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A PERMA-Based Measure of Student Well-Being in Science Learning: Development and CFA Validation

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ABSTRACT

Student well-being is essential for effective and sustainable science learning. However, no instrument has specifically assessed it based on this context's PERMA (Positive Emotion, Engagement, Relationships, Meaning, and Accomplishment) model. This study aims to develop and validate a PERMA-based well-being instrument for secondary school students. The instrument was developed through three phases: item generation and expert validation, pilot testing, and scale evaluation using Confirmatory Factor Analysis (CFA). Data were collected from 361 secondary school students, with 329 valid responses retained for analysis. The initial instrument consisted of 30 items representing the five PERMA dimensions, and 21 items were retained after CFA-based item reduction. The model was analysed using the Maximum Likelihood Robust (MLR) estimator. The five-factor model demonstrated good fit (χ^2/df = 2.01; RMSEA = 0.055; CFI = 0.964; TLI = 0.957) and met convergent validity, discriminant validity, and construct reliability criteria. The instrument is valid, reliable, and sensitive to the science learning context, supporting and integrating social-emotional learning in STEM education to enhance student well-being.

Keywords: Confirmatory Factor Analysis, PERMA, Science Education, Student Well-being

INTRODUCTION

In recent years, student well-being has become a central issue in improving the quality of global education [1], [2], aligning with the Sustainable Development Goals (SDGs) 2030 agenda, particularly Goal 3, which emphasises health and well-being as foundations for lifelong learning [3], [4]. In 21st-century education, students' emotional well-being, meaningful engagement, and fair learning opportunities are increasingly recognised as key elements in developing resilient and high-performing individuals [5], [6]. This shift reflects a broader educational perspective that integrates academic achievement with students' psychological and social well-being.

Building on this perspective, student well-being supports long-term academic success [7]. In science education, these are crucial as students engage in critical thinking, evidence-based inquiry, and collaboration [8], [9], [10]. According to OECD [11], science learning should develop core competencies such as explaining phenomena scientifically and interpreting data, fostering science identity and environmental agency. These elements enhance the relevance and personal meaning of science learning, thus strengthening student well-being. Well-being interventions in schools have also

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demonstrated lasting benefits up to a year after implementation [12], [13], [14].

The PERMA model introduced by Seligman [15], [16] is one of the main theoretical frameworks in positive psychology that explains well-being through five dimensions: Positive Emotion, Engagement, Relationships, Meaning, and Accomplishment. This model has been widely used in education and has shown a positive relationship with learning engagement and academic achievement [17], [18]. One of this model's most widely used model-based instruments is the PERMA Profiler [19], which consists of 15 items and has been cited more than 2,000 times. Despite having good content and display validity, the PERMA Profiler was developed and validated primarily for adult populations, so it has not fully represented the characteristics of adolescent students aged 12–18 years in the context of science learning.

Several studies have developed PERMA-based well-being instruments for higher education or upper-secondary education populations [20], [21], [22], [23] and teenagers in general [24], [25]; however, no one has specifically adapted it to the characteristics of science learning at the secondary school level in Indonesia. These instruments also tend to be generic and do not reflect the cognitive-affective needs typical of science learning, such as the pressures of science investigation, the perception of the relevance of science concepts, and social interaction in scientific problem-solving.

Despite previous efforts, gaps remain in the development of valid instruments specifically designed to assess student well-being in the context of science learning at the secondary school level. This study aims to develop and validate student well-being instruments based on the PERMA model that are adjusted to the characteristics of students at the secondary school level. This research is expected to make a theoretical and practical contribution by providing valid, reliable, and contextual measurement tools to holistically support social-emotional well-being integration in science learning.

MATERIAL AND METHODS

Methods

The instrument development procedure in this study adheres to best practices outlined by Boateng et al. [26], who propose a structured approach consisting of three key phases: (1) item generation and content validation, (2) scale construction—including pre-testing, item administration, and item reduction—and (3) scale evaluation, which involves testing dimensionality, reliability, and validity. These phases provide a systematic foundation for developing psychometrically robust instruments to measure complex constructs in education and behavioral sciences.

Accordingly, this study developed and validated a student well-being measurement instrument specifically for the context of science learning, based on the PERMA model proposed by Seligman [16]. The instrument reflects five core dimensions of well-being: positive emotion, engagement, relationships, meaning, and accomplishment. The development process involved identifying relevant theoretical constructs, formulating items, conducting expert content validation, performing field testing, and evaluating construct validity using Confirmatory Factor Analysis (CFA).

