ICT integration practices and challenges among biology teacher educators in selected Southern Ethiopian colleges of teacher education

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Abstract

The integration of information and communication technologies (ICTs) in education is widely acknowledged, but research on its use by teacher educators, particularly in Biology, remains limited. This study investigated how teacher educators (TEs) in Ethiopian colleges of teacher education utilized ICT in the teaching-learning process, alongside the challenges they encountered. Employing a mixed-methods approach, data were collected through questionnaires with 50 purposively selected TEs and semi-structured interviews were conducted with 18 teacher educators from three colleges. The findings revealed that 83% of the participants believed that certain complex biological concepts could not be adequately taught without the help of ICT. However, 14% to 42% of the participants admitted that they rarely or never used key tools such as LCD projectors and advanced software in their teaching. Significant differences in ICT usage were associated with age, $F(2, 49) = 3.44$, $p = .040$, $\eta^2 = .12$, and with teaching experience, $F(2, 49) = 4.19$, $p = .021$, $\eta^2 = .16$. Major challenges included insufficient pedagogical support, inadequate training, and limited access to devices. The study advocates for targeted interventions to empower TEs; enhancing technology integration is vital for advancing education in developing countries like Ethiopia.

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Introduction

Rapid technological breakthroughs have brought about a number of changes in the social and economic lives of many individuals worldwide. It is increasingly important for nations to not only adapt to these changes more readily but also to create and develop equipment, systems, structures, policies, and resources that will allow them to stay relevant (Reno & Sari, 2020). Moreover, these advancements presented increased pressure on universities, businesses, governments, and students and which forced them to turn to ICT to

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provide modern solutions to modern challenges (Akah et al., 2022). Using ICT in the processes of teaching and learning within educational institutions empowers both educators and learners. Notably, it helps students get ready to live in a culture that values information. It also acts as a catalyst for improvements in teaching methods, student outcomes, and educational quality (Alemu, 2015; Lawrence, 2018). Higher education is crucial for enhancing lifelong learning and reflecting modern learning environments. As a result, they have to use ICT to equip students with the knowledge and skills needed for success in the digital age.

Studies across many African countries indicate that ICT resources in higher education are underutilized, with instructors often hesitant to integrate them into their teaching (Salam et al., 2018; Sutter & Kihara, 2019; Tekleselase, 2019). In Ethiopia, while ICT is seen as vital for national development and educational progress, research shows that schools fail to effectively use it to enhance instruction. Technical and administrative challenges have hindered ICT adoption, reducing its potential benefits. A lack of commitment from school administrations and poor ICT policy implementation further exacerbate the ICT underutilization issue (Ministry of Education [MoE], 2022; Yizengaw & Nigussie, 2023).

Moreover, teachers' perceptions of ICT's role in the classroom and their self-assessed ICT competencies significantly influence their willingness and ability to integrate technology into teaching in these nations (Arkorful et al., 2021; Rubach & Lazarides, 2021). Understanding these psychological and cognitive barriers is crucial for improving ICT utilization in education and shaping its effective use to facilitate instruction. In Ethiopia's teacher education programs, there's a recognized need for prospective teachers to develop 21st-century skills, including digital literacy and the integration of indigenous knowledge. Despite improvements in curriculum and ICT infrastructure, ICT utilization by teacher educators and prospective teachers remains limited, partly due to persistent challenges (MoE, 2022). Studying ICT integration in Biology education is crucial to optimize technology use and meet curriculum goals, which emphasize science and ICT as tools for fostering creativity and problem-solving skills in prospective teachers.

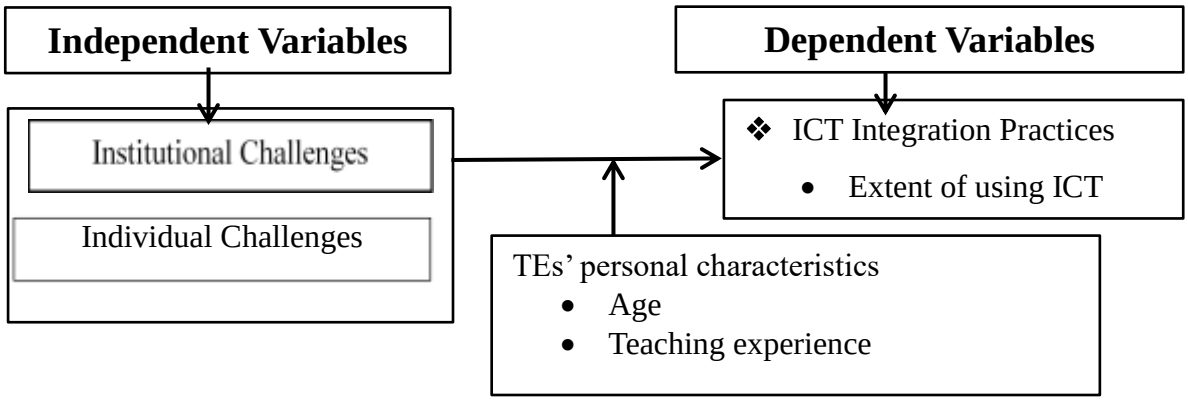
Indeed, studies on the use of ICT in Ethiopian education have been intense in primary and secondary schools and universities. However, little attention is paid to investigate colleges' educational perspectives and TEs. Furthermore, these studies concentrate on non-biological fields that contain complex and abstract concepts. Since teacher education has faced an urgent need to boost the new teachers' capacity to implement new teaching methods and use ICTs for the teaching-learning process, a more thorough study is needed to analyze TEs' ICT utilization and related challenges.

This study therefore examines the extent and nature of ICT use among Biology TEs in selected Ethiopian colleges of teacher education and identifies the individual and institutional challenges influencing integration. This is particularly relevant, as no research has specifically addressed the barriers to utilizing ICTs in the selected colleges of teacher education in Ethiopia, despite the country's renewed emphasis on ICT to enhance science education. Additionally, considering the study's primary focus on TEs, assumptions were made about how their personal characteristics (such as age and teaching experience) would affect their ICT integration practices, based on the ongoing literature debate on the subject (Hong, 2016; Kollia et al., 2020; Murithi & Yoo, 2021). The specific research questions that this study intended to address were the following:

- To what extent do teacher educators (TEs) use ICTs in the teaching-learning process of Biology?
- Is there a statistically significant difference in ICT integration practices among Biology TEs based on their age and teaching experience?
- What are the challenges faced by Biology TEs in the integration of ICT into teaching and learning practices?

