



## Generation-Z Preservice Biology Teachers' Beliefs in Using Technology in Their Future Classroom

Ahmad Kamal Sudrajat<sup>1\*</sup>, Dita Purwinda Anggrella<sup>2</sup>, Ahmad Iskak Nugroho<sup>3</sup>, Zainudin bin Hassan<sup>4</sup>

<sup>1</sup>Department of Biology Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia

<sup>2</sup>Tadris Biologi Study Program, Faculty of Tarbiyah, Universitas Islam Negeri Raden Mas Said Surakarta, Surakarta, Indonesia

<sup>3</sup>Departement of Science Education, Faculty of Mathematics and Natural Sciences, Universitas Negeri Malang, Malang, Indonesia

<sup>4</sup>School of Education, Faculty of Social Sciences and Humanities, Universiti Teknologi Malaysia, Johor Bahru, Malaysia

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#### \*Corresponding Author

Email address:

[kamalsudrajat@uny.ac.id](mailto:kamalsudrajat@uny.ac.id)

### ABSTRACT

Technology integration has become an important priority in education, particularly in preparing future teachers to use digital tools effectively in classroom practice. Limited attention, however, has been given to how Generation Z preservice biology teachers perceive technology integration in their future teaching. This study aimed to investigate their beliefs about using technology in biology learning, with particular attention to perceived benefits, functional roles of technology, external influences, and gender differences. A quantitative survey design was employed using a Likert-scale questionnaire. Data were collected from 94 final-semester preservice biology teachers at two public state universities in Indonesia. The data were analyzed using descriptive and inferential statistics to examine patterns of beliefs and differences by gender. The findings showed that male participants reported slightly higher average technological proficiency than female participants, although the difference was not statistically significant. Student engagement emerged as the most influential factor shaping preservice teachers' beliefs about using technology, followed by the function of technology and external factors. No significant gender differences were found across these three factors. These findings suggest that Generation Z preservice biology teachers, regardless of gender, demonstrate comparable readiness to integrate technology into biology learning. Implications of the study indicate that teacher education programs should prioritize the development of advanced technology-integration competencies and provide training that emphasizes pedagogical readiness rather than gender-based differentiation.

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## 1. INTRODUCTION

Technology has become an integral part of contemporary life and has significantly transformed how individuals learn, interact, and access information (Sailer et al., 2021). Educational environments have particularly benefited from this transformation because digital tools enable wider and faster access to knowledge through the internet, e-books, and online learning platforms (Haleem et al., 2022; Katzensteiner et al., 2022). Digital technology also allows learners to study more independently, engage in virtual discussions, and use educational applications that can support deeper understanding of subject matter (Kerimbayev et al., 2023; Setiawan & Rodgers, 2024). Educational technology therefore plays a central role in creating more interactive, flexible, and responsive learning environments that align with the demands of contemporary education (Szymkowiak et al., 2021).

Biology education represents a discipline in which technology integration is particularly important because many biological concepts are abstract, dynamic, and difficult to visualize through conventional instruction alone (Tapilouw, 2022). Previous studies have shown that technology can support biology learning through interactive media, animated videos, augmented reality, and virtual laboratories (Putri et al., 2024; Weng et al., 2020). Virtual laboratory environments, for example, allow students to conduct simulations of experimental activities without being constrained by the limited availability of physical laboratory tools and materials (Abdelmoneim et al., 2022). Technology integration in biology learning can therefore strengthen

conceptual understanding while also promoting critical and analytical thinking in the exploration of biological phenomena (Stadlinger et al., 2021; Utomo et al., 2020).

