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Identifying Profiles of Adolescent Flourishing Through Unsupervised Machine Learning and Variables Including Self-Compassion, Meaning in Life, Digital Wellbeing, Gratitude, and Peer Support

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A B S T R A C T

Objective: The present study aimed to identify distinct profiles of adolescent flourishing using unsupervised machine learning techniques based on self-compassion, meaning in life, digital wellbeing, gratitude, and peer support among Canadian adolescents.

Methods and Materials: This study employed a cross-sectional correlational design with an unsupervised machine learning approach. The statistical population consisted of Canadian high school students enrolled in public secondary schools during the 2025–2026 academic year. Using multistage cluster sampling, 742 adolescents were recruited, and after data screening, 711 participants were retained for final analysis. Data were collected using standardized instruments including the Flourishing Scale, Self-Compassion Scale–Short Form, Meaning in Life Questionnaire, Digital Wellbeing Scale for Adolescents, Gratitude Questionnaire–Six Item Form, and the peer support subscale of the Multidimensional Scale of Perceived Social Support. Data analysis was conducted using Python and SPSS-28. Hierarchical clustering and K-means clustering were applied to identify latent flourishing profiles. Cluster validity was evaluated using silhouette coefficients, Davies–Bouldin index, and Calinski–Harabasz index. Multivariate analysis of variance and Bonferroni post hoc tests were used to compare identified profiles across study variables.

Findings: The findings indicated that the three-cluster solution demonstrated the strongest statistical performance and conceptual interpretability compared to alternative clustering solutions. Three distinct profiles were identified, including the High Flourishing Adaptive Profile, Moderate Flourishing Vulnerable Profile, and Low Flourishing At-Risk Profile. Significant multivariate differences were observed among the profiles across flourishing, self-compassion, meaning in life, digital wellbeing, gratitude, and peer support ($p < .001$). Adolescents within the High Flourishing Adaptive Profile reported significantly higher scores across all psychological and relational variables compared to the other profiles, whereas the Low Flourishing At-Risk Profile demonstrated consistently lower functioning across all domains. Meaning in life and flourishing produced the largest effect sizes in distinguishing profile membership. Visualization analyses using t-distributed stochastic neighbor embedding additionally confirmed clear separation and structural distinctiveness among the identified flourishing profiles.

Conclusion: The findings suggest that adolescent flourishing is a multidimensional and heterogeneous construct shaped by emotional, existential, relational, and digital wellbeing factors. Self-compassion, meaning in life, gratitude, peer support, and healthy digital engagement appear to function as major protective resources associated with adaptive flourishing. The application of unsupervised machine learning techniques provided a nuanced person-centered understanding of adolescent wellbeing and highlighted the existence of distinct flourishing trajectories among youth populations. These findings support the development of strengths-based and personalized interventions aimed at enhancing flourishing and psychological resilience during adolescence.

Keywords: *Adolescent flourishing, unsupervised machine learning, self-compassion, meaning in life, digital wellbeing, gratitude, peer support, cluster analysis, positive psychology, adolescent mental health*

1. Introduction

Adolescence represents a critical developmental period characterized by rapid biological, cognitive, emotional, and social transformations that substantially influence long-term psychological functioning and quality of life. Traditionally, much of adolescent mental health research has focused on psychopathology, maladjustment, behavioral disorders, and risk-related outcomes. However, the emergence of positive psychology has shifted scholarly attention toward understanding strengths, resilience, wellbeing, and flourishing among young people. Flourishing refers to a multidimensional state of optimal functioning encompassing emotional wellbeing, psychological resilience, meaningful engagement, social connectedness, positive relationships, and purposeful living. Rather than merely representing the absence of psychological distress, flourishing reflects the presence of adaptive capacities that enable individuals to thrive across multiple domains of life (Bakracheva, 2025; VanderWeele & Lee, 2025). Contemporary developmental scholars increasingly emphasize that flourishing during adolescence predicts healthier interpersonal relationships, improved academic adjustment, stronger coping resources, and enhanced life satisfaction in adulthood (Preston et al., 2021; Verma, 2022). Consequently, identifying the psychological and social mechanisms that contribute to adolescent flourishing has become a major priority in educational psychology, developmental science, and youth mental health research.

Recent evidence suggests that flourishing in adolescence is strongly influenced by positive psychological resources that shape emotional regulation, social adaptation, and meaning-making processes. Among these protective factors, self-compassion has received substantial empirical attention due to its role in reducing self-criticism, enhancing emotional resilience, and promoting adaptive coping strategies during stressful developmental transitions. Self-compassion allows adolescents to respond to personal failures and emotional difficulties with kindness, mindfulness, and psychological flexibility instead of harsh self-judgment. Research indicates that self-compassion is associated with lower depressive symptoms, reduced self-injurious behaviors, and higher levels of emotional wellbeing among adolescents (Liu et al., 2023). Moreover, positive psychological capacities such as resilience and psychological capital have consistently been linked to healthier developmental trajectories and improved mental health outcomes in youth populations (Preston et al., 2021; Putri et al., 2023). Bakracheva emphasized that flourishing is deeply rooted in stable personality characteristics and adaptive cognitive-emotional patterns that foster resilience, optimism, and purposeful engagement with life experiences (Bakracheva, 2025). Similarly, studies examining adolescent adjustment have shown that positive emotional orientations can buffer against environmental adversity, family instability, and social stressors (Bian & Ji, 2024; Neagu, 2024). These findings collectively suggest that flourishing emerges from the interaction of internal emotional resources and external relational experiences.