Figure 1

Conceptual Framework of the Study



The conceptual framework of the study illustrates the relationships among institutional challenges, individual-level challenges, and ICT integration practices, while considering moderating factors such as age and teaching experience. In this framework, ICT integration practices represent the dependent variable, reflecting the extent to which TEs effectively utilize ICT tools in teaching and learning. This includes both hardware and software components aimed at facilitating and improving student learning. Overall, it encompasses searching for supplementary materials online, using email and managing student information, and utilizing technology as a method of demonstration and an interactive teaching approach in the classroom. This definition aligns with the framework presented by Mama and Hennessy (2013).

The institutional challenges, such as inadequate infrastructure, limited access to digital resources, poor technical support, and insufficient administrative encouragement, serve as independent variables that can either hinder or facilitate ICT integration. Likewise, individual-level challenges, including limited digital competence, negative attitudes toward technology, and resistance to change, also act as independent variables influencing how teachers adopt and implement ICT in their instructional practices.

According to Ali et al. (2018), institutional characteristic challenges are characteristics that have a systematic impact on ICT adoption within an institution but are not directly related to individual users. For example, the institutional ICT plan describes the institution's basic philosophy and aims at ICT integration processes. It comprises precise technical and infrastructure specifications, as well as methodologies for program implementation, monitoring, and evaluation.

Teachers require professional development to acquire ICT skills and a positive mindset when new technology tools and pedagogies emerge. As a result, ICT integration

requires institutional technical and pedagogical support from specialized persons with expertise in technology instruction. Timely support is essential for overcoming technological problems and inspiring instructors to implement ICT. According to Rizana et al. (2020), without sufficient support, instructors may be unwilling to deploy technology due to the risk of failure. This emphasizes the need of having a productive and successful ICT support infrastructure in higher education. However, inadequate assistance is frequently highlighted as a barrier to ICT adoption. In addition, the accessibility of the ICT infrastructure of the institutions is among the major challenges of ICT usage in the teaching-learning process in developing nations (Tekleselase, 2019).

The individual-level challenges refer to TEs' qualities in our framework, taking into account their digital mindset and digital proficiency. Attitude indicates an instructor's inclination to employ ICT in the classroom. Teachers with a good attitude about technology are more inclined to include it in their instruction. Several studies back this up, suggesting that instructors' views regarding ICT pose substantial barriers to its usage in instruction (Sutter & Kihara, 2019; Ngao et al., 2022). Similarly, ICT proficiency, the knowledge and abilities of teachers in integrating ICT into the process of teaching and learning, is an important component. Many educators have little exposure to technology tools in the classroom, which can lead to a lack of ICT competency.

Furthermore, moderating variables—particularly age and teaching experience—are anticipated to shape both the magnitude and direction of these relationships. Prior empirical research indicates that individual characteristics such as age, gender, teaching experience, and ICT competence significantly affect technology integration by shaping teachers' attitudes, self-confidence, and preparedness to use digital tools (Gebhardt et al., 2019). Evidence suggests that younger teachers tend to be more flexible and open to adopting ICT, whereas more experienced educators demonstrate more effective technology integration when sufficient training and institutional support are available (Almerich et al., 2024). In line with these findings, Basargekar and Singhavi (2017) identified significant variations in teachers' perceptions of ICT across age and experience groups, while Kollia et al. (2020) reported that older and more experienced teachers were generally less willing to adopt ICT, often due to negative perceptions and resistance to change.

Methods

A mixed research approach with concurrent embedded design was used in this study for its suitability to examine ICT integration practices of TEs and challenges they faced (Creswell, 2014). The embedded method typically focuses on a secondary research question or a specific subtopic related to the broader study. In this case, the dominant method was quantitative, with qualitative data embedded to provide deeper insights. Key qualitative questions were incorporated and analyzed to complement and support the primary quantitative findings. Using this design, the study aimed to investigate TEs' practice and challenges for incorporating ICT into the instructional practices of Biology education in selected colleges of teacher education in Ethiopia. Doing this helps to gain insight into generalizing a situation and investigate significant variations among the respondents in their ICT integration practices based on their age and teaching experience.

The study was conducted in three Colleges of Teacher Education located in two regional states in Ethiopia: Arba Minch and Dilla in the South Ethiopia Regional State and Hosanna in the Central Ethiopia Regional State, which were purposefully selected to ensure the inclusion of diverse institutional contexts and representative experiences in ICT integration within biology education. These colleges differ in terms of infrastructure development, ICT resource availability, and institutional support systems, providing a range of environments that help capture variations in the challenges and practices of ICT integration. Selecting these institutions was therefore guided not by convenience, but by the need to obtain contextually rich and comparable data that reflect the broader realities of teacher education settings in these regions. This purposive selection enhances the relevance, depth, and representativeness of the findings, enabling a more nuanced understanding of how institutional and individual factors influence ICT integration across different teacher education contexts.

These colleges collectively host a total of 50 Biology TEs. Since the total number of participants in the target group was small and manageable, the study included the entire accessible population rather than selecting a sample. This approach ensured comprehensive data collection and eliminated sampling error that might arise from excluding potential participants. This approach focuses on the complex practices and challenges of ICT integration in teacher education across three selected colleges, allowing for a thorough exploration of individual experiences and the nuanced variances influenced by factors such as age and teaching experience. This method offers a richer understanding than larger, randomized samples might provide, all while maintaining a practical and focused scope for rigorous analysis.