Challenges in integrating technology into biology learning, however, remain substantial from the teacher's perspective. Limited infrastructure, insufficient pedagogical preparation, and uneven digital competence continue to hinder teachers and preservice teachers from using technology effectively in instructional practice (Dai, 2023; Zhang et al., 2026). Similar concerns have been reported across different educational settings, where inadequate training and limited exposure to technology-rich pedagogy reduce teachers' readiness to adopt digital tools in pedagogically meaningful ways (Shi et al., 2025). Additional difficulties emerge when teachers are expected to implement more interactive forms of technology-enhanced learning, including virtual simulations, augmented reality, and digital laboratories in biology instruction (Anggrella & Sudrajat, 2024). These conditions highlight the urgent need to strengthen teacher preparation programs so that future educators are better equipped to meet the demands of 21st-century science education (Timotheou et al., 2023).

Beliefs about technology use constitute an important dimension of teacher readiness because beliefs shape how future teachers perceive the value, usefulness, and practicality of digital tools in teaching and learning. Positive beliefs about technology have been associated with greater motivation, stronger engagement, and more effective use of digital resources in educational settings (Carstens et al., 2021). Preservice teachers who perceive technology as beneficial for learning are more likely to explore digital resources and develop the pedagogical competencies required for technology-integrated instruction (Latip et al., 2023). Examination of preservice teachers' beliefs is therefore essential for understanding their readiness to design and implement technology-based learning, particularly in a subject such as biology that requires both conceptual explanation and visual representation (Crompton & Sykora, 2021).

Generation Z preservice teachers occupy a distinctive position in this discussion because they have grown up in an environment shaped by digital technology (Szymkowiak et al., 2021). Familiarity with technology, however, does not automatically translate into pedagogical readiness to use it effectively in future classrooms (Pratama et al., 2024). Previous studies have widely examined digital competence, technology integration, and teacher readiness, yet limited attention has been given to how Generation Z preservice biology teachers perceive technology use specifically in relation to their future teaching practice and the factors shaping those perceptions (Sudrajat et al., 2024a; Sudrajat et al., 2025). Greater attention to this population is needed because their beliefs may influence how technology is adopted, adapted, and enacted in biology learning contexts (Calvo-Porrall & Pesqueira-Sanchez, 2020).

This study therefore investigates Generation Z preservice biology teachers' beliefs about the use of technology in classroom learning, with particular attention to their readiness to integrate technology into future teaching practice and the factors influencing those beliefs. Focus on this group is expected to contribute to the literature by clarifying whether familiarity with digital technology among Generation Z is accompanied by confidence and pedagogical readiness for classroom integration (Lee & Coughlin, 2015). Findings from this study are also expected to provide practical insight for teacher education programs in designing more targeted strategies, including structured and hands-on experiences with educational technology, to strengthen preservice teachers' readiness and confidence in technology-integrated biology instruction.

## 2. MATERIAL AND METHOD

### *Research Design*

This study followed a structured quantitative survey workflow designed to examine Generation Z preservice biology teachers' beliefs about the use of technology in learning and to identify factors associated with those beliefs (Cohen et al., 2018). The overall research procedure is illustrated in Figure 1, beginning with the formulation of the research design and the development of the instrument based on the study objectives and conceptual framework. The next stage involved establishing the quality of the instrument through validity and reliability procedures before determining the participants and administering the questionnaire through an online data collection process. Ethical requirements were then addressed by ensuring informed consent, confidentiality, and voluntary participation. After the data had been collected, a data screening stage was conducted to identify potential issues such as incomplete responses or outliers before proceeding to statistical analysis. The final stage focused on interpreting the results and drawing conclusions regarding the patterns of

beliefs and the influence of demographic characteristics, particularly gender, on the use of learning technology among preservice biology teachers.



Figure 1. Workflow Research

### **Instrument**

Data were collected using a structured questionnaire consisting of three sections. The first section gathered demographic information, including gender, age, and university affiliation. The second section measured participants' beliefs about the use of learning technology and consisted of 22 items. The third section examined factors influencing those beliefs and consisted of 16 items. All belief-related items were rated on a five-point Likert scale ranging from strongly disagree to strongly agree. The questionnaire items were adapted from Baek et al. (2008) and were modified to align with the context of Generation Z preservice biology teachers.

