study conducted with a single cohort at one institution, these conclusions should be understood as context-specific; further research involving comparison groups or longitudinal designs would be needed to establish CTCA's broader effectiveness.

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Appendices

Table 4

CTCA-based lesson evaluation rubric

Section 1: Inclusion of the Basic Components of CTCA				
Evaluation Criteria	Successful (4)	Acceptable (3)	Needs Improvement (2)	Insufficient (1)
1. Cultural Context (Culture)	Scientific concepts are fully and meaningfully synthesized with local knowledge, traditional practices, or cultural heritage.	Cultural elements are present in the lesson, but they are not fully integrated with the scientific content.	Only superficial or general cultural examples are included.	The cultural context is not included in the lesson.
2. Technology Mediation (Technology)	Digital tools (YouTube, WhatsApp, Web 2.0, etc.) are actively used both for research and as cognitive scaffolding.	Technology use is present, but it is limited to the level of information transmission.	Only a single technological tool is used in a way that does not serve the intended purpose.	The technology component is not included in the lesson.
3. Local Context (Context)	Examples are selected directly from the school's immediate surroundings or from students' everyday living environments.	Regional examples are used, but they are not limited to the environment with which students directly interact.	General and decontextualized case studies are included.	No connection is established with the local/regional context.
Section 2: Alignment with the CTCA Implementation Process				
Implementation Steps	Successful (4)	Acceptable (3)	Needs Improvement (2)	Insufficient (1)
Step 1: Pre-Lesson Preparation	Clear and guiding tasks are given to students for investigating local knowledge and examining web resources.	A task is given, but the research steps (cultural/technological) are not sufficiently detailed.	Only a general research assignment is requested; it is not CTCA-focused.	No pre-lesson preparation is carried out.
Step 2: Group Discussion and Sharing	Data sharing is fully achieved in mixed-ability groups through social interaction during the lesson.	Groups are formed, but the peer learning and cultural data-sharing process remains weak.	The lesson is limited only to forming groups.	There is no group interaction; the lesson is entirely teacher-centered.
Step 3: Drawing, Humor, and Concretization	The topic is concretized through original drawings or humor elements using examples from students' immediate surroundings.	Drawing or humor is present, but it does not fully serve the function of simplifying the scientific concept.	Only ready-made visuals are used; students' creativity is not included.	Enriching materials such as humor or drawing are not included.
Step 4: Conceptual Clarification	Misconceptions arising from cultural beliefs are clarified by comparing them with scientific data and web resources.	Misconceptions are identified, but the synthesis of cultural and scientific data is not fully achieved.	Only scientific definitions are provided; no bridge is established with cultural data.	Conceptual misconceptions and cultural beliefs are not addressed at all.
Step 5: Digital Summary Message	A short and effective digital summary message containing the key information is available at the end of the lesson.	A summary message is available, but it does not fully comply with the CTCA format.	Only a general lesson summary is provided; digital delivery is not carried out.	There is no summarization or digital feedback process.

Table 5*Pre-service Science teachers' perspectives on CTCA-based lesson planning (comprehensive data)*