The demographic data shows a significant gender disparity, with 84% of participants being male and 16% female. Age distribution reveals that 24% are aged 20-30, 48% are 31-40, and 28% are 41-50 years old. These age categories were used to represent distinct career stages commonly recognized in educational research—early-career, mid-career, and late-career TEs. These categories also align with generational differences in digital exposure and are therefore analytically appropriate for examining variations in ICT usage. The majority have substantial teaching experience: 36% with 11-20 years and 34% with 21-30 years, indicating that nearly 70% have over a decade in the field. In terms of academic qualifications, 24% hold a first degree, while the remaining participants have master's degrees. The study also includes insights from six TEs, six college vice deans, and six department heads from the ICT and biology departments across three colleges purposefully, providing valuable perspectives for the research. They were three females and fifteen males, aged 28 to 55 years, with teaching experience ranging from 10 to 30 years.

Data collection involved semi-structured interviews and a two-section questionnaire. The first section of the questionnaire captured demographic information, while the second used five-point Likert scale questions to assess TEs' ICT usage in teaching and the challenges they faced. The questionnaire included a mix of closed and open-ended questions, with most items carefully adapted from previous studies (Baguma & Vandeyar, 2018; Nzika, 2019) to reflect the specific context of this study. The questionnaire was pilot-tested to ensure reliability and validity. Internal consistency, measured by Cronbach's alpha, was assessed twice: during the pilot and after final data collection. According to Taber (2018), a

Cronbach's alpha of 0.7 to 0.8 is considered adequate. The results showed strong internal consistency, with reliability coefficients for all constructs (extent of ICT use (EICTU), institutional challenges of ICT (ICICT), and individual-level challenges (ILCs)) exceeding 0.7. For the qualitative aspects of the study, several strategies were used to ensure trustworthiness. Member checking was conducted by sharing interview summaries with participants to verify accuracy. Peer debriefing sessions were held with a colleague experienced in qualitative methods to review coding and emerging themes. Although the principal investigator was the sole coder, a clear coding framework and iterative coding process were applied to enhance inter-coder consistency. An audit trail documenting coding decisions, analytic memos, and theme development was maintained to support reliability.

The survey was pilot tested on eighteen biology TEs at Hawassa College of Teacher Education, which resulted in the rewording and elimination of some items from the survey. In this study, both content and face validity were evaluated through peer review. Two experts from the Department of Curriculum and Instructional Supervision from Hawassa University and Bahir Dar University reviewed the survey instruments based on the extent to which the instrument effectively captures the concept under study and how well the questionnaire items are understood and accepted, respectively. Once the face validity and content of the instruments were assessed, the exploratory factor analysis (EFA) statistical method was used to examine the construct validity (Tondeur et al., 2018). A specific type of construct validity determined through factor analysis is factorial validity, which examines how questionnaire items group together based on correlations in responses and can be assessed by evaluating the logical coherence of items within each factor. Hence, EFA using Principal Axis Factoring (PAF) with Varimax rotation was conducted to examine the structure of the scales, and the EFA of all the scales confirmed the factorial validity, and the results are discussed under the result section.

A questionnaire was administered after obtaining approval from Hawassa University, Ethiopia, and based on permission granted by the respective sampled colleges. Following this, all subjects provided unambiguous verbal and written consent. The investigators provided participants with orientation regarding the purpose of the instruments to ensure they felt comfortable. Afterwards, the researchers physically collected the completed questionnaires from each respondent.

Subsequently, the principal investigator conducted eighteen in-depth interviews, using a blend of general and specific questions primarily derived from the subscales of the survey questionnaire to gather comprehensive insights. Each session began with a general interview to collect background information about the participants. This was followed by targeted questions exploring their experiences with ICT use in biology education, specifically examining the instructional practices they adopt and the individual and institutional challenges they face. Six TEs were interviewed for their direct experiences integrating ICT in teaching were the main focuses. We also interviewed college vice deans and department heads from biology and ICT departments to understand broader, institution-wide challenges that impact the integration of ICT. This approach allowed us to capture a holistic view of ICT usage in biology education, from the classroom to the institutional level. To ensure confidentiality, each participant was assigned an anonymous code. The codes used were TE

for teacher educators, VD for vice deans, DHB for department heads of Biology, and DHI for department heads of ICT.

During the data collection process, a number of measures were taken to reduce interviewer bias. Initially, we employed a semi-structured interview guide to guarantee uniformity in the questions posed to each participant. Second, in order to avoid influencing participants' answers, we kept a neutral tone and refrained from sharing personal thoughts or feelings during interviews. Third, in order to improve familiarity with the questions and minimize unintentional cues, we rehearsed the interview protocol before data collection. To guarantee accuracy and prevent subjective interpretation, every interview was audio recorded and verbatim transcribed. Lastly, in order to recognize and control any potential biases that might emerge during the interviews, reflexive notes were maintained throughout the process.

Here are a few samples of the questions we asked: Would you like to share your experience with the extent of integrating ICT in biology education? What individual and institutional challenges do you face in integrating ICT into your teaching and learning process? Do you have a personal ICT integration plan that you follow? And why do you do so? Interviews were conducted at participants' selected location and time, lasting 25–45 minutes each. All interviews were audio recorded.

The data collected were used to establish the instrument's psychometric properties (factor structure, internal consistency reliability, and discriminant validity) first. To examine TEs' ICT usage and the challenges they face, descriptive statistics such as frequencies (F), percentages (%), means (M), and standard deviations (SD) were computed. A one-sample t-test was performed to determine whether TEs' ICT integration exceeded the neutral midpoint of the scale. One-way analysis of variance (ANOVA) was used with SPSS version 24 software to assess statistically significant differences in TEs' extent of ICT utilization in the teaching-learning process based on personal factors. Moreover, to ascertain the extent of differences, effect sizes were calculated using eta squared (η^2).

The assumptions for ANOVA were checked using tests of normality and homogeneity of variance. The Shapiro–Wilk results for all age groups and ICT experience categories showed p-values greater than .05, indicating that the distribution of ICT practice scores did not significantly deviate from normality. In addition, Levene's Test for homogeneity of variances produced a non-significant result ($p = .151 > .05$), showing that the variances across groups were equal. Therefore, both the normality and homogeneity assumptions were satisfied, and it was appropriate to proceed with the standard one-way ANOVA.