To establish content validity, the instrument was reviewed by experts in educational technology and biology education, and revisions were made based on their feedback. Construct validity was examined through exploratory factor analysis to assess the underlying factor structure of the instrument. Reliability was evaluated using Cronbach's alpha coefficient, and all constructs demonstrated acceptable internal consistency with alpha values above 0.70. To strengthen methodological transparency, the specific results of expert validation, exploratory factor analysis, and reliability testing should be reported in the final manuscript, including the number of experts involved, the factor-loading criteria, and the alpha coefficients for each construct.

### **Participant and Data Collection Procedure**

The participants were 94 final-semester preservice biology teachers recruited from two public state universities in Indonesia. Of the total participants, 84 were female and 10 were male. Final-semester students were selected because they had completed most of their pedagogical coursework and teaching practice, making them well positioned to reflect on their readiness to integrate technology into future teaching. Data collection was conducted over a four-week period. The questionnaire was administered online to facilitate participant access and response efficiency. Participants were provided with information about the purpose of the study and instructions for completing the questionnaire. Participation was voluntary, and no incentives were offered. Respondents were encouraged to answer the questionnaire honestly based on their own experiences and beliefs regarding the use of technology in learning.

### **Data Analysis**

The data were analyzed using descriptive and inferential statistical techniques. Descriptive statistics were used to summarize participant characteristics and overall patterns of beliefs about technology use. Prior to inferential testing, the assumptions of normality and homogeneity of variance were examined. Inferential analysis was then conducted to examine gender-based differences in technological proficiency and in the three belief-related factors, namely external factors, function of technology, and student engagement. Given that the comparison involved two independent gender groups, the analysis was performed using one-way ANOVA, which is statistically equivalent to an independent-samples t-test for two-group comparisons. Statistical significance was determined at the 0.05 level.

### Ethical Considerations

Ethical approval for the study was obtained from the relevant institutional authority at the participating universities. All participants provided informed consent prior to completing the questionnaire. Participants were informed about the purpose of the study, the voluntary nature of their participation, and their right to withdraw at any time without penalty. No personally identifiable information was collected, thereby ensuring respondent anonymity. The data were stored in password-protected files and were accessible only to the research team. The ethics approval reference number and data retention period should be added in the final version of the manuscript if available.

## 3. RESULTS

### The Influence of Gender on Learning Technology Proficiency

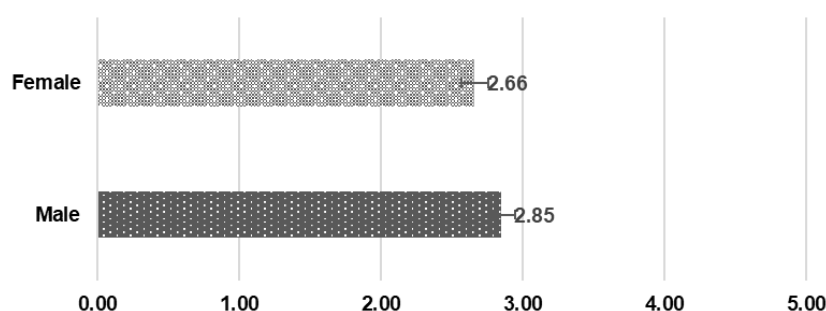


Figure 2. Average proficiency in using technology of preservice biology teachers

A descriptive comparison indicated a slight difference in learning technology proficiency between male and female preservice biology teachers, with male participants obtaining a higher mean score (2.85) than female participants (2.66). The pattern presented in Figure 2 suggests that the male group tended to report somewhat stronger perceived proficiency in using learning technology, although the numerical gap remained relatively small. This descriptive tendency may reflect the fact that gender-based variation in digital competence is sometimes still observable at the level of self-perception, even though the difference is often modest and context-dependent (Çebi & Reisoğlu, 2020; Scherer et al., 2023).

