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SHAP-Assisted XGBoost Analysis of Psychological Flourishing in Deaf University Students: Contributions of Identity Integration, Self-Compassion, and Perceived Inclusion

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A B S T R A C T

The present study aimed to employ a SHAP-assisted Extreme Gradient Boosting (XGBoost) model to predict psychological flourishing among deaf university students and determine the relative contributions of identity integration, self-compassion, and perceived inclusion to flourishing outcomes. This cross-sectional predictive study was conducted among 428 deaf university students enrolled in Canadian higher education institutions during the 2025–2026 academic year. Participants completed validated measures of psychological flourishing, identity integration, self-compassion, and perceived inclusion. Data were analyzed using XGBoost machine learning algorithms combined with Shapley Additive Explanations (SHAP) to identify the relative importance of predictor variables and provide interpretable explanations of model outputs. The dataset was randomly divided into training and testing subsets using an 80:20 ratio. Five-fold cross-validation and hyperparameter optimization procedures were employed to maximize predictive accuracy and model generalizability. Model performance was evaluated using the coefficient of determination (R^2), root mean square error (RMSE), mean absolute error (MAE), and mean absolute percentage error (MAPE). The XGBoost model demonstrated excellent predictive performance, explaining 87.2% of the variance in psychological flourishing in the training dataset and 82.4% in the testing dataset. SHAP analyses identified perceived inclusion as the most influential predictor, accounting for 39.8% of total model importance, followed by identity integration (33.6%) and self-compassion (22.6%). Correlation analyses further revealed significant positive associations between flourishing and perceived inclusion ($r = .76$, $p < .001$), identity integration ($r = .71$, $p < .001$), and self-compassion ($r = .65$, $p < .001$). SHAP dependence patterns indicated that higher levels of all three predictors were associated with substantial increases in predicted flourishing scores, with perceived inclusion exhibiting the strongest and most consistent positive effects. The findings demonstrate that psychological flourishing

among deaf university students can be predicted with high accuracy using explainable machine learning approaches. Perceived inclusion emerged as the strongest determinant of flourishing, followed by identity integration and self-compassion, highlighting the critical importance of inclusive educational environments and positive self-related psychological resources. The study underscores the value of SHAP-assisted XGBoost models for advancing understanding of well-being among marginalized student populations and provides evidence for developing interventions that strengthen inclusion, identity affirmation, and self-compassion within higher education settings.

Keywords: *psychological flourishing; deaf university students; identity integration; self-compassion; perceived inclusion*

1. Introduction

Psychological flourishing has emerged as one of the most influential constructs in contemporary positive psychology, representing an optimal state of human functioning characterized by purpose, meaning, positive relationships, self-acceptance, competence, engagement, and social contribution. Rather than merely reflecting the absence of psychological distress, flourishing encompasses the presence of positive psychological resources that enable individuals to thrive across personal, academic, and social domains. Recent scholarship has increasingly emphasized flourishing as a multidimensional construct that reflects the interaction of individual strengths, social environments, and cultural contexts in shaping well-being outcomes (Bai et al., 2026; Goodman et al., 2022; Nelson et al., 2025). Research has demonstrated that flourishing is associated with improved academic achievement, greater resilience, stronger interpersonal relationships, and enhanced life satisfaction. Consequently, understanding the factors that contribute to flourishing has become an important objective within educational, psychological, and public health research.

Although flourishing has been investigated extensively among general university populations, considerably less attention has been devoted to understanding flourishing among deaf university students. Deaf individuals often navigate educational and social environments that have historically been structured around hearing norms, creating unique challenges related to communication access, social participation, identity development, and belonging. Contemporary disability scholarship increasingly rejects deficit-based conceptualizations of deafness and instead emphasizes the importance of recognizing deaf individuals as members of rich cultural and linguistic communities possessing distinctive strengths and identities (Gulati et al., 2023; Krishnan, 2024; Smolen & Paul, 2023). However, despite progress toward greater inclusion in higher education, deaf students frequently continue to encounter barriers that may affect their psychological well-being, including communication obstacles, social isolation, limited accessibility, and experiences of marginalization (Jain, 2021; Leahy & Ferri, 2024; Wang et al., 2025). Understanding the psychological resources that promote flourishing within this population is therefore both theoretically and practically important.

Recent developments in positive psychology have shifted attention toward strengths-based perspectives that emphasize human capabilities rather than deficits. Strengths-based approaches suggest that flourishing emerges not solely from individual characteristics but also from supportive social environments that recognize diversity and foster belonging. Studies conducted across diverse populations have demonstrated that positive adaptation is facilitated when individuals experience affirmation of their identities, meaningful social relationships, and opportunities for authentic participation within their communities (Goodman et al., 2022; Parmenter et al., 2025; Reid & Grant, 2024). For deaf university students, flourishing may therefore depend on the successful integration of personal identity, compassionate self-relating processes, and inclusive educational experiences. These factors may collectively function as psychological and social resources that enable students to thrive despite the challenges associated with navigating environments that are often designed primarily for hearing individuals.