Thematic analysis of the interview data was conducted to explore TEs' ICT integration practices and challenges. To ensure confidentiality, each participant was assigned an anonymous code. The codes 'TE1' to 'TE6' were used for the six TEs, 'VD' for the vice deans, and 'DHI' and 'DHB' for the department heads of ICT and Biology, respectively. Following Braun and Clarke (2012) six-step process, the analysis involved immersing in the data, generating initial codes, identifying and reviewing themes, and naming them, culminating in a comprehensive report. Although various qualitative data analysis software's are available, the textual data was manually coded using Microsoft Word's "comments" feature for a meticulous and hands-on approach. Verbatim transcriptions of the text data from the individual interviews were made, and a preliminary examination provided an overview.

Codes were then determined based on research questions, leading to the creation of predefined core topics and subthemes.

To streamline the coding process, subthemes and code categories were distinguished using color-coding. For instance, within the broader category of challenges in ICT integration, institutional and individual-level challenges faced by TEs were identified as subthemes. Following these, thematic analysis was conducted to present the findings comprehensively. During this process, the authors reviewed the generated codes, identified areas of likeness, and combined them. Finally, the data is narrated, forming the basis for discussions, conclusions, and recommendations. The following are examples of the specific actions we took during this process.

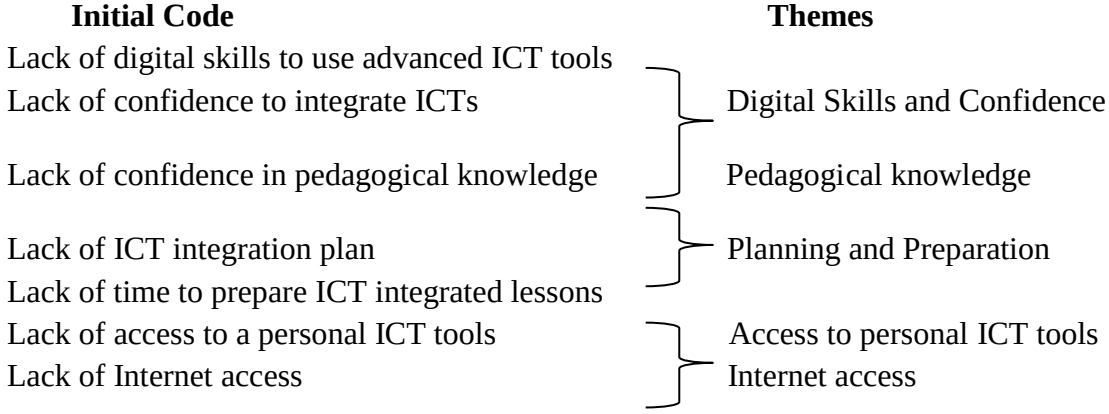
Table 1

A Thematic Organization of the Individual Level Challenges of ICT Integration

Interviewer's Questions	Participants' Response	Initial Code
Would you like to share your experience with the extent of integrating ICT in biology education? What individual and institutional challenges do you face in integrating ICT into your teaching and learning process?	I realize that many advanced ICT tools are available, but I feel the need to build my skills gradually. Starting with simpler tools helps me integrate technology into my teaching without feeling overwhelmed.	Lack of digital skills to use advanced ICT tools
	Many of us focus more on the technology itself rather on how it supports specific learning objectives and teaching strategies. I find it challenging to create lesson plans that fully leverage ICT to accommodate different learning styles; it costs me time, making me less confident in effectively integrating it.	Lack of confidence in pedagogical knowledge Lack of time to prepare ICT integrated lessons Lack of confidence to integrate ICTs
	I don't have a personal computer and rely on the library's institutional computers, and I always prepare my teaching notes using office desktops, which are often in high demand... Besides, unreliable internet access has also affected my teaching practices negatively.	Lack of access to a personal ICT tools Lack of Internet access
	Although I'm skilled with my preferred software, I rely on printed materials because I'm not confident in integrating advanced ICT tools like digital videos, graphics, and simulations into my teaching.	Lack of digital skills to use advanced ICT tools
Do you have a personal ICT integration plan that you follow? And why do you do so?	While I don't have a formal ICT integration plan that I follow, I believe that technology should enhance the learning experience without being rigidly structured, so I use it flexibly, incorporating it when it adds real value to my teaching, allowing me to stay responsive and adapt technology to fit naturally into each lesson.	Lack of ICT integration plan

Figure 2

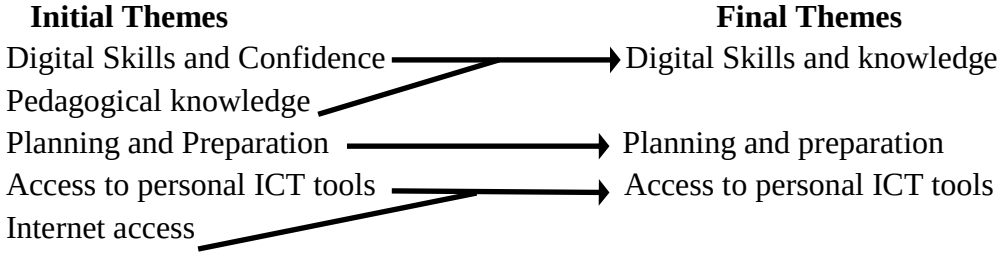
Themes Generated from Initial Coding



Following the creation of the themes, we moved on to the stage of theme assessment and naming. In this stage, we went over every subject that had been developed in the earlier stage and came up with a precise, clear final name for each one (Figure 3).

Figure 3

Final Names for Generated Themes



To enhance the credibility of the findings, quantitative and qualitative data were triangulated during the interpretation stage. The quantitative results from the survey were compared with themes emerging from the interviews to identify convergence, complementarity, or divergence.

Findings

Demographic Characteristics of the Respondents

The demographic data shows a significant gender disparity, with 84% of participants being male and 16% female. Age distribution reveals that 24% are aged 20-30, 48% are 31-40, and 28% are 41-50 years old. These age categories were used to represent distinct career stages commonly recognized in educational research—early-career, mid-career, and late-career TEs. These categories also align with generational differences in digital exposure and are therefore analytically appropriate for examining variations in ICT usage. The majority have substantial teaching experience: 36% with 11-20 years and 34% with 21-30 years, indicating that nearly 70% have over a decade in the field. In terms of academic qualifications, 24% hold a first degree, while the remaining participants have master's degrees. The study also includes insights from six TEs, six college vice deans, and six department heads from the ICT and biology departments across three colleges purposefully,

providing valuable perspectives for the research. They were three females and fifteen males, aged 28 to 55 years, with teaching experience ranging from 10 to 30 years.