Meaning in life has also been recognized as a central dimension of flourishing and adolescent wellbeing. During adolescence, individuals actively engage in identity exploration, existential reflection, and future-oriented thinking, making the search for meaning especially salient during this developmental stage. Adolescents who perceive their lives as purposeful and meaningful tend to demonstrate greater emotional stability, stronger social functioning, and more adaptive responses to adversity. Prior research has shown that gratitude, supportive relationships, and family functioning significantly contribute to adolescents' sense of meaning in life (Zhang et al., 2021). Hatchimonji et al. further argued that purpose development and character strengths are strongly intertwined with social-emotional learning competencies and adolescent psychological growth (Hatchimonji et al., 2022). Similarly, Yang et al. found that positive cognitive and emotional orientations enhance

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subjective wellbeing and learning-related adjustment among adolescents (Yang et al., 2022). Studies conducted in diverse cultural contexts have additionally demonstrated that gratitude and existential purpose act as protective mechanisms against psychological distress and maladaptive behaviors (Lee, 2023; Zhang et al., 2023). From a developmental perspective, meaning in life may therefore operate as both an emotional stabilizer and a motivational force that contributes to flourishing across social, academic, and interpersonal domains.

Gratitude has emerged as another prominent construct within positive youth development literature due to its powerful association with emotional wellbeing, resilience, social connectedness, and life satisfaction. Gratitude refers to the tendency to recognize, appreciate, and respond positively to beneficial experiences and supportive interpersonal interactions. Research increasingly demonstrates that grateful adolescents exhibit greater optimism, prosocial behavior, emotional regulation, and interpersonal trust (Armenta et al., 2022; Zhang, 2022). Armenta et al. reported that gratitude not only increases life satisfaction among youth but also motivates self-improvement and constructive future-oriented behaviors (Armenta et al., 2022). Similarly, Hussong et al. observed that gratitude experiences during the COVID-19 pandemic predicted stronger social orientation and psychological adjustment among ethnically diverse adolescents (Hussong et al., 2023). Gratitude has also been associated with reduced suicidal ideation, enhanced mindfulness, and improved body image among adolescents (Lee, 2023; Zahra et al., 2022). Additional evidence indicates that gratitude functions as a protective factor against bullying victimization, emotional distress, and trauma-related maladjustment (Liu et al., 2023; Wu et al., 2023). Intervention-based studies further reveal that gratitude training can significantly improve adolescent psychological wellbeing and resilience, particularly among vulnerable populations such as adolescents living with single parents or residing in institutional settings (Halleyda & Japar, 2023; Puspita & Ayriza, 2022). Collectively, these findings position gratitude as a major contributor to flourishing by strengthening emotional wellbeing, social cohesion, and adaptive cognitive processing.

In addition to individual psychological strengths, flourishing is profoundly shaped by interpersonal relationships and social support systems. Peer relationships become increasingly influential during adolescence as young people progressively rely on social networks for emotional validation, identity formation, and belongingness. Positive peer support has been consistently associated with improved self-esteem, emotional security, resilience, and life satisfaction. Zhang et al. demonstrated that family functioning and peer relationships mediate the association between gratitude and meaning in life among adolescents (Zhang et al., 2021). Similarly, Zhou et al. reported that parental emotional warmth contributes to prosocial online behaviors and healthier interpersonal functioning in adolescents (Zhou et al., 2024). Research examining relational flourishing further emphasizes that love, connectedness, and supportive relationships are foundational components of human flourishing across the lifespan (Bastos et al., 2025; VanderWeele & Lee, 2025). Bastos et al. additionally highlighted the importance of physiological and emotional attunement within close relationships in promoting wellbeing and adaptive functioning (Bastos et al., 2025). Adolescents who experience supportive peer environments are therefore more likely to develop emotional security, positive identity structures, and resilience against psychological adversity.

At the same time, modern adolescents are navigating increasingly digitalized social environments that profoundly shape emotional experiences, identity formation, and interpersonal functioning. Digital wellbeing has consequently become an essential component of contemporary adolescent flourishing research. While digital technologies provide opportunities for communication, creativity, and social connection, excessive or maladaptive digital engagement may contribute to anxiety, social comparison, emotional dysregulation, and reduced psychological wellbeing. Lusianawati et al. reported that problematic digital lifestyles among adolescents are associated with physical inactivity, emotional distress, and psychological instability (Lusianawati et al., 2023). Similarly, Sembiring and Mokodenseho found that unhealthy online interactions significantly affect adolescent mental health and emotional wellbeing (Sembiring & Mokodenseho, 2023). West et al., through a systematic review grounded in self-determination theory, emphasized that social media experiences influence adolescent wellbeing depending on whether online engagement supports autonomy, competence, and relatedness needs (West et al., 2024). Digital environments may therefore function as either protective or risk-enhancing contexts depending on the quality, balance, and psychological meaning of online experiences. This complexity highlights the need to integrate digital wellbeing into broader models of adolescent flourishing.