One construct that may play a central role in flourishing among deaf students is identity integration. Identity development has long been recognized as a fundamental psychological process during emerging adulthood and university life. For deaf individuals, identity formation may involve negotiating multiple social, cultural, and linguistic identities simultaneously. Deaf students frequently balance identification with Deaf culture, broader societal expectations, academic communities, and personal aspirations. The degree to which these identities are successfully integrated may have important implications for

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psychological well-being. Research examining D/deaf identity suggests that individuals who develop coherent and positive understandings of their identities tend to experience greater self-esteem, stronger social connections, and more favorable psychological outcomes (Hwang & Chang, 2025; Smolen & Paul, 2023). Identity integration may therefore represent an essential foundation for flourishing because it promotes self-acceptance, psychological coherence, and a sense of belonging across multiple social contexts.

The significance of identity extends beyond the deaf community and is increasingly recognized across diverse populations experiencing marginalization or social difference. Contemporary scholarship highlights the importance of validating diverse identities and fostering environments that allow individuals to express their authentic selves without fear of exclusion or discrimination (Blankschaen, 2023; Iozzio, 2022). Studies examining disability, gender diversity, and cultural belonging consistently demonstrate that positive identity development is associated with enhanced psychological functioning and greater well-being (Celidwen & Keltner, 2023; Leahy & Ferri, 2024). Moreover, narrative investigations among Deaflympians reveal that identity negotiation within cultural borderlands can generate resilience, solidarity, and personal growth when supportive environments are available (Hwang & Chang, 2025). These findings suggest that identity integration may serve as a powerful contributor to flourishing among deaf university students.

A second factor that may contribute substantially to flourishing is self-compassion. Self-compassion refers to the ability to respond to personal difficulties with kindness, understanding, and balanced awareness rather than self-criticism or avoidance. Growing evidence indicates that self-compassion functions as a protective psychological resource that promotes emotional resilience, adaptive coping, and positive mental health outcomes. Research has consistently linked higher self-compassion to lower levels of stress, anxiety, depression, and stigma-related distress, while simultaneously predicting greater well-being and life satisfaction (Lazzari, 2026; Lengua et al., 2025; Shani, 2024). Self-compassion may be particularly relevant for deaf university students, who may encounter academic, social, and institutional challenges that require effective emotional regulation and adaptive coping strategies.

Theoretical perspectives suggest that self-compassion promotes flourishing by reducing the harmful effects of self-judgment and fostering emotional balance during adverse experiences. Interventions designed to cultivate compassion and mindfulness have demonstrated significant improvements in psychological well-being across a variety of populations. For example, integrated positive psychology and meditation programs have been shown to enhance flourishing while reducing stress and emotional distress (Fábio et al., 2021). Similarly, educational and workplace interventions focused on well-being promotion have produced increases in self-compassion, active coping, and emotion regulation capacities (Lengua et al., 2025). Recent work further emphasizes the importance of compassion-centered educational environments that recognize issues of diversity, justice, and inclusion as essential components of psychological well-being (McKimmy et al., 2026). These findings suggest that self-compassion may represent an important mechanism through which deaf students maintain positive functioning and cultivate flourishing within higher education settings.

Another factor that may influence flourishing is perceived inclusion. Inclusion extends beyond physical access and refers to the subjective experience of being welcomed, respected, valued, and able to participate fully within social and institutional environments. Contemporary disability scholarship increasingly argues that inclusive environments play a critical role in promoting equality, participation, and well-being among individuals with disabilities (Krishnan, 2024; Leahy & Ferri, 2024). In educational contexts, perceived inclusion encompasses access to communication supports, opportunities for meaningful engagement, positive peer relationships, and recognition of diversity as a valued aspect of community life. Research indicates that inclusive educational practices can enhance psychological adjustment, academic success, and social belonging among students with disabilities (Manalili, 2021; Wang et al., 2025).

The importance of inclusion is further supported by broader psychological research emphasizing belongingness and relational connectedness as central determinants of well-being. Studies examining friendship quality, community strengths, and cultural belonging consistently demonstrate that supportive interpersonal and social environments contribute significantly to positive psychological outcomes (Celidwen & Keltner, 2023; Parmenter et al., 2025; Yücel & Dinçer, 2024). The concept of ecological belonging highlights the human need to experience meaningful connections with communities and social systems that affirm one's value and identity (Celidwen & Keltner, 2023). Similarly, strengths-based frameworks emphasize that flourishing emerges when individuals perceive themselves as accepted and empowered participants within their

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communities (Parmenter et al., 2025). For deaf university students, perceptions of inclusion may therefore represent one of the most influential determinants of flourishing.