EFA Results for the Scales Measuring TEs' Extent of ICT Use, Institutional ICT Challenges, and Individual-Level Challenges

The exploratory factor analyses of the EICTU, ICICT, and ILCs scales confirmed their factorial validity. The factorability of the seven EICTU items was assessed. The Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy was .748, and Bartlett's Test of Sphericity (BTS) ($\chi^2(21) = 100.61$, $p < .001$) was significant, indicating that the data were suitable for factor analysis. Two factors with eigenvalues greater than 1 emerged. The first factor, with four items loading strongly (.528–.827), reflects Instructional ICT Integration, capturing the use of presentation tools (e.g., PowerPoint, LCD projectors), data-processing applications (e.g., Excel), and advanced instructional software (e.g., animations and simulations). The second factor, with three items loading between .515 and .845, represents ICT Use for Information Access and Communication, covering internet use for sourcing information, the use of social media to communicate with pupils, and the use of personal devices for lesson preparation. Together, these two factors suggest that TEs' ICT integration behaviors can be understood in terms of both instructional uses and communication/ information-access uses.

The KMO measure of sampling adequacy of the eight ICICT items was 0.76, and the BTS was significant (χ^2 (28) = 134.5, p = 0.000), confirming the suitability of the data for factor analysis. The scale had two factors with eigenvalues of 4.62 and 1.86, with four items loading onto one factor and two items onto another, explaining 81.1% of the total variance. The ILCs scale had a single factor with an eigenvalue of 4.35, representing 72.6% of the total variance. The KMO measures of sampling adequacy were above 0.70, and BTS were significant (χ^2 (15) = 68.23, p = 0.000), indicating that the data met the assumptions for factor analysis. All the communalities were also above 0.5, further supporting the factorial validity of this scale, and no items were eliminated.

ICT Integration Practices of TEs' in Biology

Our findings on the use of ICT in instruction fall into two categories, encompassing both hardware and software tools that aided in boosting student engagement and streamlining information management. For instance, TEs'use web browsers to source supplementary materials, email for effective communication, and tools like LCD multimedia projectors and Microsoft Word, Excel, and PowerPoint to deliver dynamic classroom demonstrations and interactive teaching sessions.

We used a questionnaire that invites participants to evaluate how frequently they incorporate various ICT tools into their favorite instructional activities. Responses were measured on a Likert scale, where Never (N) = 1, Rarely (R) = 2, Sometimes (S) = 3, Often (O) = 4, and Always (A) = 5. The results were then converted into percentages, reflecting the extent of ICT usage in teaching and learning (Table 2).

Table 2

Descriptive Statistics of TEs' Extent of ICT Use

Items	%					M	SD
	N	R	S	O	A		
Internet/web browsers for sourcing information	0	14	36	32	18	3.54	0.95
Ms. excels/spreadsheet for analyzing	0	22	38	22	18	3.36	1.02
MS PowerPoint to prepare lessons	0	36	32	24	8	3.04	0.96
LCD multimedia projector for giving lectures	8	42	24	24	2	2.70	0.99
Advanced software (Animations/simulations)	26	34	20	16	4	2.38	1.15
Social media for sharing information (to communicate with pupils and others)	2	22	20	30	26	3.56	1.16
Personal devices; laptops, etc. to prepare lessons	2	16	22	32	28	3.68	1.11
Grand Mean						3.17	

According to Table 2, the predominant ICT tools TEs integrated into their instruction ('Often' and 'Always') included preparing lessons using personal devices (60%), sharing information with pupils and others via social media (56%), and sourcing information from the internet and web browsers (50%). Other notable ICT tools included analyzing scores and conducting various activities with MS Office Excel or Spreadsheet (40%), presenting lessons using MS PowerPoint software (32%), delivering lectures with an LCD multimedia projector (26%), and creating presentations with advanced software featuring animations or simulations (2%).

The analysis has shown key insights into Biology TEs' use of advanced software. Notably, 26% of TEs never use tools like animations or simulations, and 34% use them rarely, indicating limited adoption of these technologies. Similarly, the use of LCD multimedia projectors is low, with 8% never using them and 42% using them rarely. Additionally, 36% of TEs rarely use MS PowerPoint for lesson preparation and presentations. Overall, while a small number of TEs frequently use these ICT tools, the majority rely on basic ICT tools only occasionally, highlighting significant potential for improving technology integration.

Besides, a one-sample t-test was conducted to determine whether TEs' ICT usage (EICTU) differed significantly from the neutral midpoint of 3 ("Sometimes"). The mean EICTU score ($M = 3.17$, $SD = 0.71$) was higher than the test value, but the difference was not statistically significant, $t(49) = 1.69$, $p = .098$. These results indicate that TEs' ICT usage is not significantly above average, suggesting only a moderate level of ICT integration.

TEs' ICT Integration Practices Based on Age

The difference of TEs' age on their ICT integration practices was investigated using a one-way ANOVA, with participants divided into three age groups (20-30 years, 31-40 years, and 41-50 years). The ANOVA revealed a statistically significant difference ($F (2, 49) = 3.44$, $p = 0.04$), and the effect size ($\eta^2 = 0.12$) was moderate (Cohen, 2016). A subsequent post hoc (Tukey's HSD) analysis identified a significant difference in mean scores of ICT integration practices between TEs aged 31-40 years ($M = 3.41$, $SD = 0.67$) and those aged 41-50 years ($M = 2.81$, $SD = 0.5$). However, no significant difference was found between TEs aged 31-40 years and those aged 20-30 years ($M = 3.13$, $SD = 0.87$).