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Scholars have increasingly recognized that adolescent flourishing is highly multidimensional and cannot be adequately explained through isolated variables or linear psychological models. Rather, flourishing reflects complex interactions among emotional, cognitive, interpersonal, and environmental factors that may combine differently across individuals. Adolescents may therefore exhibit distinct flourishing profiles characterized by varying patterns of strengths and vulnerabilities. Some adolescents may possess high gratitude and peer support despite moderate digital wellbeing, while others may demonstrate strong meaning in life but reduced self-compassion. Traditional variable-centered statistical approaches often overlook such heterogeneity because they focus primarily on average relationships between variables rather than identifying naturally occurring subgroups within populations. Consequently, person-centered approaches are becoming increasingly valuable for understanding developmental diversity and identifying meaningful psychosocial profiles among adolescents.

Machine learning methods, particularly unsupervised learning techniques, provide powerful tools for identifying hidden structures and naturally emerging patterns within complex psychological datasets. Unlike traditional regression-based approaches, unsupervised machine learning algorithms can classify individuals into psychologically meaningful groups without relying on predefined outcome categories. These approaches are especially useful when studying multidimensional constructs such as flourishing, where interactions among emotional, relational, and behavioral variables may produce distinct developmental configurations. Recent psychological research increasingly advocates for the integration of artificial intelligence and machine learning methodologies into developmental and mental health sciences in order to improve classification accuracy, identify latent subgroups, and better capture individual variability. Despite growing interest in adolescent wellbeing and flourishing, relatively few studies have utilized unsupervised machine learning approaches to identify flourishing profiles based simultaneously on self-compassion, meaning in life, digital wellbeing, gratitude, and peer support.

Furthermore, the existing literature contains several important gaps. First, many studies have examined gratitude, self-compassion, digital wellbeing, or peer support independently rather than investigating their combined contribution to flourishing profiles. Second, much of the current evidence remains variable-centered and fails to address heterogeneity among adolescents. Third, there is limited research integrating positive psychological constructs with digital wellbeing indicators despite the central role of technology in adolescent life. Fourth, previous studies have often focused on psychopathology reduction rather than optimal functioning and flourishing enhancement. Finally, few studies have explored flourishing using culturally diverse adolescent populations within technologically advanced social environments such as Canada. Addressing these limitations is important for developing more personalized, strengths-based, and developmentally informed interventions that support adolescent wellbeing.

The present study therefore aimed to identify distinct profiles of adolescent flourishing using unsupervised machine learning techniques based on self-compassion, meaning in life, digital wellbeing, gratitude, and peer support among Canadian adolescents.

2. Methods and Materials

2.1. Study Design and Participants

This study employed a cross-sectional correlational design using an unsupervised machine learning approach to identify distinct profiles of adolescent flourishing based on psychological, interpersonal, and digital wellbeing indicators. The primary objective of the study was to classify adolescents into naturally occurring latent groups according to their levels of self-compassion, meaning in life, digital wellbeing, gratitude, and peer support, and to examine the multidimensional structure of flourishing among Canadian adolescents. Because the study aimed to explore hidden patterns and subgroup structures without imposing predefined outcome categories, an unsupervised learning framework was considered appropriate for capturing the heterogeneity of adolescent psychological functioning.

The statistical population consisted of high school students enrolled in public secondary schools in Toronto, Vancouver, Montreal, Calgary, and Ottawa during the 2025–2026 academic year. Participants were selected using a multistage cluster sampling procedure. Initially, several school districts from each city were randomly selected, after which schools were chosen proportionate to district size. Within each school, students from grades 9 through 12 were invited to participate voluntarily in the research. Inclusion criteria included being between 14 and 18 years of age, current enrollment in a Canadian secondary school, sufficient proficiency in English to complete the

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questionnaires independently, and informed consent from both the students and their parents or guardians. Students with diagnosed severe cognitive impairments or incomplete questionnaire responses exceeding 15% of total items were excluded from the final analysis.

A total of 742 adolescents participated in the study. After screening for missing data, response inconsistency, and multivariate outliers, 711 questionnaires were retained for final analysis. Among the participants, 358 were female and 353 were male, with a mean age of 16.21 years (SD = 1.17). The sample represented diverse socioeconomic and cultural backgrounds, reflecting the multicultural composition of Canadian urban communities. Data collection was conducted in classroom settings under the supervision of trained research assistants. Participants were informed about the confidentiality of their responses, the voluntary nature of participation, and their right to withdraw from the study at any stage without penalty.

2.2. Measures

Adolescent flourishing was assessed using the Flourishing Scale developed by Diener et al. (2010). This instrument is an 8-item self-report measure designed to evaluate psychosocial prosperity, positive functioning, purpose in life, competence, optimism, and supportive relationships. Participants responded to each statement on a 7-point Likert scale ranging from strongly disagree to strongly agree. Higher scores indicate greater levels of flourishing and psychological wellbeing. Previous studies have demonstrated satisfactory construct validity, convergent validity, and internal consistency for the scale across adolescent and adult populations. In the present study, Cronbach's alpha for the Flourishing Scale was found to be 0.89, indicating high internal reliability.