Category	Code	n	Quotations
Theme 1: Suitable Topics			
Topic scope	Socioscientific issues	15	Because socioscientific and environmental issues may vary across regions and cultures, the CTCA can be widely used in science education. (PST1)
	Topics related to daily life	7	The CTCA is very suitable for topics that can be experimented with or that we encounter in daily life. (PST11)
	Local and cultural topics	7	Relating topics to culture and foregrounding locality reinforce the topic more strongly. (PST26)
	Limitations in theoretical topics	2	It is very difficult to apply this to topics that can be understood entirely theoretically. (PST22)
Theme 2: Active Learning			
Student-centeredness	Students take an active role	19	Students take a more active role and discover their own knowledge throughout the process. (PST25)
	Sense of self-efficacy	3	Being able to figure things out on my own makes me feel good. (PST9)
Discussion environment	Group discussion	6	In the discussion stage, students actively participate in the lesson and are able to express their ideas freely. (PST5)
	Providing feedback	2	Students discuss, reach a conclusion, and find the correct answer together with the teacher. (PST26)
Quality of learning	Lasting/meaningful learning	7	It enables meaningful and lasting learning of the topics. (PST33)
	Addressing misconceptions	2	It facilitates the elimination of misconceptions. (PST25)
Enjoyable learning	Humor and creativity	5	I was greatly impressed by the open-ended nature of the 'draw and develop humor' step, as it allows students to use their creativity effectively. (PST22)
Theme 3: Culture-Technology Integration			
Cultural integration	Providing cultural awareness	12	The biodiversity topic was enriched and addressed with examples specific to Aksaray. (PST21)
	Advantage of local prior knowledge	5	Since the topic was related to my own hometown, I was able to make more connections and interpretations. (PST1)
Technology integration	Web 2.0/digital tools usage	10	It is a good thing to prepare activities for students with the help of technology and enable them to be active. (PST16)
Culture-technology integration	Culture-technology integration	6	Cultural approaches and technology are integrated; in this context, our past and future are blended together. (PST30)
Theme 4: Implementation Challenges			
Cultural difficulty	Finding cultural context	7	It was quite difficult for the drawings to include culture; I still feel as if the drawing did not fully connect with culture. (PST22)
Pedagogical difficulty	Creating a discussion environment	8	The discussion section is challenging; because it is difficult to receive feedback from the class, this section may remain insufficient. (PST26)
Creativity barrier	Difficulty in the humor development step	5	Finding humorous content related to the topic and creating a cartoon about it was challenging. (PST10)
Technical difficulty	Unfamiliarity with the steps	5	Since it was an approach, we had not encountered before, I had difficulty understanding its stages. (PST3)
	Time management (microteaching)	2	Because it was microteaching, we had difficulty keeping to the allotted time. (PST14)
Topic limitation	Limitations in theoretical topics	2	It is very difficult to apply this to topics that can be understood entirely theoretically. (PST22)
Theme 5: Comparison with Other Approaches			
Comparison with the 5E model	Difference in technology integration	9	Compared with the 5E model, the CTCA is a model in which students are more active and more intertwined with technology. (PST16)
	Cultural difference compared with the 5E model	3	While the 5E model is more related to question-answer activities and preparing presentations, the CTCA values students' own cultures and is more closely associated with technology. (PST8)

Comparison of activeness	Difference in student activity	6	In the CTCA, we are more active; in the others, the teacher usually explains and we listen. (PST11)
	Moving beyond traditional instruction	6	Throughout my education so far, I have become more aware of how negatively traditional instruction can affect students. (PST21)
Overall superiority	Well-structured/comprehensive structure	2	I think the CTCA is the most organized and cohesive approach among the other approaches. (PST18)
Theme 6: Suggestions for Improvement			
Structural suggestion	Strengthening the discussion step	7	By assigning the homework earlier, a richer discussion environment could have been created; the lesson could also take place outside the classroom. (PST33)
	Increasing student participation	7	Instead of the teacher preparing everything, students could also be asked to prepare something. (PST8)
	Clarifying the exploration step	3	The exploration part could be a little clearer; it is too open-ended, so there could be small prompts. (PST9)
	Flexibility in the humor step	2	In the draw and develop humor step, I would allow the use of alternative techniques instead of drawing. (PST18)
Technical suggestion	Include ore technology	5	Because it is microteaching, more technology could be used in some steps. (PST14)
	Strengthen homework follow-up	3	In the homework assignment part, whether the student has done the homework should be followed up. (PST28)
	New stage/gamification	2	Gamification could also be added. (PST31)
Critical suggestion	Misconception step should be optional	1	Making the misconception step compulsory for every topic implies that there should be misconceptions in every topic. (PST22)

Table 6

Pre-service science teachers' perspectives on CTCA-based microteaching practices (comprehensive data)

Category	Code	n	Quotations
Theme 1: Instructional Process: Introduction, Content, and Presentation			
Introduction phase	Attracting attention and arousing curiosity	24	In the introduction, I asked questions that would arouse students' curiosity and checked their readiness. (PST29)
Introduction phase	Assessing readiness and prior knowledge	5	I began with the question-answer technique both to attract attention and to examine readiness. (PST10)
Content development	Preparing simple and clear content	16	We paid attention to making it easy, understandable, and clear. (PST6)
Content development	Content supported with visuals and models	4	Supporting it with visuals and models. (PST12)
Content development	Fun and engaging content	8	Making it fun, lasting, and instructive. (PST15)
Content development	Attention to misconceptions	3	I paid attention to misconceptions and the experiment procedure. (PST9)
Presentation skills	Eye contact and body language	8	I paid attention to eye contact, gestures and facial expressions, and proceeding with students through question-answer interaction. (PST10)
Presentation skills	Voice tone and diction	12	I paid attention to teaching the lesson with a tone of voice that every student could hear. (PST21)
Presentation skills	Fluent and natural delivery	9	I paid attention to speaking more fluently and explaining in a way that students could understand. (PST22)
Theme 2: Student Participation and Assessment			
Active participation strategies	Ensuring participation through the question-answer technique	18	I asked students questions and involved them in the activity in groups. (PST3)
Active participation strategies	Activity- and game-based participation	11	We wanted to design an activity that students would be willing to participate in; there were no passive students. (PST5)
Active participation strategies	Group work and collaboration	7	Each student took part in the activity both individually and as part of a group. (PST31)
Assessment processes	Receiving feedback through questions	12	Feedback was received from students through questions. (PST23)