TEs' ICT Integration Practices Based on Experience

A one-way ANOVA was performed to examine the effect of teachers' years of experience (1-10 years, 11-20 years, and 21-30 years) on their use of ICT in biology teaching. The results revealed a statistically significant difference in mean ICT integration scores among the groups ($F(2, 49) = 4.19$, $p = .021$), with a large effect size ($\eta^2 = 0.16$) indicating considerable variation in ICT use. Post-hoc analysis further highlighted a significant difference between teachers with 11-20 years of experience ($M = 3.53$) and those with 21-30 years ($M = 2.95$). This advocates that TEs with less experience are more inclined to integrate ICT into their teaching than their more experienced colleagues.

Overall, the quantitative results showed that only a small number of TEs frequently use specific, mostly basic ICT tools, while the majority use them only occasionally. Our in-depth qualitative exploration aimed to provide a comprehensive understanding and robust support for the quantitative findings. The participants' responses to their ICT integration practices are given narratively as follows.

Preferred ICT Tools and Teaching approach

The study identified two main issues related to TEs' preferred ICT tools and their preferred approach to the teaching process when discussing their experience with ICT use, specifically, a reliance on basic tools and dependency on traditional methods. Notably, the findings indicated that 67% of TEs who participated in the interviews reported relying primarily on basic tools such as MS Word, Excel, and PowerPoint in their teaching–learning process. Although they expressed frustration about not utilizing more dynamic features, they continued to depend heavily on printed materials, underscoring a hesitation to fully adopt ICT. Several TEs highlighted their reliance on basic ICT tools and their limited confidence in using advanced features. For instance, one participant noted, "I efficiently source information using web browsers, Microsoft Excel, and Microsoft Word but want to improve my skills in using social media for sharing information and communicating with students" (TE4). Similarly, another TE explained, "I always prepare PPT before the session, but I can't insert animations or simulations to capture learners' attention" (TE3). This limited competence led some participants to depend on traditional materials, as reflected by one respondent who stated, "I primarily rely on printed materials for my lessons, as I am not yet confident in utilizing many advanced features of ICT tools in my classroom" (TE1).

In addition, the qualitative findings also show 33% of participants expressed doubts about ICT, questioning its superiority over traditional lectures and its effectiveness in teaching biology. Similarly, when the participants were asked about their beliefs on whether some challenging concepts in biology can be effectively taught without ICT, 17% responded affirmatively, stating they believed it was possible. However, 83% of participants confidently affirmed their belief that these could not be effectively taught without relying on ICT. Their arguments are stated as follows:

In addition, the qualitative findings also show 33% of participants expressed doubts about ICT, questioning its superiority over traditional lectures and its effectiveness in teaching biology. Similarly, when the participants were asked about their beliefs on whether some challenging concepts in biology can be effectively taught without ICT, 17% responded affirmatively, stating they believed it was possible. However, 83% of participants confidently affirmed their belief that these could not be effectively taught without relying on ICT. Some TEs raised concerns about the potential negative effects of ICT on students' learning

behaviors. For example, one participant cautioned that while ICT can support teaching, it may also encourage student passivity and reduce critical thinking if overused, noting that "easy online answers discourage deep thought" and emphasizing that "effective instruction fostering critical thinking is vital regardless of ICT use" (TE1). This participant further expressed a preference for traditional teaching methods, stating, "I believe ICT can distract students if you simply display PowerPoint… I prefer using a chalkboard mostly for teaching," and added that preparing ICT-based lessons "costs me a lot of time" (TE1).

In contrast, another TE emphasized the hands-on nature of biology and the value of experiential learning over technology-mediated instruction. As one TE explained, "Biology is inherently a hands-on subject. Experiments, dissections, and fieldwork allow students to engage directly with the material," arguing that activities such as observing and dissecting real specimens provide "a concrete understanding that screens cannot replicate" (TE6). This participant also highlighted the importance of inquiry-based and independent investigations that promote deeper understanding without heavy reliance on ICT.

Conversely, other participants viewed ICT as a powerful instructional tool, particularly for explaining abstract biological processes. One TE noted that "many biological processes, such as cellular respiration or photosynthesis, involve complex interactions that are difficult to visualize," and argued that ICT tools such as animations and simulations offer "dynamic representations that help students grasp these concepts more effectively than static images or text alone" (TE4).

Generally, both the quantitative and qualitative results indicate room for improvement in integrating advanced technology into teaching practices at these colleges of teacher education.

Challenges faced by TEs in integrating ICT

Institutional Level Challenges Table 3 presents responses to the survey that biology TEs completed on institutional-level problems they run across when utilizing technology in the classroom. The Likert scale responses allow for the measurement of the degree to which each challenge is perceived by the participants.

As it is shown in Table 3, the vast majority of TEs (more than 60%) believe that inadequate ICT tools in the library and laboratory, along with insufficient pedagogical support, are the primary obstacles to effectively integrating ICT in their instruction. Additionally, more than 55% of TEs highlight several other significant barriers: the absence of a clear institutional ICT plan, slow internet connections, lack of classroom with the necessary facilities, and insufficient in-service training opportunities. Similarly, the absence of classrooms equipped with the necessary facilities (52%, M = 3.42) presents a significant challenge. In comparison, a slightly smaller proportion of respondents (48%, M = 3.32) indicated that inadequate maintenance of unused computers hampers ICT utilization in the classroom. Conversely, only a small percentage of respondents disagree with the notion that inadequate in-service training (18%), slow internet connections (18%), and a lack of a clear institutional ICT plan (20%) are key challenges faced by TEs.

