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ADVANCING DIVERSITY RESEARCH THROUGH COGNITIVE ANALYTICS: DEVELOPMENT AND VALIDATION OF A COGNITIVE AUTONOMY ASSESSMENT DEVICE

Author :S. KUMARAN ARUL DEVARAM
Ph.D. Research Scholar
Department of English
University College of Engineering
Bharathidasan Institute of Technology Campus
Anna University
Tiruchirappalli-620 024
Tamil Nadu
India.

Corresponding Author: Dr.S.GUNASEKARAN
Assistant Professor (Selection Grade) & HoD
Department of English
University College of Engineering
Bharathidasan Institute of Technology Campus
Anna University
Tiruchirappalli- 620 024
Tamil Nadu
India.
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Abstract

The increasing emphasis on diversity, equity, and inclusion in contemporary education has created a need for innovative assessment tools capable of capturing learners' cognitive independence across diverse cultural, linguistic, and educational backgrounds. This study presents the development and validation of a Cognitive Autonomy Assessment Device (CAAD), an innovative cognitive analytics instrument designed to evaluate learners' capacity for independent thinking, decision-making, problem-solving, self-regulation, and reflective judgment. The device integrates cognitive analytics techniques with psychometric assessment principles to generate comprehensive measures of cognitive autonomy among heterogeneous learner populations. A mixed-method research design was employed, involving instrument construction, expert validation, pilot testing, and large-scale field implementation among undergraduate students representing diverse demographic groups. Statistical analyses, including reliability testing, exploratory factor analysis, and construct validation procedures, confirmed the robustness and consistency of the instrument. The findings indicate that the CAAD effectively identifies variations in cognitive autonomy levels across diverse learner categories while maintaining high validity and reliability standards. Furthermore, the study demonstrates how cognitive analytics can contribute to diversity research by providing evidence-based insights into learners' cognitive development and educational needs. The proposed assessment framework offers significant implications for educational policy, curriculum design, learner support systems, and inclusive pedagogical practices. The study contributes to the growing body of diversity research by establishing a scientifically validated tool for measuring cognitive autonomy in increasingly diverse educational environments.

1.INTRODUCTION

The twenty-first century has witnessed unprecedented transformations in educational systems, workforce structures, and social institutions driven by

globalization, technological advancement, and increasing cultural diversity. As educational environments become more heterogeneous, researchers and policymakers are placing greater emphasis on understanding how individuals think, learn, and make decisions within diverse contexts. Diversity research has traditionally focused on dimensions such as culture, ethnicity, language, gender, socioeconomic status, and educational access. While these dimensions remain critically important, contemporary scholarship increasingly recognizes that cognitive factors play a significant role in determining how individuals engage with learning opportunities, adapt to changing environments, and exercise independent judgment. Consequently, there is a growing need for innovative assessment tools capable of examining cognitive characteristics that contribute to learner success and social participation across diverse populations.

One of the most significant cognitive constructs receiving attention in recent years is cognitive autonomy. Cognitive autonomy refers to an individual's ability to think independently, evaluate information critically, make reasoned decisions, solve problems creatively, regulate learning processes, and reflect upon personal beliefs and actions. Unlike mere academic achievement, cognitive autonomy reflects an individual's capacity to function as an independent thinker capable of navigating complex social, educational, and professional environments. In increasingly diverse societies, cognitive autonomy is essential because individuals are constantly exposed to multiple perspectives, competing sources of information, and complex social realities that require thoughtful evaluation and informed decision-making.

The concept of cognitive autonomy has become particularly relevant in educational settings where learners are expected not only to acquire knowledge but also to analyze, interpret, and apply that knowledge in meaningful ways. Modern educational frameworks emphasize learner-centered approaches, critical thinking, self-directed learning, and lifelong learning competencies. These approaches require students to assume greater responsibility for their learning processes and to develop the intellectual independence necessary for effective participation in academic and professional communities. Consequently, educators and researchers have recognized the importance of assessing cognitive autonomy as a key indicator of educational development and learner empowerment.

Despite its growing significance, the measurement of cognitive autonomy remains a challenging task. Traditional assessment methods often focus on academic performance, standardized testing outcomes, or specific cognitive skills without adequately capturing the broader dimensions of independent thinking and self-regulation. Many existing instruments measure isolated constructs such as critical thinking, metacognition, self-efficacy, or problem-solving ability. While these constructs contribute to cognitive autonomy, they do not fully represent the integrated nature of autonomous cognition. Furthermore, many assessment tools have been developed within specific cultural or educational contexts, limiting their applicability to diverse learner populations. This limitation highlights the need for comprehensive and culturally responsive instruments capable of evaluating cognitive autonomy across varied demographic and educational settings.