Assessment processes	Ensuring alignment between learning outcomes and assessment	5	Appropriateness for the time and learning outcome. (PST17)
Assessment processes	Self- and peer assessment	2	I would value both self-assessment and peer assessment. (PST34)
Assessment processes	Reinforcement and rewarding	4	Students who answered correctly were rewarded (for reinforcement purposes). (PST31)
Theme 3: Technology Use			
Technology integration	Presentation with slides/projection	5	Using technology in the lesson to make it efficient; it was done with slides and video. (PST11)
Technology integration	Use of video and visual materials	2	To make the lesson more engaging, we watched videos related to the topic. (PST34)
Technology integration	Use of artificial intelligence and internet resources	2	I tried to integrate technology for students by using artificial intelligence models. (PST26)
Reasons for not using technology	Learning outcome does not require technology	14	Technology was not highly relevant to my learning outcome; I used it only for research purposes. (PST7)
Theme 4: Cultural and Regional Context			
Local and cultural connections	Including regional/local examples	21	While preparing our slides, we selected visuals from our city so that students could more easily relate to them, as they reflected the environment in which they live. (PST32)
Local and cultural connections	Cultural connection through everyday life examples	6	I made a season-city connection with the students. (PST33)
Local and cultural connections	Universal content applicable to all regions	4	It was not intended for a single region; I paid attention to choosing universal topics that cover all regions. (PST7)
Theme 5: Challenges and Enjoyable Experiences			
Implementation challenges	Managing excitement and stress	6	I got excited and could not control this excitement. (PST25)
Implementation challenges	Classroom management and control	8	There were not many aspects that challenged me, but classroom control was difficult. (PST7)
Implementation challenges	Material and technical difficulties	8	Preparing the lesson materials was quite difficult. (PST32)
Implementation challenges	Time constraint	3	The shortness of my time was the issue. (PST21)
Enjoyable and motivational experiences	Enjoyment of conducting activities and games	19	I had a lot of fun while having them play the game. (PST32)
Enjoyable and motivational experiences	Interaction and motivation with students	14	Students' active participation in the lesson, both learning and socializing, made the experience enjoyable for me. (PST26)
Enjoyable and motivational experiences	Experiencing the teaching profession	2	Even though it lasted only 10 minutes, experiencing teaching made me very happy. (PST21)

An Example of a Lesson Plan Prepared by Pre-Service Teachers

CTCA Implementation Steps (*The original Turkish text is provided in parentheses*)

Group (PSTs): G5 (PST13-PST15)

SSI: Biodiversity

Learning outcome: FB.6.7.1.1 Being able to question the importance of biodiversity for wildlife

Step 1: Get the assignment and research (15 minutes)

(a) Students are informed in advance that the lesson will address questioning the importance of biodiversity for natural life. (b) Students are asked to reflect on the local aspects of biodiversity in natural life, cultural practices, or their ideas about natural life related to biodiversity. They are informed that they will share the ideas developed through this activity with their classmates. (c) Students are asked to investigate places in Aksaray that host different species by consulting artificial intelligence tools, older family or community members, magazines, and academic articles.

((a) Öğrencilere sınıfta biyoçeşitliliğin doğal yaşam için önemini sorgulayabilme konusunun ele alınacağı hakkında önceden bilgi verilir. (b) Öğrencilerin biyoçeşitliliğin doğal yaşamdaki yerel yönleri, kültürel uygulamaları veya biyoçeşitlilikle ilgili doğal yaşama yönelik düşünceleri istenir. Öğrenciler bu çalışmalarını sonucunda oluşacak düşüncelerini sınıfta arkadaşları ile paylaşacakları konusunda bilgilendirilir. (c) Aksaray'da bulunan ve farklı canlı türlerine ev sahipliği yapan yerler hakkında yapay zekadan, büyüklerinden, dergi ve makalelerden araştırmaları istenir.))