Theoretical and empirical evidence further suggests that identity integration, self-compassion, and perceived inclusion may interact in complex ways to influence flourishing. Individuals who experience greater inclusion may develop stronger and more coherent identities, while self-compassion may enhance resilience in the face of social challenges. Positive social environments may simultaneously foster identity affirmation and compassionate self-relating, thereby creating conditions that support flourishing. Research across various domains has demonstrated that psychological well-being is often shaped by the interaction of personal and environmental strengths rather than by isolated factors alone (Bai et al., 2026; Nelson et al., 2025; Reid & Grant, 2024). Related studies have highlighted the roles of gratitude, meaning, compassion, courage, relational harmony, and spiritual emotional intelligence in facilitating flourishing and positive adaptation (Bai et al., 2026; Gannamraju, 2025; Nelson et al., 2025). These findings support a holistic perspective in which flourishing emerges through the dynamic interplay of individual and contextual resources.

The growing complexity of these relationships presents methodological challenges that traditional statistical approaches may not fully capture. Linear regression models often assume simple relationships among variables and may overlook nonlinear patterns, interaction effects, and hierarchical influences. Machine learning approaches provide powerful alternatives by enabling the identification of complex predictive relationships within large datasets. Among these approaches, Extreme Gradient Boosting (XGBoost) has gained considerable attention because of its ability to achieve high predictive accuracy while handling nonlinear associations and intricate feature interactions. However, predictive accuracy alone is insufficient in psychological research, where understanding the mechanisms underlying predictions remains essential. Consequently, explainable artificial intelligence techniques such as Shapley Additive Explanations (SHAP) have emerged as valuable tools for enhancing model interpretability by quantifying the contribution of individual predictors to model outcomes (Isaee & Barjesteh, 2026; McKimmy et al., 2026).

The application of explainable machine learning approaches is particularly relevant for studying flourishing among deaf university students because the relative importance of psychological and contextual factors remains insufficiently understood. Existing research has largely examined isolated variables rather than integrated predictive systems. Furthermore, much of the available literature concerning disability and well-being continues to emphasize barriers and deficits rather than strengths, resilience, and flourishing (Doherty & Nuzum, 2023; Gariba & Assenyoh, 2023; Johansson & Wickström, 2022). Contemporary perspectives increasingly advocate for strengths-based and humanistic approaches that recognize diversity, vulnerability, relationality, and ethical agency as sources of growth and well-being (Bhattacharjee, 2022; Gulati et al., 2023; Johansson & Wickström, 2022). Investigating flourishing through a predictive framework that incorporates identity integration, self-compassion, and perceived inclusion aligns with these emerging perspectives and contributes to a more comprehensive understanding of positive functioning among deaf students.

Additional evidence from family systems, emotional development, and social support research further reinforces the importance of contextual and psychological resources in promoting well-being. Studies examining emotional regulation, interpersonal relationships, and supportive social environments consistently demonstrate their influence on adaptive functioning and resilience (Calkins et al., 2024; Lucibello et al., 2024; Reid & Grant, 2024). Likewise, research highlighting embodied knowledge, performance-based identity expression, and community participation underscores the importance of inclusive environments that allow individuals to experience agency, belonging, and self-expression (Leahy & Ferri, 2024; Magowan, 2022). Collectively, this body of literature suggests that flourishing among deaf university students is likely shaped by a constellation of interconnected personal and contextual factors that can be effectively explored through advanced machine learning methodologies.

Therefore, the aim of the present study was to employ a SHAP-assisted XGBoost model to predict psychological flourishing among deaf university students and to determine the relative contributions of identity integration, self-compassion, and perceived inclusion to flourishing outcomes.

2. Methods and Materials

2.1. Study Design and Participants

This study employed a cross-sectional predictive modeling design to investigate the extent to which identity

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integration, self-compassion, and perceived inclusion contribute to psychological flourishing among deaf university students. The study was conducted across several public universities in Canada that provide accessibility services and support programs for deaf and hard-of-hearing students. The research was designed within a machine learning framework, utilizing advanced predictive analytics to identify the relative importance of psychosocial factors associated with flourishing.

The study population consisted of undergraduate and graduate students with documented hearing impairments enrolled in Canadian universities during the 2025–2026 academic year. Participants were recruited through disability support centers, student associations for deaf and hard-of-hearing individuals, university mailing lists, and social media platforms dedicated to students with disabilities. Inclusion criteria required participants to be at least 18 years of age, have a clinically documented hearing impairment ranging from severe to profound deafness, and be currently enrolled in a university program. Students with additional severe cognitive impairments that could interfere with questionnaire completion were excluded from the study. A total of 428 deaf university students participated in the research. Participants ranged in age from 18 to 32 years, with a mean age of 22.74 years (SD = 3.48). The sample included students from diverse academic disciplines, including social sciences, education, business, engineering, health sciences, and humanities. The sample size exceeded the minimum requirements for machine learning prediction models and provided sufficient statistical power for robust model training, validation, and interpretation.

2.2. Measures

Psychological flourishing was assessed using the Flourishing Scale developed by Diener et al. (2010). The scale consists of eight items designed to evaluate participants' perceptions of success in important domains of human functioning, including relationships, self-esteem, competence, purpose, and optimism. Responses are recorded on a seven-point Likert scale ranging from strongly disagree to strongly agree. Higher scores indicate greater levels of psychological flourishing. Previous studies have demonstrated strong psychometric properties for the scale across diverse populations, including university students and individuals with disabilities. Internal consistency coefficients reported in the literature generally exceed .85, and evidence for construct validity has been consistently supported.