The data were collected from 361 students at a public school in the Yogyakarta area, encompassing grades 7, 8, and 9. This public school was selected through convenience sampling due to ease of access, existing collaboration, and time constraints in the data collection process [27]. Convenience sampling was deemed appropriate given the early-stage nature of instrument validation, where the primary goal is to assess construct reliability and structure rather than generalize findings to a broader population [26], [28]. However, limited to a public school, the sample involved students from diverse academic backgrounds and grade levels, allowing for internal variation. After data cleansing, 329 valid responses were retained for analysis, excluding those with extreme values, inconsistent patterns, or substantial missing data [29].

Table 1. Student Demographics

Category	Subcategory	Frequency	Percentage
Gender	Male	169	46.8%
	Female	192	53.2%
Age (years old)	12	6	1.7%
	13	113	31.3%
	14	114	31.6%
	15	109	30.2%
	16	18	5.0%
	17	1	0.3%

This research has obtained ethical approval from the relevant school. Participants are provided with complete information about the purpose of the research, the principle of data confidentiality, and the right to withdraw at any time without consequences. Consent is also obtained from the student's parents or guardians.

Instrument

Items were developed based on the five dimensions of the PERMA model and adapted to the context of science learning. The development process referred to indicators from the PERMA Profiler [19] and was contextualised by reviewing the science education literature. Each PERMA dimension was initially represented by six items on a 5-point Likert scale to ensure conceptual coverage and support unidimensionality testing [26]. A total of 30 items—six for each domain (positive emotion, engagement, relationships, meaning, and accomplishment)—were retained for further testing. Detailed indicators and item statements are presented in Table 2.

Table 2. Questionnaire Item by PERMA Domain

Domain	Item code	Questionnaire item
Positive Emotion	P1	I feel happy with the way science is taught
	P2	I feel stressed during science class
	P3	I am grateful to learn through the method used in science class
	P4	I often feel grateful for the lessons in science
	P5	I feel happy during or after participating in science learning
	P6	I frequently feel happy during or after learning science
Engagement	E1	I pay full attention during science class
	E2	I can stay focused from the beginning to the end of the science lesson
	E3	I enjoy learning science so much that time seems to fly by
	E4	My heart and mind are fully involved during science learning
	E5	I often feel enthusiastic when learning science
	E6	Science learning makes me excited and absorbed in the atmosphere
Relationships	R1	My friends support me during science learning
	R2	My science teacher helps and motivates me to achieve my learning goals

Domain	Item code	Questionnaire item
	R3	I feel close and familiar with my classmates in science class
	R4	I feel comfortable and accepted in my science study group
	R5	I feel that my relationships with classmates in science have improved
	R6	Science learning has improved my relationship with the teacher
Meaning	M1	Science lessons give me insight into my future goals
	M2	I feel science learning aligns with my dreams and aspirations
	M3	I understand more about the relevance of science to daily life
	M4	Science learning helps me understand its real-world application
	M5	I feel that my contribution makes the science class more positive
	M6	I feel that my contributions to science learning are appreciated
Accomplishment	A1	I feel successful in achieving my goals in science learning
	A2	I feel that my efforts contribute to my success in learning science
	A3	I am proud of my progress in science learning
	A4	I am proud because my efforts in science have produced the results I expected
	A5	I often achieve satisfying outcomes in science learning
	A6	I am happy with my achievements after working hard in science class

Procedures

Content validation was conducted by three experts in education and science instruction using the Content Validity Index (CVI) approach, with an I-CVI threshold of ≥ 0.78 [30]. All items achieved an I-CVI score of 1.00, indicating excellent content relevance. An initial pilot involved nine students to assess how clear and easy to understand the questionnaire items were and to get a first look at their reliability. Based on the feedback gathered, adjustments were made to improve the phrasing and layout before the questionnaire was shared more broadly. The instrument was administered via Google Forms to a larger sample, facilitated by science teachers in selected schools. Convenience sampling was used due to logistical constraints. The resulting data were then prepared for construct evaluation.