Self-compassion was measured using the Self-Compassion Scale–Short Form developed by Raes et al. (2011), derived from Neff's original self-compassion framework. The instrument contains 12 items assessing self-kindness, common humanity, and mindfulness, as well as reverse-scored dimensions including self-judgment, isolation, and overidentification. Responses are rated on a 5-point Likert scale ranging from almost never to almost always. Higher scores reflect greater self-compassion and adaptive emotional self-regulation. Prior research has confirmed the factorial validity and reliability of the scale among adolescents and young adults. In the current study, the overall Cronbach's alpha coefficient was 0.87.

Meaning in life was evaluated using the Meaning in Life Questionnaire developed by Steger et al. (2006). The questionnaire consists of 10 items divided into two dimensions: presence of meaning and search for meaning. Participants rate each item on a 7-point Likert continuum from absolutely untrue to absolutely true. Higher scores represent stronger perceptions of life meaning and existential coherence. The scale has been widely validated in international adolescent populations and demonstrates strong psychometric characteristics. In this study, Cronbach's alpha coefficients for the presence and search subscales were 0.85 and 0.82, respectively.

Digital wellbeing was assessed using the Digital Wellbeing Scale for Adolescents developed by Vanden Abeele (2021). This instrument measures balanced technology use, emotional experiences related to digital engagement, perceived online control, and healthy interaction with social media and digital devices. The scale includes 18 items rated on a 5-point Likert scale from never to always. Higher scores indicate healthier digital habits and more adaptive integration of technology into daily life. Previous investigations have reported acceptable validity and reliability among adolescent populations. In the current sample, the Cronbach's alpha coefficient for the overall scale was 0.90.

Gratitude was measured using the Gratitude Questionnaire–Six Item Form developed by McCullough et al. (2002). The instrument evaluates dispositional gratitude and the tendency to recognize and appreciate positive experiences and supportive social interactions. Participants respond on a 7-point Likert scale ranging from strongly disagree to strongly agree. Higher scores reflect stronger gratitude orientation and positive emotional functioning. Previous studies have confirmed the scale's reliability and predictive validity in adolescent psychological wellbeing research. In the present study, Cronbach's alpha for the gratitude measure was 0.84.

Peer support was evaluated using the peer subscale of the Multidimensional Scale of Perceived Social Support developed by Zimet et al. (1988). This scale measures adolescents' perceptions of emotional, interpersonal, and practical support received from peers and close friends. The peer support component contains 4 items scored on a 7-point Likert scale ranging from very strongly disagree to very strongly agree. Higher scores indicate stronger perceived peer connectedness and relational support. The instrument has shown strong reliability and construct validity across multicultural adolescent samples. In the current study, the

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peer support subscale demonstrated a Cronbach's alpha coefficient of 0.86.

2.3. Data Analysis

Data analysis was conducted using Python programming language version 3.11 and SPSS version 28. Initially, descriptive statistics including means, standard deviations, skewness, kurtosis, and correlation coefficients were calculated to examine the distributional properties of the variables and preliminary associations among study constructs. Missing data were handled using expectation-maximization imputation for cases with less than 5% missing responses. Prior to machine learning analysis, all variables were standardized using z-score normalization to ensure equal contribution of features to clustering algorithms and to reduce scale-related bias.

To identify latent flourishing profiles among adolescents, unsupervised machine learning techniques were employed. The primary clustering method used in this study was K-means clustering due to its effectiveness in detecting homogeneous subgroups within multidimensional psychological datasets. Hierarchical agglomerative clustering was first conducted to estimate the optimal number of clusters and examine the underlying structure of the data. Subsequently, K-means clustering was implemented using Euclidean distance metrics and iterative centroid optimization procedures. Multiple cluster solutions ranging from two to six groups were evaluated.

Several performance indicators including silhouette coefficient, Davies–Bouldin index, Calinski–Harabasz criterion, and elbow method analysis were used to determine the optimal clustering solution. The final model selection was based on both statistical adequacy and psychological interpretability of the resulting profiles. Cluster stability was further evaluated through bootstrapped resampling procedures and split-sample validation to ensure reproducibility of subgroup classifications.

After cluster extraction, multivariate analysis of variance was performed to compare the identified flourishing profiles across self-compassion, meaning in life, digital wellbeing, gratitude, peer support, and overall flourishing scores. Post hoc Bonferroni comparisons were used to determine pairwise group differences. Effect sizes were calculated using partial eta squared values to estimate the magnitude of between-cluster differences. Additionally, two-dimensional data visualization techniques including principal component analysis and t-distributed stochastic neighbor embedding were utilized to visually inspect cluster separation and profile distinctiveness. Statistical significance for all inferential analyses was set at $p < .05$.

3. Findings and Results

The final analysis was conducted on data obtained from 711 Canadian adolescents between the ages of 14 and 18 years. Among the participants, 358 individuals (50.35%) were female and 353 individuals (49.65%) were male. The mean age of the participants was 16.21 years (SD = 1.17). Regarding educational level, 24.75% of the students were enrolled in grade 9, 25.88% in grade 10, 24.19% in grade 11, and 25.18% in grade 12. In terms of family socioeconomic status, 28.41% of participants reported low socioeconomic status, 49.79% reported moderate socioeconomic status, and 21.80% reported high socioeconomic status. Approximately 67.93% of participants reported daily social media use exceeding three hours, while 32.07% reported usage below three hours per day. Preliminary data screening indicated that skewness and kurtosis values for all study variables fell within the acceptable range of ±2, confirming the normal distribution of the variables and supporting the suitability of subsequent multivariate analyses and machine learning procedures.