Table 3

Institutional-level Challenges

Items	%					M	SD
	SD	DA	U	A	SA		
Lack of a clear institutional ICT plan	8	12	22	38	20	3.50	1.18
Slow Internet connection for accessing resources	2	16	24	50	8	3.46	0.93
Inadequate ICT tools in the library and laboratory	4	22	14	50	10	3.40	1.06
Lack of classroom with the necessary facilities	0	28	16	26	30	3.58	1.19
Insufficient pedagogical support for TEs	0	24	14	32	30	3.68	1.15
Lack of maintenance for non-used computers	10	20	22	24	24	3.32	1.31
Frequent power failures or blackouts	12	18	18	20	32	3.42	1.41
Inadequate in-service training opportunities	2	16	26	28	28	3.64	1.12
Grand Mean						3.49	1.13

Note. SD=Strongly Disagree; DA=Disagree; U= Undecided; A=Agree; SA=Strongly Agree

Individual-Level Challenges

The grand mean score on the individual challenge scale is 3.08 with a standard deviation of 1.25 (Table 4). This suggests that respondents have a strong impression of their own individual characteristics and how these affect their ICT integration practices, in addition to the institutional challenges**.**

Upon detailed analysis, it was found that the majority of TEs expressed a lack of confidence in their pedagogical knowledge for integrating ICT into their instructional activities. This sentiment is reflected in the mean score of 3.48, and 58% of the TEs agree that they feel not confident in their pedagogical knowledge. Furthermore, many respondents cited the lack of personal devices as the second most important challenge; with a mean score of 3.38, 54% of TEs agree that they don't have adequate personal devices. Similarly, a considerable number of respondents (42%) agreed with insufficient confidence to integrate ICTs into their teaching practices (M = 3.06) and lack of digital skills to use ICT effectively 42% of TEs (M = 2.94).

Table 4

Individual Level Challenges of ICT Integration

Statements	%					M	SD
	SD	DA	U	A	SA		
I don't have necessary digital skills to use ICT in my teaching effectively	10	36	12	34	8	2.94	1.20
I don't have ICT integration plan	16	32	14	24	14	2.88	1.33
I don't feel confident in my ability to integrate ICT into my teaching practices	20	12	26	26	16	3.06	1.36
I don't have sufficient time to prepare ICT integrated lessons	16	22	30	26	6	2.84	1.16
I am not confident in my pedagogical knowledge	10	14	18	34	24	3.48	1.28
I don't have sufficient personal devices to integrate ICT	4	26	16	36	18	3.38	1.17
Grand Mean						3.08	1.25

In contrast, a notable portion of respondents did not firmly agree that lack of ICT integration plan and lack of time to prepare ICT-integrated lessons are major obstacles to using ICT in their teaching-learning activities, with cumulative percentages of agreement of respondents for these statements being 38% and 32%, respectively.

The quantitative results show that most TEs do not incorporate a variety of ICT tools, including basic ones, into their instructional practices. The findings also highlight various individual and institutional challenges that TEs perceive as obstacles to effective ICT integration.

Similar to the quantitative result, the qualitative data from individual interviews revealed critical institutional and individual-level challenges that TEs face when integrating ICT into their instructional practices. The qualitative findings of this study reveal two main themes underlying institutional-level challenges: infrastructure and resources, and institutional ICT planning and support. From these themes, three critical challenges emerged, consistently highlighted by all interviewees (100%) across the colleges involved in this study: insufficient pedagogical support for teacher educators (TEs), inadequate in-service training opportunities, and lack of adequately equipped classrooms. Colleges lack structured guidance and adequate resources to support TEs in delivering quality education, and limited access to professional development constrains their ability to keep pace with contemporary educational demands. Several participants emphasized that effective ICT integration requires both pedagogical knowledge and technical competence; however, they reported insufficient institutional support to develop these skills. For instance, one TE explained that although efforts are made to incorporate ICT into classroom practice, the absence of formal training creates uncertainty about whether ICT is being used appropriately, noting that “official training has never been conducted for TEs in our college” (TE1).

Institutional support for ICT integration was widely perceived as inadequate across all participant groups. Similar to TE1, DHI3 acknowledged a lack of pedagogical guidance and formal institutional training for incorporating ICT into teaching and learning. As the ICT department head, DHI3 admitted that although ICT training sessions are planned annually, none have been implemented to date. However, ICT support is generally provided informally when staff experience challenges, suggesting the absence of organized and sustained professional development initiatives.

This lack of institutional direction was consistently echoed by all participants, including college deans, who unanimously reported the absence of a clearly defined and operational ICT plan. While institutions reportedly possess ICT plans and allocated budgets, participants emphasized that these plans lack concrete technical details, infrastructural specifications, and clear mechanisms for implementation, monitoring, and evaluation. As a result, progress in ICT integration remains limited and fragmented.

In addition to planning and training gaps, participants frequently cited infrastructural constraints as a major institutional challenge. Issues such as limited access to ICT equipment, slow internet connectivity, frequent power interruptions, and insufficient maintenance services were repeatedly mentioned. Half of the TE interviewees indicated that the scarcity of essential resources discourages them from integrating ICT into their teaching. For example, several participants reported preparing digital instructional materials but being unable to use

them in classrooms due to the limited availability of LCD projectors, forcing them to rely on printed handouts instead.

Beyond institutional factors, the findings also revealed substantial individual-level challenges that further hinder ICT integration. These challenges were grouped into three major themes: digital skills and knowledge, access to personal ICT tools, and planning and preparation. A large proportion of participants (83%) reported limitations in pedagogical knowledge, confidence, and ICT integration skills, which affected their ability to align technology use with instructional objectives. Many participants noted that they focused more on operating technology than on designing ICT-supported pedagogical strategies, often finding ICT-based lesson planning time-consuming and confidence-reducing.

Access to personal ICT tools also emerged as a significant barrier, with 83% of participants reporting inadequate access to personal computers and reliable internet connectivity. Some TEs relied heavily on shared institutional computers, which were often unavailable due to high demand, further constraining lesson preparation and ICT use.

Finally, all participants acknowledged the absence of a structured personal ICT integration plan, which they believed negatively influenced their teaching practices. While some TEs reported using ICT flexibly and selectively based on perceived instructional value, the lack of deliberate plans limited systematic and effective integration. Overall, participants' responses underscore the combined impact of institutional and individual barriers and highlight the urgent need for structured training, clear planning, and improved resource provision to support meaningful ICT integration in teaching and learning.

Discussion

This study aimed to explore how TEs utilize ICT in their Biology teaching and how their personal characteristics influence these practices. It also explored the challenges that TEs face in integrating ICT in colleges of teacher education. The overall findings from the quantitative and qualitative data revealed that TEs predominantly use specific ICT tools such as web browsers, email, Microsoft Office, and social media in their teaching. The study revealed an intriguing paradox: while the majority of TEs (83%) confidently believed that ICT is essential for teaching challenging biology concepts, a significant number did not translate this belief into practice. Between 14% and 42% of TEs reported that they use ICT tools like LCD projectors and advanced software only occasionally, and 8% to 26% admitted to never using them at all. Besides, one-sample t-test results indicate that TEs' ICT usage is not significantly above average, suggesting only a moderate level of ICT integration. This gap underscores disconnects between their beliefs and classroom practices, pointing to potential barriers to ICT adoption in teaching.