Step 2: Discuss with the group and share the result (25 minutes)

To ensure diversity in the information obtained from artificial intelligence tools, older family or community members, magazines, and academic articles, students with mixed abilities are assigned to different groups. Each group is asked to select a group leader. A brainstorming process is then initiated within the groups, and the cultural/web-based reflections are documented and presented by the group leader. The teacher concludes the topic by sharing local and cultural practices related to biodiversity.

(Yapay zekadan, büyüklerinden, dergi ve makalelerden edinilen bilgilerin çeşitliliği için karma yetenekli öğrenciler farklı gruplarda toplanır. Grup lideri belirlemeleri istenir. Grup içinde beyin fırtınası süreci başlatılır ve kültürel/web tabanlı yansımalar grup lideri tarafından belgelenerek sunulur. Öğretmen biyoçeşitliliğe yönelik yerel/kültürel uygulamaları paylaşarak konuyu tamamlar.))

Step 3: Draw and develop sense of humour (15 minutes)

The teacher continues the lesson using information, images, videos, and audio recordings obtained by researching areas in Aksaray that host biodiversity. A concept cartoon is created by the teacher using Canva and left incomplete so that students can contribute to and further develop the drawings. The drawings may also be created using paper and pencil. Humorous elements may be incorporated into this section. An example of a drawing that can be developed at this stage is presented below.

(Öğretmen Aksaray'da bulunan biyoçeşitliliğe ev sahipliği yapan bölgeleri araştırarak bulduğu; görsel, video, ses kayıtları ile ilgili bilgilerle dersi iletir. Öğretmen tarafından Canva uygulaması kullanılarak kavram karikatürü oluşturulur ve yarım bırakılır, öğrencilerin de katılımı ile çizimlerin geliştirilmesini sağlayabilir. Çizimler kâğıt-kalem kullanılarak oluşturulabilir. Bu bölüm mizah içerebilir. Bu bölümde oluşturulabilecek bir çizim örneği aşağıda sunulmuştur.))

Step 4: Make sense of the concepts and clear the misconception (10-15 minutes)

To facilitate conceptual understanding, the importance of local/cultural practices and research is revisited in the classroom. If students hold any misconceptions, the teacher addresses and corrects them. When necessary, tools such as artificial intelligence, textbooks, and conceptual change texts may be used to resolve these misconceptions. An incomplete example of a conceptual change text is presented below.

(Kavramları anlamlandırmak için yerel/kültürel uygulama ve araştırmanın önemi sınıfta hatırlatılır. Eğer öğrencilerde kavram yanlışlığı varsa öğretmen tarafından giderilir. Gerekli görülürse, yapay zeka, ders kitabı kullanılarak kavramsal değişim metinleri gibi araçlara yer vererek kavram yanlışlıkları giderilir. Tamamlanmamış örnek bir kavramsal değişim metni aşağıda sunulmuştur.))

Step 5: Summarize and send a message (10-15 minutes)

At the end of the lesson, the teacher shares an infographic summary on biodiversity, created using Canva and containing visuals and a specified character limit, with the students via text message/email, EBA, or a web-based application. A QR code system may also be used to help students become familiar with technology. An example is provided below.

(Dersin sonunda öğretmen biyoçeşitlilik ile ilgili belirli karakter sayısı içeren görseller de bulunan Canva uygulaması yardımıyla oluşturulmuş infografik özeti öğrencilere kısa mesaj/mail, EBA veya web tabanlı bir uygulama aracılığıyla iletir. Burada öğrencilerin teknolojiye aşina olmaları için karekod sistemi kullanılabilir. Buna bir örnek aşağıda verilmiştir.))

Example Drawing for the “Draw and Develop Sense of Humour” Step (Turkish)



Example Conceptual Change Text for the “Make Sense of Concepts and Clear the Misconception” Step

“The coexistence of different species within biodiversity negatively affects the continuity of the food chain and threatens ecosystem stability...”

(“Biyçeşitlilikte farklı türlerin bir arada olması, besin zincirinin devamlılığını olumsuz etkilemekte ve ekosistemin güvencesini tehdit etmektedir...”)

Example Infographic for the “Summarize and Send a Message” Step (Turkish)