Table 1

Means, Standard Deviations, and Correlations Among Study Variables

Variables	Mean	SD	1	2	3	4	5	6
1. Flourishing	41.83	7.29	1					
2. Self-Compassion	38.94	6.48	0.61	1				
3. Meaning in Life	46.17	8.13	0.67	0.54	1			
4. Digital Wellbeing	58.42	10.76	0.49	0.46	0.44	1		
5. Gratitude	33.75	5.87	0.64	0.51	0.59	0.39	1	
6. Peer Support	21.68	4.35	0.56	0.42	0.48	0.37	0.52	1

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The descriptive findings presented in Table 1 demonstrated that adolescents in the sample reported moderate to relatively high levels of flourishing, meaning in life, gratitude, and peer support. Among the predictor variables, digital wellbeing displayed the highest variability, suggesting substantial differences in adolescents' experiences with digital engagement and online behavioral regulation. Correlation analyses revealed statistically significant positive associations among all study variables. Flourishing showed the strongest correlation with meaning in life (r = 0.67), followed closely by gratitude (r = 0.64) and self-compassion (r = 0.61), indicating that adolescents who experienced stronger existential purpose, positive emotional orientation, and compassionate self-relating tended to report substantially higher psychological flourishing. Peer support also demonstrated a meaningful positive relationship with flourishing (r = 0.56), highlighting the importance of supportive peer relationships during adolescence. Digital wellbeing exhibited moderate positive associations with all psychological variables, suggesting that healthier digital habits and balanced online engagement were linked to more adaptive psychosocial functioning. The correlation matrix further indicated the absence of problematic multicollinearity, as none of the intercorrelations exceeded the critical threshold of 0.80, thereby supporting the inclusion of all variables in subsequent clustering and multivariate analyses.

Table 2

Cluster Fit Indices for Determining the Optimal Number of Flourishing Profiles

Number of Clusters	Silhouette Coefficient	Davies–Bouldin Index	Calinski–Harabasz Index
2	0.41	1.18	382.74
3	0.53	0.79	468.29
4	0.47	0.96	431.11
5	0.39	1.24	397.86
6	0.34	1.39	365.18

The results of the clustering performance evaluation are presented in Table 2. Multiple statistical indicators were examined to identify the most appropriate clustering solution for adolescent flourishing profiles. Among the evaluated models, the three-cluster solution demonstrated the strongest overall performance. Specifically, the three-cluster model yielded the highest silhouette coefficient (0.53), indicating stronger within-cluster cohesion and clearer separation between clusters compared to alternative solutions. In addition, the Davies–Bouldin index reached its lowest value (0.79) in the three-cluster solution, suggesting minimal overlap and superior discriminant validity among identified profiles. The Calinski–Harabasz index also reached its highest value within the three-cluster configuration, further supporting its statistical superiority. Collectively, these findings indicated that adolescent flourishing within the present sample was optimally represented by three psychologically meaningful and statistically distinct profiles. Based on the psychological characteristics of each subgroup, the clusters were subsequently labeled as "High Flourishing Adaptive Profile," "Moderate Flourishing Vulnerable Profile," and "Low Flourishing At-Risk Profile."

Table 3

Comparison of Identified Flourishing Profiles Across Study Variables

Variables	High Flourishing Adaptive Profile (n = 276) Mean ± SD	Moderate Flourishing Vulnerable Profile (n = 287) Mean ± SD	Low Flourishing At-Risk Profile (n = 148) Mean ± SD	F	p	Partial η^2
Flourishing	49.62 ± 4.18	41.07 ± 3.89	30.44 ± 5.21	412.86	0.001	0.54
Self-Compassion	44.28 ± 4.77	38.11 ± 4.86	30.15 ± 5.42	269.47	0.001	0.43
Meaning in Life	54.36 ± 5.24	45.12 ± 5.67	33.74 ± 6.28	387.29	0.001	0.52
Digital Wellbeing	67.81 ± 7.42	57.44 ± 7.85	44.63 ± 8.91	241.65	0.001	0.41
Gratitude	39.46 ± 4.08	33.18 ± 4.13	25.74 ± 4.85	294.17	0.001	0.45
Peer Support	25.39 ± 2.87	21.11 ± 3.08	15.92 ± 3.94	226.48	0.001	0.39