Table 1. Results of the analysis of the influence of gender on learning technology proficiency

		Sum of Squares	df	Mean Square	F	Sig.
Learning technology proficiency	Between Groups	.319	1	.319	2.144	.147
	Within Groups	13.703	92	.149		
	Total	14.023	93			

A one-way ANOVA was conducted to determine whether the observed difference was statistically meaningful, and the results are reported in Table 1. The analysis showed that the difference in learning technology proficiency between male and female participants was not statistically significant,  $F(1, 92) = 2.144$ ,  $p = .147$ , indicating that gender did not significantly explain variation in learning technology proficiency within this sample. This result suggests that the overall level of perceived technological proficiency was statistically comparable across genders, which is consistent with recent evidence showing that gender gaps among preservice teachers are often small or non-significant when technology access and learning exposure are relatively similar (Sudrajat et al., 2024a; Sergeeva et al., 2024).

### Factors Influencing Beliefs in Using Technology

Descriptive analysis of the three factors influencing preservice biology teachers' beliefs about using learning technology revealed a clear hierarchical pattern across the measured dimensions. Student engagement obtained the highest mean score (3.68), followed by function of technology (3.42), whereas external factors showed the lowest mean score (3.21). The distribution presented in

Figure 3 indicates that beliefs about technology use were shaped primarily by pedagogical considerations related to how technology could foster more active and engaging learning experiences. This pattern suggests that participants were more likely to value learning technology when they perceived it as capable of increasing student participation, interest, and classroom involvement, a tendency that has also been highlighted in recent studies on engagement-oriented technology use in education (David & Weinstein, 2024; Haleem et al., 2022).

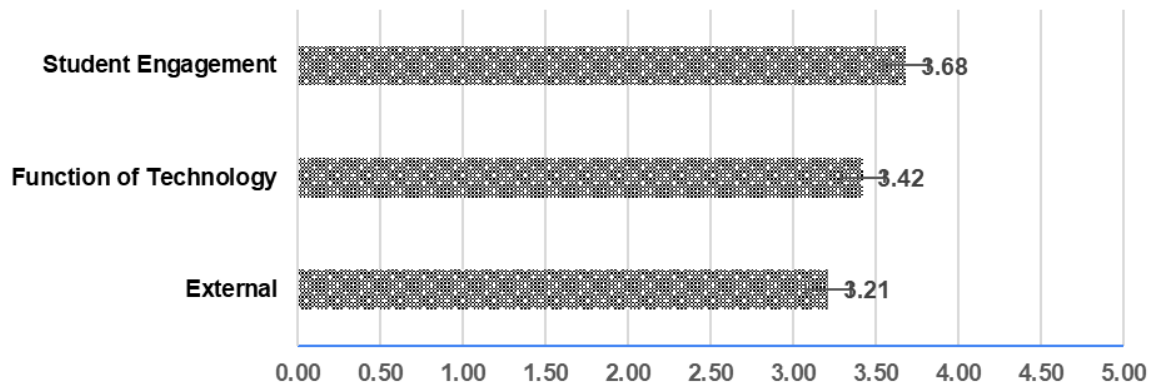


Figure 3. Factors that influence preservice biology teachers to use learning technology

The second-highest mean score for function of technology indicates that practical instructional considerations also played an important role in shaping participants' beliefs. Learning technology was not only viewed as a means of improving engagement, but also as a useful resource for supporting instructional delivery, classroom management, and learning evaluation. By contrast, the lower mean score for external factors suggests that environmental or institutional influences were perceived as less central than the direct pedagogical and functional benefits of technology. This result implies that internal beliefs about instructional value were more prominent than contextual support in encouraging technology use, which is consistent with studies emphasizing the importance of perceived utility and motivational transfer in technology adoption among teachers (Backfisch et al., 2021; Stumbrienė et al., 2024).