Data Analysis

The instrument's psychometric properties were comprehensively evaluated through Confirmatory Factor Analysis (CFA) using JASP version 0.19.3 to test the hypothesised five-factor structure. The Maximum Likelihood Robust (MLR) estimator accounted for moderate non-normality in the data [31], [32]. Model fit was evaluated using several goodness-of-fit indices. The criteria applied included a Chi-square/df ratio of ≤ 3, indicating an acceptable level of model fit. In addition, the Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), and Goodness of Fit Index (GFI) were expected to reach values of at least 0.90 to demonstrate adequate model adequacy. Furthermore, the Root Mean Square Error of Approximation (RMSEA) and the Standardised Root Mean Square Residual (SRMR) were required to be ≤ 0.08, reflecting a good level of model fit. Construct validity was examined through convergent validity (AVE ≥ 0.50) and discriminant validity (HTMT ≤ 0.85), with HTMT providing greater sensitivity than the Fornell-Larcker criterion [33], [34]. Composite Reliability (CR) was calculated for each factor, with a cutoff of ≥ 0.70 [29]. Items with factor loadings below 0.50 were removed to maintain construct integrity.

RESULTS AND DISCUSSION

Preliminary Analysis

A preliminary analysis was performed to verify the adequacy of the data and test the normal distribution assumptions that are the basis for confirmatory factor analysis (CFA). The number of valid participants after the data cleansing process was 329 students, exceeding the minimum recommendation for CFA ≥ 200 respondents [32]. The data distribution was evaluated through skewness, kurtosis values, and Shapiro-Wilk tests. Although Shapiro-Wilk's p-value indicates a violation of univariate normality ($p < 0.001$), this is tolerable at large sample sizes because CFA with an MLR estimator can overcome such violations [29], [31]. Therefore, CFA analysis can still be performed.

Initial Model Test and Item Removal

Preliminary CFA analysis was conducted to test the five-dimensional model's suitability based on PERMA's theoretical structure. Items are valid with *a standardised loading factor* ≥ 0.50 [29]. Nine items, including P2, P4, and M2, were removed from the model due to low loading values. This deletion does not interfere with the theoretical representation because each dimension still has a minimum of three valid indicators. The details of the loading values are shown in Table 3.

Table 3. Standardized Loading Values and Indicator Validity

Factor	Indicator	Std. estimate	Std. Error	z-value	p	Description
Positive Emotion	P1	0.794	0.028	28.564	<.001	Valid
	P2	0.340	0.052	6.556	<.001	Not valid
	P3	0.773	0.029	26.654	<.001	Valid
	P4	0.484	0.059	8.223	<.001	Not valid
	P5	0.796	0.027	29.389	<.001	Valid
	P6	0.699	0.035	19.829	<.001	Valid
Engagement	E1	0.883	0.019	45.543	<.001	Valid
	E2	0.841	0.024	34.577	<.001	Valid
	E3	0.764	0.028	27.036	<.001	Valid
	E4	0.414	0.046	8.989	<.001	Not valid
	E5	0.670	0.039	17.054	<.001	Valid
	E6	0.786	0.027	29.328	<.001	Valid
Relationships	R1	0.866	0.018	48.708	<.001	Valid
	R2	0.861	0.019	45.047	<.001	Valid
	R3	0.468	0.053	8.878	<.001	Not valid
	R4	0.811	0.023	35.963	<.001	Valid
	R5	0.464	0.053	8.784	<.001	Not valid
	R6	0.731	0.030	24.613	<.001	Valid
Meaning	M1	0.742	0.031	24.095	<.001	Valid
	M2	0.493	0.048	10.163	<.001	Not valid
	M3	0.831	0.020	41.096	<.001	Valid
	M4	0.864	0.018	47.423	<.001	Valid
	M5	0.828	0.022	38.415	<.001	Valid
	M6	0.477	0.050	9.510	<.001	Not valid
Accomplishment	A1	0.830	0.021	40.268	<.001	Valid
	A2	0.846	0.019	44.064	<.001	Valid
	A3	0.869	0.019	46.640	<.001	Valid
	A4	0.477	0.067	7.086	<.001	Not valid
	A5	0.828	0.019	44.427	<.001	Valid
	A6	0.482	0.070	6.848	<.001	Not valid

The revised model is then retested, resulting in a good fit index. Fit values such as $\chi^2/df = 2.01$, RMSEA = 0.055, SRMR = 0.043, and CFI and TLI above 0.95 indicate that the five-factor structure of PERMA is consistent with empirical data [35]. A summary of the CFA model fit indicators is presented in Table 4.