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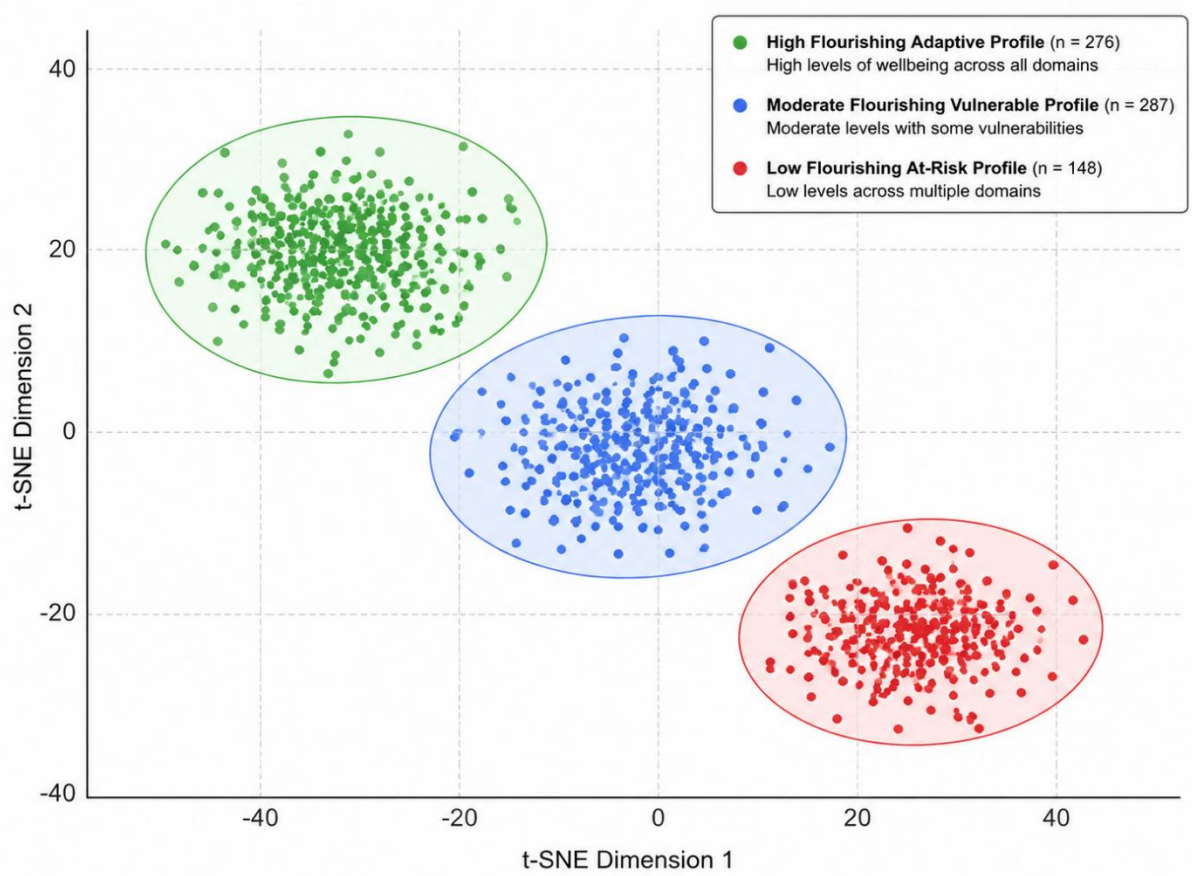
The multivariate comparisons reported in Table 3 demonstrated highly significant differences among the three flourishing profiles across all psychological and interpersonal variables. Adolescents classified within the High Flourishing Adaptive Profile consistently obtained the highest scores on flourishing, self-compassion, meaning in life, digital wellbeing, gratitude, and peer support. In contrast, participants categorized within the Low Flourishing At-Risk Profile exhibited substantially lower scores across all measured domains, indicating widespread emotional, existential, social, and digital vulnerability. The Moderate Flourishing Vulnerable Profile occupied an intermediate position, reflecting relatively functional psychological adjustment but lower levels of resilience and psychosocial resources compared to the highly flourishing group. The largest effect sizes were observed for flourishing (Partial $\eta^2 = 0.54$) and meaning in life (Partial $\eta^2 = 0.52$), suggesting that existential purpose and positive psychological functioning played particularly central roles in distinguishing adolescent flourishing profiles. Bonferroni post hoc analyses further confirmed that all pairwise group differences were statistically significant at $p < .001$. These findings collectively support the multidimensional nature of adolescent flourishing and indicate that the identified profiles differ not only in overall wellbeing, but also in emotional regulation capacities, social connectedness, gratitude orientation, and adaptive digital functioning.

Figure 1

Two-Dimensional Visualization of Adolescent Flourishing Profiles Using t-Distributed Stochastic Neighbor Embedding (t-SNE)



The visual inspection of the t-distributed stochastic neighbor embedding representation demonstrated a clear and meaningful separation among the three identified flourishing profiles. The High Flourishing Adaptive Profile appeared as a highly cohesive and densely clustered group characterized by elevated levels of positive psychosocial functioning and relatively low within-group variability. The Moderate Flourishing Vulnerable Profile occupied a transitional position between the high and low flourishing groups, suggesting partial overlap in certain psychosocial characteristics while maintaining an overall distinguishable identity. In contrast, the Low Flourishing At-Risk Profile displayed broader dispersion patterns, reflecting greater heterogeneity and instability in emotional, social, and digital

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wellbeing characteristics. The spatial distribution of the clusters further supported the validity of the unsupervised machine learning classification procedure and confirmed that adolescent flourishing is not a single homogeneous construct, but rather a multidimensional phenomenon composed of distinct psychological profiles with varying degrees of resilience, emotional balance, interpersonal support, and digital adaptation. The figure additionally demonstrated that meaning in life, gratitude, and self-compassion contributed strongly to cluster separation, as individuals with higher scores on these variables were consistently positioned within the adaptive flourishing region of the visualization space.