#### **Gender influence on factors that drive confidence to use learning technologies**

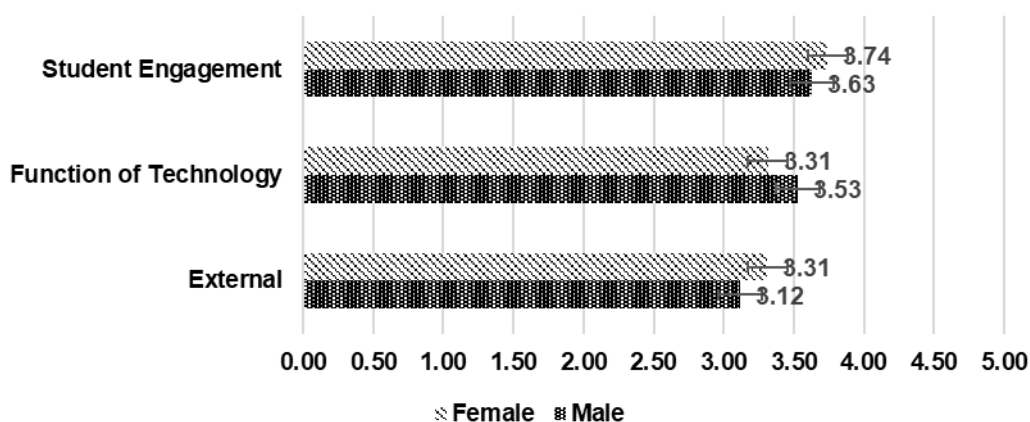


Figure 4. Average scores of factors that drive confidence to use gender-based learning technologies

A descriptive comparison of the three belief-related factors showed only minor gender-based variation in the average scores. Female participants reported slightly higher mean scores in student engagement (3.74 vs. 3.63) and external factors (3.31 vs. 3.12), whereas male participants obtained a somewhat higher mean score in function of technology (3.53 vs. 3.31). The pattern displayed in [Figure 4](#) indicates that both groups shared broadly similar perceptions of the factors that encouraged confidence in using learning technology, with the observed differences appearing relatively small across all three dimensions. These descriptive results suggest that male and female preservice biology teachers differed only marginally in the relative emphasis they placed on engagement-related, functional, and external considerations when evaluating learning technology.

**Table 2.** T-test results of the influence of gender on each factor

		Sum of Squares	df	Mean Square	F	Sig.
External Factor	Between Groups	.321	1	.321	.737	.393
	Within Groups	40.088	92	.436		
	Total	40.409	93			
Function of Technology	Between Groups	.412	1	.412	.646	.424
	Within Groups	58.595	92	.637		
	Total	59.007	93			
Student Engagement	Between Groups	.112	1	.112	.184	.669
	Within Groups	56.171	92	.611		
	Total	56.283	93			

Inferential testing was conducted to examine whether the observed mean differences represented statistically meaningful gender-based variation, and the results are presented in [Table 2](#). The one-way ANOVA showed that no significant gender differences were found in external factors,  $F(1,92) = .737$ ,  $p = .393$ , function of technology,  $F(1, 92) = .646$ ,  $p = .424$ , or student engagement,  $F(1,92) = .184$ ,  $p = .669$ . These findings indicate that gender did not significantly influence how preservice biology teachers perceived the role of learning technology across the three examined factors. The overall pattern therefore points to a relatively comparable belief structure between male and female participants, which is consistent with recent studies suggesting that gender-related differences in preservice teachers' technology beliefs are often limited or domain-specific rather than broadly distributed across all dimensions ([Sudrajat et al., 2024a](#); [Sergeeva et al., 2024](#)).