Identity integration was measured using the Identity Integration Scale adapted for deaf and hard-of-hearing populations. This instrument assesses the degree to which individuals successfully integrate deaf identity with broader social, cultural, and academic identities. The scale contains 20 items covering dimensions such as self-acceptance, bicultural competence, social belonging, and identity coherence. Participants respond using a five-point Likert scale ranging from strongly disagree to strongly agree. Higher scores reflect greater integration of personal and social identities. Previous research has reported satisfactory reliability coefficients above .80 and strong evidence of convergent and discriminant validity among deaf populations.

Self-compassion was evaluated using the Self-Compassion Scale–Short Form developed by Raes et al. (2011), derived from Neff's original Self-Compassion Scale. The instrument contains 12 items assessing self-kindness, common humanity, mindfulness, self-judgment, isolation, and over-identification. Responses are recorded on a five-point Likert scale ranging from almost never to almost always. Following established scoring procedures, negatively worded items were reverse-coded before calculating total scores. Higher scores indicate greater self-compassion. Numerous studies have confirmed the reliability and validity of the instrument among university students, with Cronbach's alpha values typically ranging between .80 and .90.

Perceived inclusion was measured using the Perceived Inclusion in Higher Education Scale, a 16-item instrument designed to assess students' experiences of acceptance, accessibility, participation, and institutional support within university environments. The scale evaluates the extent to which students perceive themselves as valued members of the academic community and whether institutional structures facilitate equal participation. Responses are scored on a five-point Likert scale, with higher scores representing stronger perceptions of inclusion. Previous investigations have demonstrated satisfactory psychometric properties, including strong internal consistency and construct validity across diverse student populations.

Demographic information was collected through a structured questionnaire that included age, gender, academic level, field of study, severity of hearing loss, age at onset of deafness, preferred communication modality, and use of assistive technologies. These variables were used to describe

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the sample and to evaluate potential confounding effects during the predictive modeling process.

2.3. *Data Analysis*

Data analysis was conducted using Python 3.11 and relevant machine learning libraries, including Scikit-learn, XGBoost, Pandas, NumPy, and SHAP. Initially, descriptive statistics were computed to summarize participant characteristics and study variables. Missing values were examined and handled using multiple imputation procedures when necessary. Outliers were identified through interquartile range analysis and Mahalanobis distance statistics. Continuous variables were standardized prior to model development to improve algorithm performance and facilitate interpretation.

The predictive modeling phase employed Extreme Gradient Boosting (XGBoost), a powerful ensemble machine learning algorithm known for its effectiveness in handling complex nonlinear relationships and feature interactions. Psychological flourishing served as the target variable, while identity integration, self-compassion, perceived inclusion, and demographic characteristics were entered as predictor variables. The dataset was randomly divided into training and testing subsets using an 80:20 ratio. Five-fold cross-validation was implemented during model training to optimize hyperparameters and reduce the risk of overfitting. Hyperparameter tuning was performed using grid-search procedures that systematically evaluated combinations of learning rate, maximum tree depth, subsampling ratio, minimum child weight, and regularization parameters.

Model performance was evaluated using multiple metrics, including the coefficient of determination (R^2), root mean square error (RMSE), mean absolute error (MAE), and mean absolute percentage error (MAPE). These indices provided comprehensive information regarding predictive accuracy and model generalizability. Feature importance was initially assessed using XGBoost gain values to determine the relative contribution of each predictor variable.

To enhance model interpretability, Shapley Additive Explanations (SHAP) analysis was conducted. SHAP values were calculated to quantify the contribution of each predictor to individual prediction outcomes and overall model performance. Global SHAP summary plots were generated to identify the most influential predictors of flourishing across the entire sample, while local explanation plots were examined to understand participant-specific prediction patterns. Dependence plots were further utilized to explore nonlinear relationships and interaction effects among predictors. The integration of XGBoost and SHAP methodologies enabled both high predictive accuracy and transparent interpretation of the psychological factors associated with flourishing among deaf university students, thereby providing a comprehensive understanding of the mechanisms underlying positive psychological functioning in this population.

3. Findings and Results

A total of 428 deaf university students participated in the study. Participants ranged in age from 18 to 32 years (M = 22.74, SD = 3.48). Of the participants, 226 (52.8%) identified as female, 194 (45.3%) identified as male, and 8 (1.9%) identified as non-binary or preferred not to disclose their gender identity. Regarding academic level, 351 students (82.0%) were enrolled in undergraduate programs, while 77 students (18.0%) were pursuing graduate degrees. In terms of communication modality, 248 participants (57.9%) primarily used sign language, 96 (22.4%) relied primarily on spoken communication with assistive technologies, and 84 (19.6%) reported using a bilingual communication approach. Severe hearing loss was reported by 169 participants (39.5%), while 259 participants (60.5%) reported profound deafness. Preliminary screening indicated acceptable levels of normality for all variables, with skewness and kurtosis values within recommended ranges. Missing data accounted for less than 2% of all observations and were successfully addressed using multiple imputation procedures.