Table 4. CFA Model Fit Index

Fit Index	Observed Value	Recommended Cut-off	Interpretation
Chi-square/df (χ^2/df)	2.01	≤ 3.00	Good fit
RMSEA (Root Mean Square Error of Approximation)	0.055	≤ 0.08	Acceptable fit
SRMR (Standardized Root Mean Square Residual)	0.043	≤ 0.08	Very good fit
CFI (Comparative Fit Index)	0.964	≥ 0.90	Very good fit
TLI (Tucker-Lewis Index)	0.957	≥ 0.90	Very good fit
GFI (Goodness-of-Fit Index)	0.909	≥ 0.90	Good fit
NFI (Normed Fit Index)	0.931	≥ 0.90	Good fit
IFI (Incremental Fit Index)	0.964	≥ 0.90	Very good fit
PNFI (Parsimony Normed Fit Index)	0.784	≥ 0.70	Acceptable fit
RNI (Relative Non-centrality Index)	0.964	≥ 0.90	Very good fit

Convergent and Discriminant Validity

Convergent validity is tested with *the Average Variance Extracted* (AVE) value. Two of the five constructs had an AVE < 0.50 in early models. However, after removing the invalid indicator, the entire construct shows an AVE ≥ 0.59, which indicates that more than 50% of the variance of the item can be explained by the construct it represents in Table 5.

Table 5. AVE Values before and after Item Deletion

Factor	AVE before	AVE after
Positive emotion	0,449	0,590
Engagement	0,555	0,659
Relationships	0,461	0,665
Meaning	0,477	0,675
Accomplishment	0,528	0,716

Discriminant validity was analysed using the Heterotrait-Monotrait ratio (HTMT), which is considered more sensitive than the Fornell-Larcker approach [33]. Table 6 shows that HTMT values before and after item removal remain below the 0.85 threshold, indicating that the construct tested is empirically distinctive.

Table 6. HTMT Ratio between Constructs before and after Item Removal

Factor	Positive Emotion	Engagement	Relationships	Meaning	Accomplishment
Positive Emotion	1.000/1.000				
Engagement	0.601/0.701	1.000/1.000			
Relationships	0.628/0.671	0.536/0.639	1.000/1.000		
Meaning	0.638/0.634	0.456/0.534	0.680/0.702	1.000/1.000	
Accomplishment	0.534/0.607	0.453/0.514	0.639/0.640	0.524/0.534	1.000/1.000

Construct Reliability

The internal consistency of the construct was tested using *Composite Reliability* (CR). Before the item's deletion, the entire CR value is still within the moderate limit (0.57–0.68). After the revision of the model, the CR value increased significantly, and the whole construct reached a CR ≥ 0.78, which indicates high reliability [36]. Details of CR values are presented in Table 7.

Table 7. Composite Reliability (CR) Values before and after Item Removal

Factor	CR before	CR after
Positive emotion	0,57	0,78
Engagement	0,66	0,81
Relationships	0,65	0,80
Meaning	0,66	0,86
Accomplishment	0,68	0,90

Relationships Between Latent Constructs

The covariance analysis between constructs showed that all PERMA dimensional pairs were statistically significantly related ($p < .001$). The *Positive Emotion* dimension had the highest correlation with *Engagement* ($r = 0.709$), strengthening the affective dimension's position as a predictor of student involvement in science learning. In contrast, *the Engagement–Accomplishment relationship* ($r = 0.499$) was relatively weaker, indicating the possible influence of other mediators or moderator variables outside of PERMA. The correlation value between constructs and their confidence limits is detailed in Table 8.