#### 4. DISCUSSION

##### *The Influence of Gender on Learning Technology Proficiency*

The pattern of scores reported in [Figure 1](#) indicates only a marginal difference in learning technology proficiency between male and female preservice biology teachers, with male participants showing a slightly higher mean score. This descriptive tendency, however, was not supported by statistical evidence, as the ANOVA results presented in [Table 1](#) showed that the gender-based difference was not significant. Taken together, these findings suggest that technological proficiency in this sample was distributed in a broadly comparable manner across gender groups, rather than being meaningfully differentiated by gender. Such a result may reflect the increasingly shared nature of digital access, exposure, and participation in contemporary higher education, where both male and female students are embedded in technology-rich academic environments ([Mothafar et al., 2024](#); [Qazi et al., 2022](#)). A similar tendency has been noted in recent studies indicating that gender disparities in digital competence are becoming less pronounced, particularly among younger cohorts whose everyday learning practices are closely intertwined with digital technologies ([Gnams, 2021](#); [Sudrajat et al., 2024a](#)).

The convergence of the descriptive trend in [Figure 1](#) and the non-significant inferential result in [Table 1](#) further suggests that gender, by itself, may no longer provide a sufficiently robust explanation for variations in technology-related proficiency among preservice teachers. A more plausible interpretation is that technological competence is shaped by a broader constellation of factors, including prior digital experience, learning opportunities, individual interest, and the availability of institutional support ([Huffman et al., 2013](#); [Moreira-Choez et al., 2024](#)). Viewed from this perspective, the present finding carries an important implication for teacher education: efforts to strengthen technology integration should be oriented toward expanding equitable access to training, infrastructure, and pedagogically meaningful digital experiences, rather than relying on gender-based assumptions about technological capability ([Kang et al., 2019](#); [Niiranen, 2017](#)).

### **Factors Influencing Beliefs in Using Technology**

The hierarchical pattern displayed in [Figure 2](#) shows that student engagement emerged as the most influential factor shaping preservice biology teachers' beliefs about the use of learning technology, followed by function of technology and external factors. This ordering suggests that participants primarily valued technology for its perceived pedagogical capacity to foster more interactive, motivating, and participatory learning experiences. Such an emphasis is theoretically meaningful because beliefs about technology use are often strengthened when digital tools are perceived not merely as technical add-ons, but as pedagogical resources capable of enhancing students' attention, involvement, and active participation in the learning process ([David & Weinstein, 2024](#); [Haleem et al., 2022](#)). In the context of biology education, this finding is particularly relevant, as technology can support visualization, interactivity, and the exploration of abstract or dynamic biological concepts that may be less accessible through conventional instruction alone ([Imtinan et al., 2023](#); [Putri et al., 2024](#)).

A second pattern evident from [Figure 2](#) is the relatively high positioning of function of technology, indicating that preservice teachers also attached considerable importance to the practical usefulness of digital tools in instructional delivery, classroom management, and learning evaluation. This result suggests that technology was not perceived solely in motivational terms, but also in instrumental terms, namely as a resource that can improve the efficiency, organization, and effectiveness of teaching practice. Such an interpretation aligns with previous literature showing that perceived usefulness remains a central determinant of educational technology adoption, particularly when technology is understood as supporting both pedagogical performance and instructional decision-making ([Backfisch et al., 2021](#); [Crompton & Sykora, 2021](#)). Viewed from this perspective, teacher education programs should not limit technology preparation to issues of engagement alone, but should also strengthen preservice teachers' understanding of how digital tools can function within the everyday realities of pedagogical work ([Sudrajat et al., 2025](#); [Timotheou et al., 2023](#)).

The lower position of external factors in [Figure 2](#) further indicates that participants' confidence in using learning technology was driven more strongly by internally perceived pedagogical value than by external encouragement or institutional support. This does not imply that policies, infrastructure, peer support, or lecturer encouragement were unimportant; rather, it suggests that these influences were considered less central than the direct educational benefits of technology itself. Such a pattern may reflect the characteristics of Generation Z preservice teachers, who tend to be more familiar with digital environments and therefore more likely to evaluate technology through the lens of personal usefulness and instructional relevance than through external pressure alone ([Baek et al., 2008](#); [Stumbrienė et al., 2024](#)). A further implication is that stronger intrinsic endorsement of technology may provide a more sustainable basis for meaningful and innovative educational use than reliance on external conditions alone ([Goroizidis & Papaioannou, 2016](#); [Sudrajat et al., 2024b](#)).