Table 1

Descriptive Statistics and Correlations Among Study Variables

Variable	Mean	SD	1	2	3	4
1. Psychological Flourishing	42.87	7.31	—			
2. Identity Integration	71.43	10.22	.71***	—		
3. Self-Compassion	39.18	6.84	.65***	.58***	—	

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4. Perceived Inclusion	58.92	9.46	.76***	.67***	.61***	—

Table 1 presents descriptive statistics and bivariate correlations among the principal study variables. Psychological flourishing demonstrated a relatively high average score (M = 42.87, SD = 7.31), indicating generally positive psychological functioning among participants. Identity integration (M = 71.43, SD = 10.22), self-compassion (M = 39.18, SD = 6.84), and perceived inclusion (M = 58.92, SD = 9.46) also exhibited moderate to high mean values. Correlation analyses revealed statistically significant positive associations among all study variables. The strongest relationship emerged between perceived inclusion and psychological flourishing ($r = .76$, $p < .001$), suggesting that students who perceived greater inclusion within the university environment experienced substantially higher levels of flourishing. Identity integration was also strongly associated with flourishing ($r = .71$, $p < .001$), while self-compassion demonstrated a moderately strong positive relationship with flourishing ($r = .65$, $p < .001$). Significant positive intercorrelations among the predictor variables indicated that students who reported stronger identity integration also tended to report higher self-compassion and greater perceptions of inclusion. These findings provided preliminary evidence supporting the suitability of the selected predictors for subsequent machine learning analyses.

Table 2

Performance Metrics of the SHAP-Assisted XGBoost Prediction Model

Metric	Training Set	Testing Set
R^2	.872	.824
RMSE	2.61	3.17
MAE	1.98	2.46
MAPE (%)	5.84	7.03
Explained Variance	.875	.828

The predictive performance of the XGBoost model is summarized in Table 2. Results indicated excellent predictive accuracy across both training and testing datasets. The model explained 87.2% of the variance in psychological flourishing in the training sample and maintained strong generalizability in the testing sample, where 82.4% of variance was explained. The relatively small difference between training and testing performance metrics suggests minimal overfitting and strong robustness of the developed model. Root Mean Square Error values of 2.61 and 3.17 for the training and testing datasets, respectively, indicate that prediction errors remained relatively small compared to the overall variability observed in flourishing scores. Similarly, Mean Absolute Error values below 2.5 points further demonstrate the model's precision in estimating individual flourishing levels. The Mean Absolute Percentage Error remained below 8% in both datasets, reflecting highly accurate predictive performance. Collectively, these results indicate that identity integration, self-compassion, and perceived inclusion, when analyzed through an XGBoost framework, provide substantial explanatory power for understanding psychological flourishing among deaf university students.

Table 3

Global SHAP Feature Importance Values for Psychological Flourishing Prediction

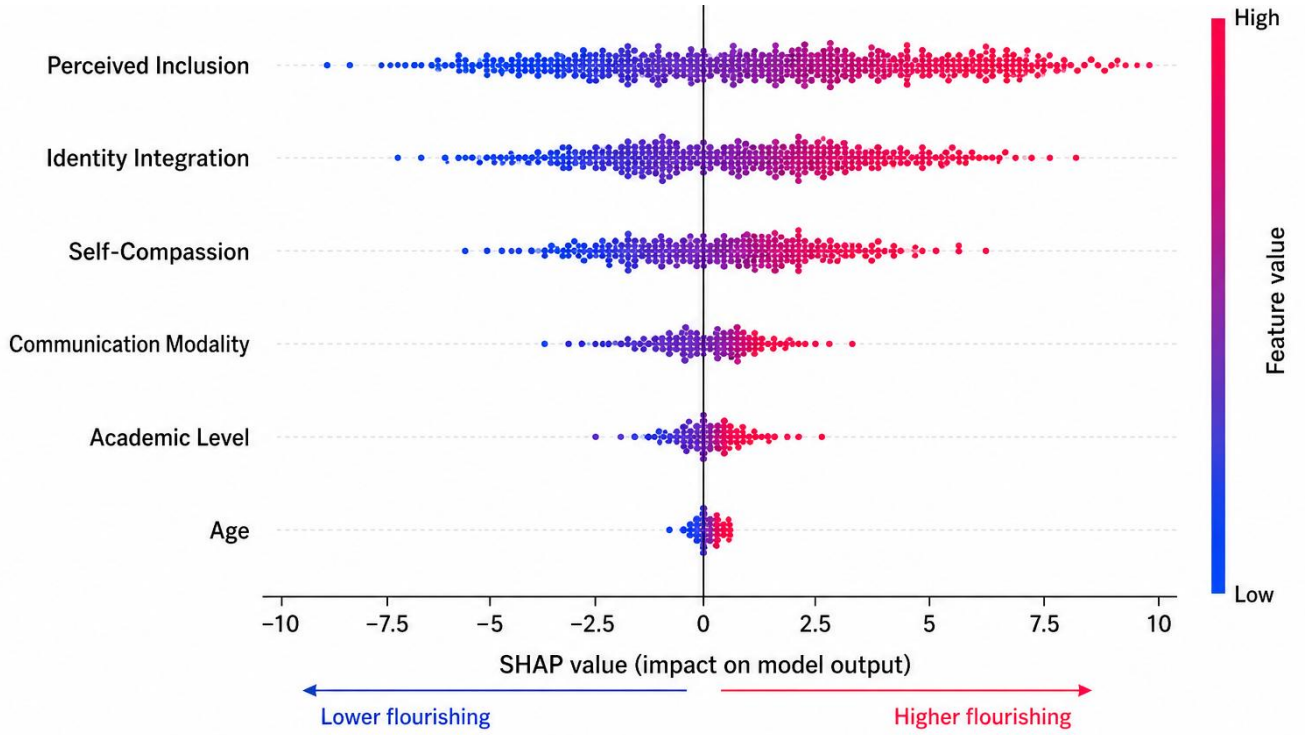
Predictor Variable	Mean Absolute SHAP Value	Relative Importance (%)	Rank
Perceived Inclusion	3.42	39.8	1
Identity Integration	2.89	33.6	2
Self-Compassion	1.94	22.6	3
Communication Modality	0.19	2.2	4
Academic Level	0.11	1.3	5
Age	0.05	0.5	6