4. Discussion

The present study aimed to identify distinct profiles of adolescent flourishing using unsupervised machine learning techniques based on self-compassion, meaning in life, digital wellbeing, gratitude, and peer support among Canadian adolescents. The findings revealed three psychologically meaningful profiles labeled as the High Flourishing Adaptive Profile, Moderate Flourishing Vulnerable Profile, and Low Flourishing At-Risk Profile. Significant differences were observed among these profiles across all study variables, indicating that flourishing among adolescents is not a uniform construct but rather a multidimensional phenomenon characterized by varying combinations of emotional, cognitive, social, and digital functioning capacities. The identification of these profiles supports the theoretical assumption that adolescent wellbeing develops through complex interactions among internal psychological resources and external relational experiences rather than through isolated factors alone.

One of the most important findings of the present study was the central role of meaning in life in distinguishing flourishing profiles. Adolescents classified within the High Flourishing Adaptive Profile demonstrated substantially higher levels of meaning in life compared to those in the moderate and at-risk groups. This finding highlights the importance of existential purpose and future-oriented cognition during adolescence, a developmental period characterized by identity exploration and psychological transition. Adolescents who perceive their lives as meaningful are more likely to experience emotional stability, goal-directed motivation, resilience, and adaptive coping capacities. The findings align with previous studies indicating that meaning in life is strongly associated with psychological wellbeing and positive adjustment among adolescents (Hatchimonji et al., 2022; Zhang et al., 2021). Zhang et al. demonstrated that gratitude and positive family and peer relationships significantly strengthen adolescents' sense of life meaning, which subsequently enhances wellbeing and adaptive functioning (Zhang et al., 2021). Similarly, Hatchimonji et al. emphasized that purpose development and social-emotional competencies are deeply interconnected in positive youth development (Hatchimonji et al., 2022). The current findings extend previous research by demonstrating that meaning in life not only contributes to wellbeing but also serves as a major distinguishing factor separating flourishing and psychologically vulnerable adolescents.

The results additionally revealed that self-compassion significantly differentiated the identified flourishing profiles, with adolescents in the High Flourishing Adaptive Profile reporting the highest levels of self-compassion. This finding suggests that compassionate self-relating may function as a protective emotional mechanism that enables adolescents to regulate stress, tolerate emotional difficulties, and maintain psychological balance during challenging developmental experiences. Adolescents with greater self-compassion may be less likely to engage in harsh self-criticism, emotional avoidance, or maladaptive coping strategies, thereby enhancing their capacity for flourishing. These findings are consistent with prior evidence indicating that self-compassion is associated with reduced emotional distress, lower self-injury risk, and stronger resilience among adolescents (Liu et al., 2023; Preston et al., 2021). Liu et al. found that self-compassion indirectly reduced nonsuicidal self-injury through gratitude and posttraumatic growth mechanisms among adolescents exposed to traumatic experiences (Liu et al., 2023). Likewise, Preston et al. emphasized the protective role of positive psychological capital in promoting youth mental health and adaptive coping capacities (Preston et al., 2021). The present findings therefore support the growing positive psychology literature suggesting that self-compassion is a foundational emotional resource underlying adolescent flourishing.

Another major finding concerned the role of gratitude in differentiating flourishing profiles. Adolescents within the High Flourishing Adaptive Profile exhibited markedly higher gratitude levels than adolescents in the vulnerable and at-risk profiles. Gratitude appears to contribute to flourishing by strengthening positive emotional experiences, reinforcing social bonds, and promoting adaptive cognitive interpretations of life events. Grateful adolescents may be

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more likely to appreciate social support, interpret challenges constructively, and maintain optimistic perspectives regarding their future. These findings are highly consistent with previous empirical evidence linking gratitude to psychological wellbeing, resilience, life satisfaction, and prosocial behavior (Armenta et al., 2022; Lee, 2023; Zhang, 2022). Armenta et al. demonstrated that gratitude enhances both life satisfaction and self-improvement motivation among youth populations (Armenta et al., 2022). Similarly, Zhang reported that gratitude positively predicts prosocial behavior and adaptive social functioning among adolescents (Zhang, 2022). Additional studies have shown that gratitude buffers against suicidal ideation, emotional distress, and bullying-related harm (Lee, 2023; Wu et al., 2023). The findings of the present study further align with intervention research indicating that gratitude training programs can improve adolescent psychological wellbeing and resilience (Halleyda & Japar, 2023; Puspita & Ayriza, 2022). These results collectively suggest that gratitude may function as a core emotional strength promoting adolescent flourishing across social, emotional, and existential domains.

Peer support also emerged as a significant distinguishing variable among flourishing profiles. Adolescents classified within the adaptive flourishing group reported substantially higher perceived peer support compared to adolescents in the vulnerable and at-risk groups. This finding reflects the developmental importance of peer relationships during adolescence, when social belongingness, acceptance, and interpersonal validation become increasingly central to identity development and emotional wellbeing. Supportive peer environments may strengthen adolescents' emotional security, resilience, and self-worth while simultaneously reducing feelings of isolation and psychological vulnerability. The findings are consistent with previous research emphasizing the importance of social connectedness in adolescent flourishing (Bastos et al., 2025; VanderWeele & Lee, 2025). Bastos et al. highlighted that emotionally attuned relationships significantly contribute to physiological and psychological wellbeing (Bastos et al., 2025). Furthermore, Wong et al. argued that gratitude and positive social processes within adolescent group interactions foster emotional support, empathy, and collective wellbeing (Wong et al., 2024). The present findings additionally correspond with research showing that family warmth, social support, and positive interpersonal experiences contribute to adaptive adolescent functioning and resilience (Neagu, 2024; Zhou et al., 2024). Thus, peer support appears to function not only as a relational resource but also as a developmental context that facilitates flourishing.