The emergence of cognitive analytics offers new opportunities to address these challenges. Cognitive analytics refers to the systematic collection, analysis, and interpretation of cognitive data to understand patterns of thinking, learning, decision-making, and problem-solving. By combining insights from cognitive psychology, educational measurement, data analytics, and artificial intelligence, cognitive analytics enables researchers to examine cognitive processes with greater depth and precision than traditional assessment approaches. These analytical techniques provide valuable information about how individuals process information, respond to challenges, and develop cognitive independence over time.

In the context of diversity research, cognitive analytics presents a particularly promising avenue for investigation. Diverse learner populations often exhibit varying cognitive experiences influenced by cultural backgrounds, linguistic practices, educational opportunities, and social environments. Understanding these variations requires sophisticated assessment frameworks capable of identifying meaningful patterns while avoiding cultural bias and stereotyping. Cognitive analytics facilitates this process by generating evidence-based insights into learner behavior and cognitive development. Through advanced analytical methods, researchers can identify factors that support or hinder cognitive autonomy among different groups and develop

targeted interventions to promote equitable educational outcomes.

The integration of cognitive analytics into diversity research aligns with broader efforts to create inclusive educational systems. Inclusive education seeks to ensure that all learners, regardless of their backgrounds or characteristics, have equal opportunities to achieve their full potential. Achieving this goal requires a comprehensive understanding of the diverse cognitive strengths and challenges that learners bring to educational environments. Traditional approaches often focus on deficits or performance gaps, whereas cognitive autonomy assessment emphasizes learners' capacities for independent thought, adaptability, and self-directed growth. This strengths-based perspective contributes to a more equitable and empowering understanding of learner diversity.

Another important factor driving interest in cognitive autonomy is the rapid expansion of digital technologies and information ecosystems. Contemporary learners operate within environments characterized by abundant information, digital communication platforms, and constantly evolving technological tools. While these resources offer unprecedented access to knowledge, they also create challenges related to information evaluation, critical reasoning, and decision-making. Learners must navigate complex information landscapes, distinguish credible sources from misinformation, and make informed judgments based on available evidence. Cognitive autonomy therefore becomes an essential competency for effective participation in digital societies. Educational institutions increasingly recognize the need to cultivate these competencies, yet reliable tools for measuring their development remain limited.

The present study addresses this gap through the development and validation of a Cognitive Autonomy Assessment Device (CAAD). The proposed device is designed to provide a comprehensive and scientifically rigorous framework for evaluating cognitive autonomy among diverse learner populations. Unlike conventional assessment instruments that focus on isolated cognitive abilities, the CAAD incorporates multiple dimensions of autonomous cognition, including independent thinking, critical evaluation, reflective judgment, self-regulated learning, decision-making, and problem-solving. By integrating these dimensions into a unified assessment framework, the

device seeks to capture the complexity and multidimensional nature of cognitive autonomy.

The development of the Cognitive Autonomy Assessment Device is grounded in interdisciplinary theoretical foundations. The study draws upon principles from cognitive psychology, constructivist learning theory, self-determination theory, metacognitive research, and educational assessment. Cognitive psychology emphasizes the processes through which individuals acquire, process, and apply information. Constructivist perspectives highlight learners' active role in constructing knowledge through interaction and reflection. Self-determination theory underscores the importance of autonomy as a fundamental psychological need that supports motivation and personal growth. Metacognitive research contributes insights into self-awareness and self-regulation, while educational assessment provides methodological frameworks for instrument development and validation. Together, these perspectives inform the conceptualization and operationalization of cognitive autonomy within the proposed device.

A distinctive feature of the study is its emphasis on diversity-sensitive assessment. Historically, many psychological and educational assessments have been criticized for cultural bias and limited generalizability. Instruments developed within one cultural context may not accurately reflect the experiences or perspectives of individuals from different backgrounds. To address this concern, the Cognitive Autonomy Assessment Device has been designed with attention to inclusivity, accessibility, and contextual relevance. The development process incorporates expert validation, pilot testing, and empirical evaluation across diverse participant groups to ensure that the instrument remains responsive to variations in cultural, linguistic, and educational experiences.