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The SHAP analysis provided detailed insight into the relative importance of predictor variables within the XGBoost model. As shown in Table 3, perceived inclusion emerged as the most influential predictor of psychological flourishing, accounting for 39.8% of total model importance. Higher levels of perceived inclusion consistently contributed to increases in predicted flourishing scores across participants. Identity integration ranked as the second most important predictor, contributing 33.6% of the model's explanatory capacity. Students demonstrating stronger integration of deaf identity with broader social and academic identities were predicted to experience substantially greater flourishing. Self-compassion represented the third most influential variable, accounting for 22.6% of overall predictive importance. Although demographic characteristics contributed modestly to prediction accuracy, their influence was substantially smaller than that of the psychosocial variables. The SHAP summary plot further demonstrated that high values of perceived inclusion, identity integration, and self-compassion were consistently associated with positive SHAP values, indicating increased predicted flourishing. The distribution of SHAP values also revealed nonlinear effects, particularly for perceived inclusion, where gains in flourishing became increasingly pronounced at higher levels of inclusion. These findings underscore the central role of inclusive educational environments and positive self-related psychological processes in promoting flourishing among deaf university students.

Figure 1

SHAP Summary Plot Illustrating the Relative Contributions of Identity Integration, Self-Compassion, and Perceived Inclusion to Psychological Flourishing



Taken together, the findings demonstrate that psychological flourishing among deaf university students can be predicted with a high degree of accuracy using SHAP-assisted XGBoost modeling. Across all analyses, perceived inclusion emerged as the strongest contributor to flourishing, followed by identity integration and self-compassion. The convergence of correlational evidence, predictive modeling results, and SHAP-based interpretability analyses provides robust support for the proposition that both environmental and intrapersonal resources play critical roles in fostering optimal psychological functioning among deaf students in higher education. The results further highlight the value of explainable artificial intelligence approaches in psychological research, as they permit not only accurate prediction but also transparent interpretation of the

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mechanisms underlying positive mental health outcomes in marginalized student populations.

4. Discussion

The present study employed a SHAP-assisted XGBoost model to examine the relative contributions of identity integration, self-compassion, and perceived inclusion to psychological flourishing among deaf university students in Canada. The findings revealed that the developed machine learning model demonstrated excellent predictive performance, explaining more than 82% of the variance in psychological flourishing within the testing dataset. Furthermore, SHAP analyses indicated that perceived inclusion emerged as the most influential predictor of flourishing, followed by identity integration and self-compassion. These findings provide important evidence that both environmental and intrapersonal resources contribute substantially to positive psychological functioning among deaf students and highlight the value of explainable artificial intelligence approaches for identifying key determinants of well-being in marginalized populations.

One of the most notable findings of the present study was the strong predictive role of perceived inclusion. SHAP analyses demonstrated that perceived inclusion accounted for the largest proportion of explanatory importance within the model and exhibited the strongest bivariate association with flourishing. This finding suggests that students who perceive themselves as valued, respected, and actively included within the university environment are substantially more likely to experience higher levels of psychological flourishing. Such findings are highly consistent with contemporary theories emphasizing belongingness as a fundamental psychological need and a critical determinant of well-being. Research on inclusive equality has repeatedly demonstrated that genuine participation in educational, cultural, and social institutions is essential for promoting psychological health among individuals with disabilities (Leahy & Ferri, 2024). When individuals experience environments that recognize and accommodate their needs while affirming their value, they are more likely to develop positive self-perceptions and experience greater life satisfaction.