Studies show that positive ICT beliefs often enhance its use in education (Halim & Sulaiman, 2020; Ngao et al., 2022). However, our findings align with Taimalu and Luik (2019), revealing no significant link between TEs' ICT beliefs and their actual usage. In addition, the limited use of advanced tools like animations, simulations, and specialized software among many TEs aligns with findings from studies by Scherer et al. (2019), where a significant portion of educators rarely or never engage with these resources. This suggests a

missed opportunity to enhance lesson delivery and engagement through the use of more dynamic presentation tools, which could potentially improve the learning experience.

Studies have shown that teachers tend to adopt technologies that are easy to use, readily available, and perceived as beneficial for their instructional needs (Tondeur et al., 2017). However, research suggests that the effective integration of ICTs, beyond just basic tools, can enhance student engagement, improve learning outcomes, and promote higher-order thinking skills (Dini et al., 2024). Therefore, the result of this study highlights the importance of providing TEs with the necessary support, training, and resources to integrate a wider range of ICT tools into their instructional activities in order to maximize the potential benefits for student learning.

A one-way ANOVA shows a significant difference in ICT integration between TEs aged 31-40 and those aged 41-50, with the younger group demonstrating higher integration levels. The observed effect size ($\eta^2 = 0.12$) represents a moderate practical significance, indicating that the difference between these age groups is educationally meaningful. This suggests that age contributes appreciably to variations in ICT integration practices, with early-career teachers being more open to new technologies while more experienced teachers may be resistant or lack confidence and skills. Additionally, TEs with 11-20 years of experience show higher ICT integration than those with 21-30 years with a large effect size ($\eta^2 = 0.16$), indicating considerable variation in ICT use, aligning with Tondeur et al. (2017) on the complex relationship between experience and technology use. Moreover, the study's findings indicate that older, more experienced teachers generally have less ICT usage. This aligns with research by Bingimlas (2018), which identified age and experience as significant factors in technology adoption and integration. Similarly, Basargekar and Singhavi (2017) found notable differences in perceptions based on teachers' age and years of experience. Kollia et al. (2020) also reported that older, more experienced instructors are less likely to incorporate ICT due to negative perceptions and reluctance to change. However, Abidoye and Adeyemi (2020) found that in Nigeria, Biology teachers' perceived ICT usage for instructional activities did not significantly differ based on their teaching experience.

Unlike the finding of this study, Peng et al. (2023) suggests that experienced teachers can be more effective at integrating ICT due to their deeper understanding of pedagogical practices and their ability to leverage technology effectively. These variations in ICT utilization by age and teaching experience underscore the importance of tailored professional development programs that address the unique needs and contexts of TEs.

The findings of this study identified insufficient pedagogical support, inadequate in-service training opportunities, lack of classrooms with the necessary facilities, and a lack of a clear institutional ICT plan as key institutional-level challenges of TEs in confidently integrating both basic and advanced ICT tools into their teaching process. These findings are consistent with Ghavifekr and Rosdy's (2015) emphasis on the importance of professional development programs for teachers to enhance their pedagogical skills in using ICT. Studies by Bingimlas (2018) and Yizengaw and Nigussie (2023) identified lack of access to resources as a major barrier to ICT integration. As Tondeur et al. (2017) note, the absence of a well-defined institutional ICT plan is a great challenge. He highlighted the need for a clear, shared vision and strategic planning for successful ICT integration in educational institutions.

Whereas, lack of confidence in pedagogical knowledge, limited access to personal devices, and insufficient digital skills and confidence are key individual level challenges. Furthermore, the time-consuming nature of creating lessons and experimental tasks using ICT and a preference for traditional teaching methods are found as barriers. This finding is in line with a study by Taimalu and Luik (2019), who found that teachers' self-efficacy beliefs are significant predictors of their ICT integration in teaching. This finding is also consistent with Joshi and Khatiwada (2024), who identified lack of personal access to computers as a significant barrier to ICT integration. Moreover, this result is consistent with Nzika (2019), who observed that those lecturers' insufficient perceived ICT abilities hinder them from effectively using educational technologies in teaching. Overall, the findings of this study emphasize the need for tailoring professional development programs to the individual requirements and settings of TEs at various career stages in order to achieve education goals in developing countries such as Ethiopia in science courses like Biology.

Conclusion

The study concluded that most TEs primarily use basic ICT tools when teaching biology, underutilizing more sophisticated ones which could help them to improve instruction and student participation. The study discovered that, in comparison to their older and more experienced peers, younger and less experienced TEs exhibit higher degrees of ICT integration. Offering professional development programs specifically designed to meet the requirements and circumstances of TEs at various career phases is crucial.

According to this study, main institutional-level challenges include insufficient pedagogical support, inadequate in-service training, a lack of well-equipped classrooms, and the absence of a clear institutional ICT plan. At the individual level, TEs struggle with limited confidence in their pedagogical knowledge, access to personal devices, and digital skills, as well as a preference for traditional teaching methods.

Given these conclusions, we recommend that teacher education colleges devote more attention to the use of ICT for teaching and learning. They should provide comprehensive support, training, and resources to enable TEs to effectively integrate a wider range of ICT tools into their teaching, thereby maximizing the potential benefits for student learning and engagement. TEs should also make excellent use of technology in their lessons in a way that their prospective teachers can embrace the benefits of ICT in educational practices.

Limitations of the study

The study was limited to Biology TEs in three colleges of teacher education in Ethiopia; this restricts the results' generalizability beyond these specific institutions. Therefore, future studies in this area should encompass a more diverse range of colleges and TEs in other fields of study to gain broader insights into TEs ICT integration practices and the challenges they encounter. Furthermore, TEs’ age and teaching experience were the only demographic characteristics involved in this study. Future research should take into account additional parameters.

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