The significance of this research extends beyond educational measurement. Accurate assessment of cognitive autonomy has important implications for educational policy, curriculum development, learner support services, and institutional decision-making. Educational leaders require reliable data to design programs that foster critical thinking, independent learning, and intellectual resilience. Policymakers seek evidence-based strategies for promoting equity and inclusion within educational systems. Researchers need robust instruments to

investigate cognitive development and diversity-related outcomes. The Cognitive Autonomy Assessment Device aims to address these needs by providing a validated tool capable of generating meaningful and actionable insights.

Furthermore, the study contributes to ongoing discussions regarding the future of diversity research. Contemporary diversity studies increasingly emphasize the intersection of social, cultural, psychological, and educational factors. Understanding diversity requires more than demographic classification; it requires examining how individuals experience, interpret, and respond to their environments. Cognitive autonomy represents a valuable lens through which these experiences can be explored because it reflects individuals' capacities to engage actively with their social and educational contexts. By linking cognitive analytics with diversity research, the present study advances a more holistic understanding of learner development and inclusion.

The validation of the Cognitive Autonomy Assessment Device also reflects broader methodological advancements within educational and social science research. Modern research increasingly relies on data-driven approaches to enhance accuracy, reliability, and interpretability. Cognitive analytics supports these objectives by enabling sophisticated analysis of cognitive patterns and learner behaviors. Through rigorous validation procedures, including reliability testing, factor analysis, and construct validation, the present study seeks to establish the scientific credibility of the proposed instrument and demonstrate its suitability for diverse educational applications.

In conclusion, the growing complexity of contemporary educational environments necessitates innovative approaches to understanding and assessing learner development. Cognitive autonomy has emerged as a critical competency that supports independent thinking, informed decision-making, and lifelong learning. However, existing assessment methods often fail to capture the multidimensional and context-sensitive nature of this construct. The integration of cognitive analytics into diversity research offers new possibilities for addressing these limitations and generating deeper insights into cognitive development across diverse populations. The development and validation of the Cognitive Autonomy Assessment Device represents an important step toward achieving this goal. By providing a reliable, valid, and inclusive

assessment framework, the study contributes to educational innovation, diversity research, and the advancement of equitable learning opportunities for all learners.

2. OBJECTIVES OF THE STUDY

1. To develop a Cognitive Autonomy Assessment Device (CAAD) for measuring cognitive autonomy among diverse learner populations.
2. To identify the key dimensions of cognitive autonomy, including independent thinking, critical reasoning, self-regulation, decision-making, and reflective judgment.
3. To examine the reliability and validity of the Cognitive Autonomy Assessment Device through empirical testing and statistical analysis.
4. To investigate differences in cognitive autonomy levels among learners from diverse cultural, linguistic, and educational backgrounds.
5. To evaluate the effectiveness of cognitive analytics in advancing diversity research and supporting inclusive educational practices.

3. REVIEW OF LITERATURE

The increasing emphasis on diversity, equity, and inclusion in contemporary education has encouraged researchers to investigate not only demographic and sociocultural differences among learners but also the cognitive factors that influence learning outcomes. Among these factors, cognitive autonomy has emerged as a critical construct associated with independent thinking, self-regulated learning, reflective judgment, and decision-making. Simultaneously, advances in cognitive analytics have provided researchers with innovative tools to assess cognitive processes and learning behaviors with greater precision. The convergence of diversity research, cognitive autonomy, and cognitive analytics has therefore become a significant area of scholarly inquiry.

Early studies on cognitive autonomy were grounded in developmental psychology and educational theory. Researchers viewed autonomy as an individual's capacity to think independently and make decisions free from excessive external influence. Cognitive autonomy was initially examined within the broader framework of psychological autonomy, focusing on learners' abilities to regulate their thoughts and actions. Studies consistently demonstrated that autonomous

learners exhibited higher levels of motivation, problem-solving ability, and academic achievement. These foundational investigations established cognitive autonomy as a significant predictor of educational success and lifelong learning.

The constructivist perspective significantly influenced subsequent research on cognitive autonomy. Constructivist scholars argued that learners actively construct knowledge through interaction, reflection, and experience. According to this perspective, cognitive autonomy develops when learners engage in inquiry-based activities, collaborative problem-solving, and reflective learning processes. Research conducted across diverse educational contexts found that student-centered pedagogies promoted greater intellectual independence and critical thinking. Learners exposed to inquiry-oriented instruction demonstrated stronger capacities for evaluating information, generating original ideas, and applying knowledge to unfamiliar situations.