The strong contribution of perceived inclusion is further supported by studies emphasizing the importance of relational and community-based resources for flourishing. Goodman et al. argued that thriving communities cultivate opportunities for participation, leadership, and social connectedness, thereby facilitating sustainable well-being and personal growth (Goodman et al., 2022). Similarly, research on ecological belonging suggests that individuals flourish when they perceive themselves as meaningful members of interconnected social systems that affirm their identities and contributions (Celidwen & Keltner, 2023). Among deaf university students, perceptions of inclusion likely extend beyond physical accessibility to encompass communication access, peer acceptance, institutional support, and opportunities for meaningful participation. Such experiences may foster a sense of psychological safety and belonging that enables students to pursue academic and personal goals with greater confidence and engagement. These findings also align with research demonstrating that inclusive educational practices improve adjustment and participation among deaf and hard-of-hearing students (Wang et al., 2025).

The results additionally indicated that identity integration was the second most influential predictor of flourishing. Students who reported greater coherence between their deaf identity and broader social, academic, and personal identities were more likely to exhibit elevated flourishing scores. This finding is theoretically meaningful because identity integration reflects the successful negotiation of multiple social memberships and self-definitions. Previous scholarship has consistently emphasized that identity development is a central component of positive adaptation among deaf individuals. Smolen and Paul noted that positive identity formation enables deaf students to navigate educational environments while maintaining a strong sense of self and community connection (Smolen & Paul, 2023). Similarly, narrative investigations of Deaflympians revealed that successful identity negotiation across cultural boundaries contributes to resilience, solidarity, and psychological growth (Hwang & Chang, 2025). The present findings extend this literature by demonstrating that identity integration not only correlates with well-being but also serves as a major predictor of flourishing within a sophisticated machine learning framework.

The importance of identity integration may be understood through broader perspectives on diversity, self-acceptance, and social recognition. Scholars have argued that flourishing is facilitated when individuals are able to express their authentic identities without experiencing stigma or exclusion (Blankschaen, 2023; Iozzio, 2022). Positive identity integration may promote psychological flourishing by reducing internal conflict, enhancing self-esteem, and strengthening social belonging. Furthermore, studies

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examining disability perspectives have increasingly emphasized moving beyond deficit-oriented frameworks toward models that recognize disability identities as valuable sources of knowledge, resilience, and cultural richness (Gariba & Assenyoh, 2023; Krishnan, 2024). The current findings support these perspectives by demonstrating that students who successfully integrate their identities are better positioned to achieve positive psychological functioning.

Self-compassion emerged as the third most important predictor of flourishing. Although its relative importance was somewhat lower than that of inclusion and identity integration, it nevertheless contributed substantially to model performance and maintained a strong positive relationship with flourishing. This finding is highly consistent with the growing body of literature identifying self-compassion as a critical psychological resource associated with emotional resilience, adaptive coping, and mental health. Self-compassion enables individuals to respond to personal challenges with kindness and understanding rather than harsh self-criticism, thereby reducing vulnerability to stress and psychological distress (Shani, 2024). Among deaf university students, self-compassion may be particularly important because it provides a means of coping with experiences of exclusion, communication barriers, and academic pressures without internalizing negative self-evaluations.

The present findings correspond closely with intervention studies demonstrating the psychological benefits of self-compassion. Lengua et al. found that programs promoting well-being significantly enhanced self-compassion, emotion regulation, and adaptive coping capacities among helping professionals (Lengua et al., 2025). Likewise, compassion-based interventions have been associated with improvements in mental health, resilience, and flourishing across diverse populations (Lazzari, 2026; McKimmy et al., 2026). Positive psychology interventions integrating mindfulness and compassion practices have similarly been shown to increase flourishing and reduce stress-related symptoms (Fábio et al., 2021). The current results suggest that similar mechanisms may operate among deaf university students, whereby self-compassion facilitates flourishing through enhanced emotional regulation, reduced self-criticism, and greater psychological flexibility.

An important contribution of this study lies in its demonstration that flourishing among deaf students is best understood through the combined influence of social and psychological factors rather than through individual characteristics alone. The SHAP analyses revealed that contextual variables such as perceived inclusion exerted stronger effects than demographic variables, highlighting the significance of environmental conditions in shaping well-being outcomes. This finding is consistent with strengths-based and ecological perspectives emphasizing that flourishing emerges from interactions between individuals and supportive environments (Parmenter et al., 2025; Reid & Grant, 2024). Research on strengths-based psychological frameworks suggests that well-being is enhanced when personal resources are supported by inclusive social structures and opportunities for participation (Parmenter et al., 2025). The prominence of inclusion within the current model reinforces the importance of creating educational systems that actively support accessibility, equity, and belonging.