### **Gender Influence on Factors That Drive Confidence to Use Learning Technologies**

The pattern presented in [Figure 3](#) indicates that male and female preservice biology teachers showed only minor variation in the mean scores of student engagement, function of technology, and external factors. This descriptive similarity was reinforced by the inferential evidence reported in [Table 2](#), which showed that none of the observed differences reached statistical significance. Taken together, these findings suggest that gender did not function as a meaningful differentiating factor in shaping how participants perceived the role of learning technology across the three dimensions examined. Rather than reflecting gender-based distinctions, the results point to a broadly shared evaluative framework in which male and female preservice biology teachers interpreted the value of learning technology in largely comparable ways. This pattern is consistent with studies suggesting that gender may not always be a decisive factor in technology-related beliefs, particularly when participants are situated in educational contexts characterized by expanding digital access and increasing exposure to technology-integrated learning environments ([Akawo et al., 2025](#); [Timotheou et al., 2023](#)).

A further interpretation of the convergence between [Figure 3](#) and [Table 2](#) is that the technological background of Generation Z may have contributed to a more uniform orientation toward learning technology across gender groups. Having grown up with digital devices, online communication, and technology-mediated forms of learning, individuals from this generation may develop relatively similar levels of familiarity, comfort,

and expectations regarding educational technology use (Chang & Chang, 2023; Szymkowiak et al., 2021). Previous work has likewise suggested that generational characteristics can shape patterns of technology adoption when digital practices become embedded in routine academic and social life (Calvo-Porrall & Pesqueira-Sanchez, 2020; Lee & Coughlin, 2015). This interpretation should nevertheless be treated with caution, as the present study did not directly examine the influence of prior training, digital exposure, or pedagogical preparation on participants' beliefs. A plausible possibility is that relatively similar teacher education experiences may have contributed to the comparable patterns observed across gender, but this remains an empirical question that warrants further investigation (Dumford et al., 2023; Pratama et al., 2024).

### **Research Implication and Limitation**

This result provides a strong basis for educational institutions to design learning technology development programs that are free of gender bias. This is advanced by the fact that preservice teacher students already have strong technological skills. However, this study has limitations. First, the study was conducted using self-assessment. Self-assessment has the weakness of less objective results. Second, the sample size was unbalanced between males and females, so generalizations of the data should be made with caution. However, this unbalanced sample size is characteristic of biology study programs. Future research is recommended to use tests or observations to measure the proficiency of prospective biology teachers in using technology. Furthermore, the study sample was very limited, which may affect the generalizability of the results. Future research is recommended to use a broader sample and involve various study programs including balancing the sample size between males and females.

## **5. CONCLUSION**

This study demonstrates that Generation Z preservice biology teachers hold generally positive beliefs about the use of learning technology in future teaching, with student engagement emerging as the most influential factor shaping those beliefs, while gender-based differences in technological proficiency and belief-related factors were not statistically significant. These findings indicate that preservice biology teachers' confidence in using technology is more closely associated with the perceived pedagogical value and functional usefulness of technology than with demographic differences. The study contributes to the literature by showing that engagement-oriented and utility-based considerations play a central role in shaping technology-related beliefs among preservice teachers. Practical implications suggest that teacher education institutions need to provide structured training, meaningful hands-on experiences with educational technology, and pedagogically grounded support for technology integration, particularly in biology education. Such efforts are expected to strengthen preservice biology teachers' readiness to respond effectively to the demands of technology-integrated teaching and learning in the digital era.

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