During the past decade, self-regulated learning (SRL) has emerged as one of the most important theoretical frameworks associated with cognitive autonomy. Self-regulated learning refers to learners' ability to plan, monitor, and evaluate their own learning activities. Recent studies have demonstrated strong relationships between self-regulation and autonomous cognition. Research utilizing learning analytics and trace-data methodologies has shown that high-performing learners engage more frequently in monitoring, evaluation, and reflection processes than lower-performing learners. These findings suggest that cognitive autonomy is closely connected with learners' capacity to regulate their cognitive activities and adapt their strategies according to task requirements. Recent network-analysis research further indicates that self-regulated learning processes can be identified through digital learning traces, providing new opportunities for assessing cognitive autonomy through cognitive analytics.

Another important body of literature focuses on critical thinking as a central dimension of cognitive autonomy. Critical thinking researchers argue that autonomous learners possess the ability to evaluate evidence, question assumptions, identify biases, and make reasoned judgments. Numerous studies conducted in higher education settings have confirmed positive relationships between critical thinking skills and academic performance. Scholars have also highlighted the role of

reflective judgment in enabling learners to navigate ambiguity and complexity. Contemporary educational frameworks increasingly regard critical thinking as an essential twenty-first-century competency and a key indicator of autonomous cognition.

Research on diversity and inclusion has further expanded understanding of cognitive autonomy. Earlier diversity studies primarily focused on access, participation, and achievement disparities among different demographic groups. However, recent investigations emphasize the importance of recognizing diverse cognitive experiences and learning pathways. Scholars have argued that learners from different cultural, linguistic, and socioeconomic backgrounds may demonstrate autonomy in different ways. Consequently, assessment tools designed to measure cognitive autonomy must be culturally responsive and sensitive to contextual variations. This perspective has encouraged researchers to develop more inclusive frameworks capable of capturing diverse expressions of independent thinking and decision-making.

Culturally responsive education has contributed significantly to this discussion. Researchers examining multicultural learning environments have demonstrated that culturally relevant pedagogical practices promote learner agency, self-efficacy, and intellectual independence. Students who perceive their cultural identities as valued within educational settings are more likely to engage actively in learning and develop autonomous thinking skills. These findings suggest that cognitive autonomy is not solely an individual characteristic but is also influenced by social, cultural, and institutional contexts.

The growing availability of digital technologies has introduced new dimensions to the study of cognitive autonomy. Educational technology researchers have increasingly investigated how digital environments support or constrain autonomous learning. Learning management systems, adaptive learning platforms, intelligent tutoring systems, and online collaborative tools generate large volumes of learner data that can be analyzed to understand cognitive processes. This development has given rise to the field of cognitive analytics, which integrates data science, educational psychology, and learning analytics to examine learner cognition in real time.

Cognitive analytics has become a transformative methodology in educational research. By analyzing behavioral data, interaction patterns, decision pathways, and learning trajectories, cognitive analytics enables researchers to identify underlying cognitive processes that may not be observable through traditional assessments. Recent studies demonstrate that cognitive analytics can provide valuable insights into learners' problem-solving strategies, self-regulatory behaviors, and cognitive engagement levels. These capabilities make cognitive analytics particularly useful for assessing multidimensional constructs such as cognitive autonomy.

The emergence of artificial intelligence has further accelerated developments in cognitive analytics. AI-driven educational systems increasingly provide personalized learning experiences based on learner behaviors and performance patterns. Recent systematic reviews indicate that artificial intelligence has substantial potential to support cognitive development, personalized learning, and educational inclusion while also presenting challenges related to ethics, bias, and learner dependence. Researchers have emphasized the importance of designing AI-supported educational systems that strengthen rather than diminish learner autonomy.

A significant area of contemporary research concerns the relationship between artificial intelligence and cognitive autonomy. The rapid adoption of generative AI tools such as intelligent tutoring systems and conversational agents has generated both enthusiasm and concern among educators. Recent systematic reviews reveal that while AI technologies can enhance learning efficiency and provide personalized support, excessive reliance on AI may weaken critical thinking, analytical reasoning, and independent decision-making. Researchers have reported that overdependence on AI-generated responses can reduce learners' motivation to engage in deeper cognitive processing and reflective thinking. These findings underscore the continuing importance of measuring cognitive autonomy in technology-rich educational environments.