The findings also align with broader scholarship emphasizing relationality, compassion, and meaning as foundations of flourishing. Nelson et al. described harmonious living as emerging from balanced relationships among self, community, and environment (Nelson et al., 2025). Similarly, Bai et al. identified gratitude, meaning, and moral elevation as important contributors to positive mental health (Bai et al., 2026). Studies examining spiritual emotional intelligence have likewise highlighted the role of self-awareness, compassion, and interconnectedness in promoting psychological well-being (Gannamraju, 2025). Although these constructs were not directly examined in the present study, they support the broader interpretation that flourishing results from multidimensional processes involving both internal strengths and external sources of support.

The current findings also resonate with research examining friendship quality, relational experiences, and social support. Yücel and Dinçer demonstrated that supportive friendships contribute significantly to self-development and well-being through processes of self-change and relational growth (Yücel & Dinçer, 2024). Likewise, Doherty and Nuzum emphasized the importance of meaningful communication and authentic interpersonal encounters for fostering psychological connection and well-being (Doherty & Nuzum, 2023). For deaf university students, inclusive relationships may reinforce both identity integration and self-compassion, creating synergistic pathways toward flourishing. Such interpretations help explain why inclusion emerged as the strongest predictor within the machine learning model.

The use of explainable machine learning techniques represents another important contribution of this study.

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Traditional statistical methods often focus on average effects and may overlook complex nonlinear relationships among variables. In contrast, the SHAP-assisted XGBoost model provided both high predictive accuracy and transparent explanations regarding the relative contributions of predictors. The model's strong performance indicates that flourishing among deaf university students can be predicted reliably using a combination of psychosocial variables. Furthermore, the SHAP analyses revealed nuanced patterns showing that increases in inclusion, identity integration, and self-compassion were associated with progressively greater gains in flourishing. These findings demonstrate the value of integrating psychological theory with advanced computational methods to improve understanding of well-being processes.

More broadly, the findings support contemporary movements within disability scholarship that advocate for humanistic, strengths-oriented, and inclusive approaches. Rather than conceptualizing deafness primarily in terms of limitations or deficits, current perspectives emphasize the importance of recognizing cultural identity, diversity, agency, and social participation as foundations of well-being (Gulati et al., 2023; Manalili, 2021). Research examining disability rights, ethical agency, and vulnerability similarly highlights the importance of creating environments that enable individuals to thrive while honoring their unique identities and experiences (Jain, 2021; Johansson & Wickström, 2022). The present findings provide empirical support for these perspectives by demonstrating that flourishing among deaf students is strongly associated with factors reflecting inclusion, identity affirmation, and compassionate self-relating.

5. Conclusion

The results also have implications for understanding psychological flourishing within broader educational contexts. Studies investigating university environments have increasingly emphasized the need to address social dynamics, power relations, and experiences of marginalization that influence student well-being (Bhattarai et al., 2025). Creating educational systems that foster inclusion and respect for diversity may therefore not only improve academic outcomes but also promote flourishing and mental health. The current findings suggest that universities seeking to support deaf students should move beyond basic accommodation models toward comprehensive approaches that cultivate belonging, identity affirmation, and emotional well-being.

Several limitations should be acknowledged when interpreting the findings of this study. First, the cross-sectional design prevents causal conclusions regarding the relationships among perceived inclusion, identity integration, self-compassion, and flourishing. Second, all variables were measured using self-report instruments, which may be influenced by response biases and social desirability effects. Third, although the sample was drawn from multiple Canadian universities, the findings may not generalize to deaf students in different cultural, educational, or policy contexts. Fourth, the study focused on a limited set of psychosocial predictors and did not include potentially relevant variables such as social support, resilience, academic self-efficacy, communication accessibility, or experiences of discrimination. Finally, despite the strong predictive performance of the machine learning model, replication in independent samples is necessary to confirm the stability and generalizability of the identified predictor rankings.

Future research should employ longitudinal designs to examine how identity integration, self-compassion, and perceived inclusion influence flourishing over time and to explore potential causal pathways among these variables. Researchers should also investigate additional predictors that may contribute to flourishing among deaf students, including resilience, social connectedness, community engagement, academic experiences, and communication accessibility. Comparative studies involving hearing and deaf students could further clarify whether the identified predictors operate similarly across populations. Future investigations may also benefit from incorporating qualitative methodologies to explore lived experiences underlying flourishing and from testing intervention programs specifically designed to enhance inclusion, identity development, and self-compassion within higher education settings.

The findings suggest several practical implications for universities, disability support services, counselors, and policymakers. Educational institutions should prioritize the development of genuinely inclusive campus environments that extend beyond accommodation and actively promote belonging, participation, and recognition of deaf culture. Programs designed to strengthen identity development and foster positive identity integration may contribute substantially to student well-being. Universities should also consider implementing self-compassion and well-being

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training initiatives that enhance emotional resilience and adaptive coping. Faculty and staff training focused on accessibility, communication inclusion, and disability awareness may further strengthen students' perceptions of inclusion. Collectively, such initiatives have the potential to create educational environments in which deaf students not only succeed academically but also experience high levels of psychological flourishing and personal growth.

Authors' Contributions

Authors equally contributed to this article.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

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Declaration of Interest

The authors report no conflict of interest.

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Ethics Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

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