Table 8. Covariance between Factors and Significance

	Std. estimate	Std. Error	z-value	p	95% Confidence Interval	
					Lower	Upper
Positive Emotion↔ Engagement	0.709	0.038	18.429	< .001	0.634	0.785
Positive Emotion↔ Relationships	0.679	0.037	18.235	< .001	0.606	0.751
Positive Emotion↔ Meaning	0.615	0.044	13.838	< .001	0.528	0.702
Positive Emotion↔ Accomplishment	0.604	0.045	13.395	< .001	0.516	0.693
Engagement↔ Relationships	0.646	0.040	16.153	< .001	0.568	0.725
Engagement↔ Meaning	0.533	0.048	11.080	< .001	0.439	0.627
Engagement ↔ Accomplishment	0.499	0.048	10.301	< .001	0.404	0.594
Relationships ↔ Meaning	0.669	0.038	17.454	< .001	0.593	0.744
Relationships ↔ Accomplishment	0.650	0.041	15.973	< .001	0.571	0.730
Meaning ↔ Accomplishment	0.522	0.051	10.307	< .001	0.423	0.622

Contribution of Indicators (R^2 and Z-value)

The contribution of indicators to latent constructs is evaluated through the value of the determination coefficient (R^2) and Z-value. The R^2 value indicates the proportion of the indikator's variance described by its construct, while the Z-value indicates the significance of the relationship. Indicators E1 ($R^2 = 0.836$) in Engagement, R1 (0.767) in Relationships, and M4 (0.755) in Meaning are indicators with the highest contribution in their respective constructs. All indicators had a Z-value > 1.96 and were statistically significant ($p < .001$), reinforcing the structural consistency of the instrument. Details of the R^2 and Z-values are presented in Table 9.

Table 9. R^2 and Z-values for Retained Indicators

Item	R^2	Z-value
P1	0.638	28.200
P3	0.576	24.557
P5	0.643	29.947
P6	0.506	20.530
E1	0.836	53.291
E2	0.698	30.630
E3	0.524	22.692
E6	0.597	27.353
R1	0.767	50.487
R2	0.744	43.485
R4	0.653	34.579
R6	0.514	22.602
M1	0.546	23.276
M3	0.707	41.297
M4	0.755	46.125
M5	0.680	36.237
A1	0.691	38.979
A2	0.726	43.685
A3	0.749	44.086
A5	0.686	42.579

Overall, the high R^2 values in indicators such as E1, R1, and M4 indicate that these three dimensions strongly represent the indicators structurally. These findings support the stability of the PERMA five-dimensional model in measuring student well-being in science learning.

Visual Models and Structural Implications

Figure 1 presents the final model of student well-being based on the five dimensions of PERMA, showing the linkages between latent constructs and the relative contribution of indicators through *standardised loading values*. This visualisation strengthens the structural validity of the model, while showing a stable and representative factor structure in the context of science learning. The analysis of the value of the determination coefficient (R^2) identified indicators such as E1 (0.836), R1 (0.767), and M4 (0.755) as dominant contributors in their respective constructs.

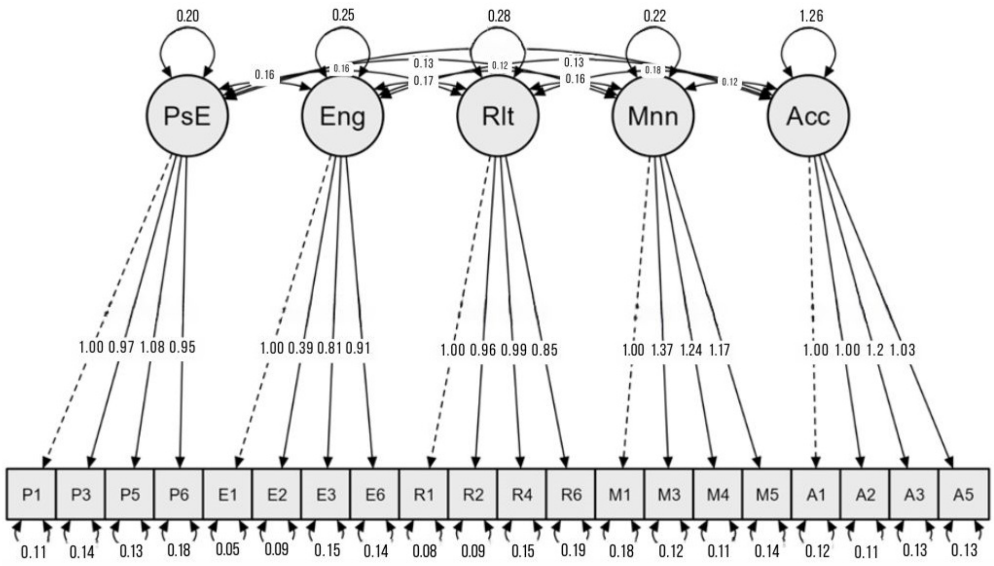

Figure 1. The Second Plot Model

These findings indicate that positive emotion, engagement, relationships, meaning, and accomplishment are key elements in the well-being of science students. The visualisation of the model serves as a theoretical confirmation. It provides an empirical basis for designing pedagogical strategies more geared towards the dimensions of well-being that have the most influence on the student's learning experience. With strong statistical support and a model structure consistent with theory, these results provide a solid foundation for further discussion of the role of student well-being in PERMA-based science learning.