Several recent studies have explored the role of generative artificial intelligence in self-directed learning. Findings suggest that AI tools can support learner autonomy by providing immediate feedback, personalized guidance, and access to information. However, scholars consistently caution that the educational

benefits of AI depend on appropriate pedagogical integration and active learner engagement. Research emphasizes that educators remain central to fostering autonomous learning because technology alone cannot replace reflective judgment, metacognitive awareness, or independent reasoning.

Recent scholarship has also highlighted the importance of learner agency as a component of cognitive autonomy. Agency refers to an individual's capacity to act intentionally, make choices, and influence learning outcomes. Researchers argue that agency, autonomy, and self-regulation are interconnected constructs that collectively contribute to learner success. Studies conducted in higher education environments indicate that students who exhibit higher levels of agency demonstrate stronger academic resilience, greater persistence, and enhanced problem-solving abilities. Emerging theoretical models propose that agency should be considered a foundational element in future cognitive autonomy assessment frameworks.

Measurement issues remain a central concern within the literature. Traditional instruments assessing autonomy often rely on self-report questionnaires that may be influenced by response bias and contextual factors. Researchers have increasingly advocated for multidimensional assessment approaches that combine psychometric scales, behavioral indicators, observational data, and analytics-based measures. Learning analytics and cognitive analytics provide opportunities to capture authentic learner behaviors and generate more comprehensive assessments of cognitive autonomy. Despite these advances, there remains a shortage of validated instruments specifically designed to measure cognitive autonomy across diverse populations.

Recent literature also identifies important concerns regarding fairness, validity, and inclusivity in assessment practices. Scholars emphasize that assessment tools must be sensitive to cultural diversity and avoid privileging particular cognitive styles or educational experiences. Instruments developed within narrowly defined contexts may fail to capture the strengths and perspectives of learners from different backgrounds. Consequently, researchers increasingly advocate for inclusive assessment frameworks that recognize multiple pathways to autonomous thinking and learning.

The concept of cognitive autonomy has also gained attention in discussions of future-ready skills. International educational organizations and policymakers identify critical thinking, problem-solving, adaptability, creativity, and lifelong learning as essential competencies for success in rapidly changing societies. These competencies are closely aligned with cognitive autonomy. As educational institutions seek to prepare learners for complex social and technological environments, the ability to assess cognitive autonomy accurately becomes increasingly important.

A review of contemporary studies reveals several significant research gaps. First, existing assessments often measure isolated constructs such as critical thinking, metacognition, or self-regulation rather than cognitive autonomy as an integrated phenomenon. Second, many available instruments lack adequate validation across culturally diverse populations. Third, few studies have combined cognitive analytics with psychometric assessment to create comprehensive measures of cognitive autonomy. Fourth, the rapid growth of artificial intelligence and digital learning environments necessitates new approaches capable of examining autonomy within technology-mediated contexts. Finally, limited research has explored how cognitive autonomy can serve as an indicator of educational equity and inclusion within diversity research.

The present study addresses these gaps through the development and validation of a Cognitive Autonomy Assessment Device (CAAD). By integrating principles from cognitive psychology, self-regulated learning theory, cognitive analytics, and diversity studies, the proposed instrument seeks to provide a reliable, valid, and inclusive framework for measuring cognitive autonomy. The study contributes to the emerging literature by combining psychometric rigor with analytics-based approaches and by emphasizing the importance of cognitive autonomy as a key construct within contemporary diversity research.

In summary, the literature demonstrates that cognitive autonomy is a multidimensional construct encompassing independent thinking, critical reasoning, self-regulation, reflective judgment, and learner agency. Recent advances in cognitive analytics and artificial intelligence have expanded opportunities for assessing these dimensions while simultaneously highlighting the need to preserve human autonomy within

technology-enhanced learning environments. Although substantial progress has been made, the lack of comprehensive, diversity-sensitive assessment instruments remains a significant challenge. The development of a validated Cognitive Autonomy Assessment Device therefore represents a timely and meaningful contribution to educational research, cognitive analytics, and diversity studies.

4. METHODOLOGY

4.1 Research Design

The present study adopted a mixed-method research design to develop and validate a Cognitive Autonomy Assessment Device (CAAD) for assessing cognitive autonomy among diverse learner populations. A mixed-method approach was considered appropriate because the development of a standardized assessment instrument requires both qualitative and quantitative procedures. The qualitative component facilitated the identification of the conceptual dimensions of cognitive autonomy and the development of assessment items, whereas the quantitative component enabled the statistical evaluation of the instrument's reliability, validity, and applicability across diverse educational settings.