The findings regarding digital wellbeing are especially important given the increasing role of digital technologies in adolescent life. Adolescents within the High Flourishing Adaptive Profile demonstrated significantly healthier digital wellbeing patterns than those in the vulnerable and at-risk groups. This suggests that balanced and adaptive digital engagement may support psychological wellbeing, whereas problematic online experiences may contribute to emotional instability and reduced flourishing. Contemporary adolescents spend substantial portions of their daily lives interacting within digital environments, making digital wellbeing a critical component of overall psychosocial adjustment. The findings align with studies indicating that unhealthy digital lifestyles and problematic online interactions negatively affect adolescent mental health (Lusianawati et al., 2023; Sembiring & Mokodenseho, 2023). West et al. further emphasized that social media use influences wellbeing depending on whether online engagement supports psychological needs such as autonomy, competence, and social connectedness (West et al., 2024). The current results extend previous research by demonstrating that digital wellbeing contributes directly to broader flourishing profiles rather than functioning merely as an isolated behavioral outcome. Adolescents who maintain healthier digital habits may experience stronger emotional regulation, improved interpersonal relationships, and greater psychological balance.

The identification of the Moderate Flourishing Vulnerable Profile is also theoretically meaningful. Adolescents within this group demonstrated relatively functional psychological adjustment but significantly lower levels of self-compassion, gratitude, peer support, and digital wellbeing compared to the adaptive flourishing group. This finding suggests that many adolescents may not experience severe psychological distress while simultaneously lacking the emotional and relational resources necessary for optimal flourishing. Such adolescents may appear psychologically stable in conventional mental health assessments despite possessing latent vulnerabilities that could increase future risk for emotional difficulties under stressful circumstances. This observation supports the argument advanced by positive psychology scholars that wellbeing and psychopathology should not be viewed as opposite ends of a single continuum (Bakracheva, 2025; Verma, 2022). Rather, flourishing represents a distinct dimension of functioning requiring

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active cultivation of strengths, meaning, and supportive relationships.

5. Conclusion

The machine learning methodology employed in this study also contributes theoretically and methodologically to adolescent flourishing research. Traditional variable-centered approaches often assume population homogeneity and overlook naturally occurring developmental subgroups. In contrast, the unsupervised clustering approach used in the present study successfully identified psychologically meaningful profiles characterized by unique combinations of strengths and vulnerabilities. This finding supports the growing application of machine learning approaches in psychological and developmental sciences to better capture human complexity and heterogeneity. By integrating self-compassion, meaning in life, gratitude, peer support, and digital wellbeing within a person-centered analytical framework, the present study provides a more comprehensive understanding of adolescent flourishing and highlights the multidimensional nature of positive youth development.

6. Limitations & Suggestions

One limitation of the present study concerns its cross-sectional design, which prevents causal interpretation of the observed relationships among flourishing-related variables. Although the machine learning approach successfully identified distinct profiles, the directionality and developmental progression of these profiles cannot be determined. Additionally, the study relied exclusively on self-report questionnaires, which may have increased the risk of social desirability bias, recall bias, and subjective response distortion. The sample was also limited to Canadian adolescents from urban educational settings, which may restrict the generalizability of the findings to rural populations or adolescents from different cultural backgrounds. Furthermore, although the clustering solution demonstrated strong statistical adequacy, different machine learning algorithms or alternative feature combinations may produce somewhat different subgroup structures.

Future research should employ longitudinal designs to investigate the developmental stability and transitions of flourishing profiles across adolescence and early adulthood. Researchers are encouraged to examine how changes in digital behavior, peer relationships, self-compassion, and gratitude influence profile membership over time. Future studies could additionally incorporate biological, behavioral, and ecological indicators of wellbeing to provide a more comprehensive multidimensional understanding of flourishing. Cross-cultural comparative research would also be valuable for examining whether flourishing profiles differ across sociocultural contexts and educational systems. Moreover, future machine learning studies could integrate more advanced techniques such as deep learning, latent transition analysis, or hybrid predictive-clustering models to improve classification precision and identify developmental risk trajectories more accurately.

From a practical perspective, the findings of the present study suggest that schools, mental health professionals, and youth development programs should adopt strengths-based approaches aimed at cultivating flourishing rather than focusing exclusively on symptom reduction. Interventions designed to enhance gratitude, self-compassion, meaning in life, and peer connectedness may substantially improve adolescent wellbeing and resilience. Educational institutions could implement social-emotional learning programs that promote emotional awareness, compassionate self-reflection, supportive peer interactions, and balanced digital engagement. Parents and educators should also encourage healthy technology use patterns while fostering emotionally supportive environments that strengthen adolescents' sense of belonging and psychological security. Finally, the use of machine learning approaches in educational and mental health settings may help identify vulnerable adolescents early and support the development of more personalized prevention and intervention strategies tailored to different flourishing profiles.

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Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical 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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Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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Authors' Contributions

All authors equally contributed to this article.

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