Discussion

Student well-being is vital in fostering academic achievement, especially in science education, where thinking, emotions, and social interaction are deeply interconnected. Based on this framework, this study focuses on developing and validating student well-being measurement instruments based on the PERMA model that are contextualised for science learning at the secondary school level. The confirmatory factor analysis (CFA) results show that the five-dimensional structure of PERMA can be empirically replicated with a model fit index that shows good conformity, supporting the structural validity of the instrument in the context of science learning.

The findings provide theoretical support for using the PERMA framework in formal education, particularly in cognitively challenging subjects like science. Positive emotion is the most impactful of all the components, as it helps drive students' engagement, sense of purpose, social bonds, and personal accomplishments. These results are consistent with previous studies [37], [38], but it is reinforced by empirical findings from the context of science, which in particular demand high emotional resilience and social interaction. In addition, the strong contribution of *the engagement* and *meaning* dimensions confirms recent findings showing that these two aspects are closely related to student engagement in STEM learning [39], [40] and long-term performance [10], [41] as well as students' preferences in determining the direction of their future studies [42].

From the psychometric side, the convergent and discriminant validity obtained shows that each dimension in this instrument has good structural integrity. All indicators meet the criteria of factor charge, AVE, and composite reliability, which indicates that the construct is consistent and conceptually distinguishable. Despite the correlation between dimensions, the model structure still shows clear differentiation, maintains the accuracy of interpreting the results, and supports the understanding that the well-being dimensions in science learning complement each other, not overlap.

Practically, this instrument provides a reliable measurement tool for educators, researchers, and policymakers to map student well-being contextually. Teachers can draw on the data from these tools to shape teaching strategies more in tune with students' needs—for example, by designing meaningful learning activities, encouraging stronger classroom relationships, and helping students experience genuine progress and success. These findings also contribute to the global agenda of integrating *social-emotional learning* (SEL) in STEM education, which is recognised as an important strategy for improving motivation, retention, and learning outcomes [43], [44], [45].

However, there are some limitations. Convenience *sampling* techniques and research locations limited to the Yogyakarta area limit the generalisation of findings. Moreover, although the PERMA model offers a strong framework, some critics highlight that it is rooted in individualistic and Western-centric values, which do not necessarily fully reflect the expression of well-being in a collectivist culture such as Indonesia [38], [46] where spirituality and social harmony are central to well-being [47]. Because of that, it opens opportunities to integrate alternative models in developing advanced instruments, such as the multidimensional well-being model developed by Huppert & So [48] and OECD [49].

Further research is suggested to test cross-cultural validity, reach a wider level of education (primary and upper secondary schools), and apply a longitudinal approach to understand how students' well-being develops over a more extended period. Testing the relationship between the well-being dimension and academic achievement and participation in SEL and STEM education pathways is also an important agenda to support science education that is more oriented towards the holistic development of students. Thus, this research makes a significant conceptual and practical contribution by developing student well-being instruments that are theory-based and empirically validated in science learning. This instrument opens space for developing more humane, reflective, and sustainable pedagogical strategies in science education.

CONCLUSION

This study developed and validated a PERMA-based instrument to measure student well-being in science learning. Confirmatory factor analysis (CFA) results confirmed good construct validity, high reliability, and adequate model fit. The instrument includes five dimensions—Positive Emotion, Engagement, Relationships, Meaning, and Accomplishment, providing a holistic measure of secondary students' well-being in science classrooms. These findings highlight the relevance of positive psychology in fostering meaningful, supportive, and engaging science learning. Theoretically, the study shows that the PERMA model can be effectively adapted to science education and potentially to other subject areas. Practically, the instrument offers a useful tool for teachers, counselors, and researchers to assess and support student well-being. However, the study was limited to convenience sampling from a single public school; therefore, further research is needed to test its generalisability and predictive validity across diverse contexts.

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