The study was conducted in four sequential phases: (i) conceptualization and item generation, (ii) expert validation, (iii) pilot testing and refinement, and (iv) large-scale validation through psychometric and cognitive analytics procedures. This systematic process ensured that the developed instrument was theoretically grounded, empirically validated, and suitable for use in diversity-related educational research.

4.2 Participants and Sampling

The study involved undergraduate students from various higher educational institutions representing different academic disciplines, socio-economic backgrounds, and cultural contexts. Diversity was intentionally incorporated into the sample because the primary objective of the study was to develop an assessment tool capable of measuring cognitive autonomy across heterogeneous learner populations.

A stratified random sampling technique was employed to ensure adequate representation of various learner categories. The final sample consisted of 500 undergraduate students.

Table 1

Demographic Profile of Participants (N = 500)

Category	Sub-Category	Number	Percentage (%)
Gender	Male	250	50.0
	Female	250	50.0
Residence	Rural	220	44.0
	Urban	280	56.0
Educational Background	First-Generation Learners	180	36.0
	Continuing-Generation Learners	320	64.0
Language Background	Multilingual Learners	290	58.0
	Monolingual Learners	210	42.0
Total		500	100

The inclusion of students from different backgrounds facilitated a comprehensive examination of cognitive autonomy and enhanced the generalizability of the findings. Participants were selected from engineering, science, humanities, and management programmes to ensure disciplinary diversity.

4.3 Development of the Cognitive Autonomy Assessment Device

The Cognitive Autonomy Assessment Device was developed following established psychometric instrument development procedures. Initially, an extensive review of literature relating to cognitive autonomy, self-regulated learning, critical thinking, metacognition, learner agency, reflective judgment, and decision-making was undertaken.

Based on theoretical and empirical evidence, six major dimensions of cognitive autonomy were identified:

Table 2

Dimensions of Cognitive Autonomy

Dimension	Description
Independent Thinking	Ability to form opinions and judgments independently
Critical Reasoning	Capacity to evaluate information logically and objectively
Decision-Making Ability	Ability to make informed and reasoned decisions

Problem-Solving Competence	Capacity to address unfamiliar challenges effectively
Self-Regulated Learning	Ability to monitor and manage one's learning processes
Reflective Judgment	Capacity for self-reflection and evaluation of experiences

Based on these dimensions, an initial pool of 72 items was generated. The items were designed to capture learners' cognitive behaviors, attitudes, and tendencies associated with autonomous thinking. The statements were written using simple, culturally neutral language to avoid linguistic bias and ensure accessibility to participants from diverse backgrounds.

Examples of assessment statements included:

- I independently evaluate information before accepting it as true.
- I consider multiple viewpoints before making decisions.
- I regularly monitor my learning progress.
- I can solve unfamiliar problems without excessive assistance.
- I reflect on my mistakes to improve future performance.

All items were measured using a five-point Likert scale.

Table 3

Response Scale Used in the Instrument

Response Option	Score
Strongly Agree	5
Agree	4
Neutral	3
Disagree	2
Strongly Disagree	1

Higher scores represented higher levels of cognitive autonomy.

4.4 Content Validation and Pilot Testing

To ensure content validity, the preliminary instrument was submitted to a panel of ten experts comprising specialists in educational psychology, psychometrics, cognitive science, diversity studies, and higher education. The experts evaluated each item based on relevance, clarity, representativeness, linguistic appropriateness, and cultural neutrality.

The Content Validity Index (CVI) was calculated for each item. Items with CVI values below 0.80 were revised or removed. Following expert review:

- 12 items were modified.
- 8 items were removed.
- 4 new items were added.

Subsequently, a pilot study was conducted involving 100 undergraduate

students who were not included in the final sample. The objectives of the pilot study were to evaluate item clarity, identify ambiguities, estimate completion time, and assess preliminary reliability.

The pilot study findings revealed that the instrument was user-friendly and understandable. The average completion time was approximately 20 minutes. Based on participant feedback and statistical analysis, six redundant items were removed and two items were revised. The final version of the instrument consisted of 62 items distributed across the six dimensions.

4.5 Data Collection Procedure

Data collection was carried out after obtaining institutional approval and informed consent from participants. The finalized Cognitive Autonomy Assessment Device was administered through both online and offline modes to maximize participation.

Participants were informed about:

- The purpose of the research.
- Voluntary nature of participation.
- Confidentiality of responses.
- Right to withdraw at any stage.

The administration process was standardized to ensure consistency across all settings. Participants completed the instrument individually without external assistance. The collected responses were coded and entered into statistical software packages for analysis.

4.6 Cognitive Analytics Framework

A distinctive feature of the present study was the integration of cognitive analytics into the validation process. Cognitive analytics involves the use of data-driven techniques to identify patterns in cognitive behavior, decision-making, and learning processes.

The cognitive analytics framework was designed to generate deeper insights into learners' cognitive autonomy beyond conventional psychometric measurement.

Table 4

Components of the Cognitive Analytics Framework

Component	Purpose
Response Pattern Analysis	Examine consistency of cognitive responses
Decision Profile Analysis	Assess independent decision-making tendencies
Self-Regulation Index	Measure learning management behaviors
Reflective Thinking Index	Evaluate levels of self-reflection
Problem-Solving Profile	Assess adaptive cognitive responses

Diversity Comparison Analysis	Compare autonomy levels across learner groups

Response pattern analysis enabled the identification of consistent and inconsistent cognitive behaviors. Decision profile analysis examined how learners approached judgment and choice-making situations. Self-regulation indicators measured learners' ability to plan, monitor, and evaluate learning activities.

The diversity comparison component was particularly important because it allowed the researchers to investigate cognitive autonomy differences among rural and urban learners, multilingual and monolingual learners, and first-generation and continuing-generation students.

4.7 Data Analysis Techniques

The collected data were analyzed using SPSS Version 29 and AMOS software.

Descriptive Statistics

Descriptive statistical procedures were employed to summarize participant responses and examine general trends in cognitive autonomy.

The following measures were calculated:

- Mean
- Standard Deviation
- Frequency Distribution
- Percentage Analysis

Inferential Statistics

Inferential statistical techniques were employed to investigate relationships and differences among variables.

Table 5

Statistical Techniques Used

Statistical Technique	Purpose
Independent Sample t-test	Compare two groups
One-Way ANOVA	Compare multiple groups
Pearson Correlation	Examine relationships among variables
Multiple Regression	Identify predictors of cognitive autonomy
Cluster Analysis	Develop cognitive autonomy profiles
Pattern Recognition Analysis	Identify cognitive behavior trends

These analyses facilitated comprehensive evaluation of cognitive autonomy across diverse learner populations.

4.8 Reliability and Validity of the Instrument

Reliability and validity analyses were conducted to determine the scientific robustness of the assessment device.

Reliability Analysis

Internal consistency reliability was assessed using Cronbach's Alpha coefficient.

Table 6

Reliability Coefficients of the Cognitive Autonomy Assessment Device

Dimension	Cronbach's Alpha
Independent Thinking	0.89
Critical Reasoning	0.91
Decision-Making Ability	0.87
Problem-Solving Competence	0.90
Self-Regulated Learning	0.92
Reflective Judgment	0.88
Overall Instrument	0.93

The overall reliability coefficient of 0.93 indicated excellent internal consistency.

Split-half reliability analysis further confirmed the stability of the instrument with a Spearman-Brown coefficient of 0.91.

Construct Validity

Exploratory Factor Analysis (EFA) and Confirmatory Factor Analysis (CFA) were performed to establish construct validity.

The suitability of the data for factor analysis was assessed using the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's Test of Sphericity.

Table 7

Results of Factorability Tests

Test	Value
Kaiser-Meyer-Olkin (KMO)	0.92
Bartlett's Test of Sphericity	$p < 0.001$

The results confirmed that the dataset was appropriate for factor analysis.

Exploratory Factor Analysis extracted six factors corresponding to the theoretical dimensions of cognitive autonomy. These six factors collectively explained 72% of the total variance.

Confirmatory Factor Analysis was subsequently conducted to verify the factor structure.

Table 8

Confirmatory Factor Analysis Fit Indices

Fit Index	Obtained Value	Recommended Value
CFI	0.95	> 0.90
TLI	0.94	> 0.90
RMSEA	0.05	< 0.08
SRMR	0.04	< 0.08

The obtained values indicated a satisfactory model fit and confirmed the construct validity of the assessment device.

4.9 Ethical Considerations

The study strictly adhered to accepted ethical standards governing

educational and social science research. Participation was voluntary, and informed consent was obtained from all respondents before data collection. Participants were assured that their identities would remain anonymous and that the collected information would be used solely for academic purposes.

No personally identifiable information was collected. Participants were informed of their right to withdraw from the study at any stage without any consequences. Data confidentiality and security were maintained throughout the research process. The study involved no physical, psychological, or academic risk to the participants.

The methodology combined psychometric instrument development procedures with advanced cognitive analytics techniques to develop and validate a Cognitive Autonomy Assessment Device suitable for diverse learner populations. Through systematic item construction, expert validation, pilot testing, large-scale administration, reliability assessment, construct validation, and cognitive analytics-based profiling, the study established a scientifically robust and inclusive assessment framework. The methodological approach provides a strong foundation for examining cognitive autonomy within contemporary diversity research and contributes to the development of evidence-based educational practices that support inclusive learning environments.

5. RESEARCH ANALYSIS AND DISCUSSION

The research analysis of the present study focuses on the development, validation, and practical relevance of the Cognitive Autonomy Assessment Device (CAAD) in measuring cognitive autonomy among diverse learner populations. The data obtained from 500 undergraduate students were analyzed to examine the reliability, validity, dimensional structure, and diversity-based variations of cognitive autonomy. The findings indicate that cognitive autonomy is a multidimensional construct that includes independent thinking, critical reasoning, decision-making ability, problem-solving competence, self-regulated learning, and reflective judgment.

5.1 Overall Cognitive Autonomy Level of Learners

The overall analysis revealed that the learners demonstrated a moderate to high level of cognitive autonomy. This suggests that most students possessed the ability to think independently, evaluate

information, make decisions, and reflect on their learning experiences. However, variations were observed across different dimensions, indicating that cognitive autonomy does not develop uniformly among all learners.

Table 1

Overall Cognitive Autonomy Scores of Participants

Level of Cognitive Autonomy	Score Range	Number of Students	Percentage
High	230–310	178	35.6%
Moderate	155–229	248	49.6%
Low	62–154	74	14.8%
Total	—	500	100%

The table shows that nearly half of the participants fell under the moderate category, while 35.6% demonstrated high cognitive autonomy. Only 14.8% showed low levels of cognitive autonomy. This finding indicates that a majority of learners have developed basic autonomous cognitive abilities, though many still require structured academic support to strengthen higher-order thinking skills.

5.2 Dimension-Wise Analysis of Cognitive Autonomy

The six dimensions of cognitive autonomy were analyzed separately to understand the specific strengths and limitations of learners.

Table 2

Dimension-Wise Mean Scores of Cognitive Autonomy

Dimension	Mean Score	Standard Deviation	Interpretation
Independent Thinking	4.12	0.68	High
Critical Reasoning	3.86	0.72	Moderate to High
Decision-Making Ability	3.74	0.76	Moderate
Problem-Solving Competence	3.91	0.70	Moderate to High
Self-Regulated Learning	3.68	0.81	Moderate
Reflective Judgment	3.95	0.69	Moderate to High

The highest mean score was found in Independent Thinking, which indicates that learners were relatively confident in forming their own opinions and judgments.

This suggests that students are gradually moving away from passive learning and are beginning to express individual viewpoints. Reflective Judgment and Problem-Solving Competence also recorded comparatively strong scores, showing that learners were able to reflect on their learning experiences and respond to academic challenges.

However, Self-Regulated Learning received the lowest mean score. This indicates that many learners still require guidance in planning, monitoring, and evaluating their learning processes. Although students may think independently, they may not always possess the discipline or strategies required to manage their learning effectively. Decision-Making Ability also showed only a moderate level, suggesting that students often need support in making informed academic and personal choices.

5.3 Reliability and Validity Analysis

The reliability analysis confirmed that the Cognitive Autonomy Assessment Device is a consistent and dependable tool. The overall Cronbach's Alpha value was 0.93, which indicates excellent internal consistency. This means that the items included in the instrument measured the intended construct in a stable and coherent manner.

Table 3

Reliability Analysis of CAAD

Dimension	Cronbach's Alpha	Interpretation
Independent Thinking	0.89	Very Good
Critical Reasoning	0.91	Excellent
Decision-Making Ability	0.87	Very Good
Problem-Solving Competence	0.90	Excellent
Self-Regulated Learning	0.92	Excellent
Reflective Judgment	0.88	Very Good
Overall Scale	0.93	Excellent

The reliability values for all dimensions were above 0.80, confirming that each dimension had strong internal consistency. This proves that the instrument can be used confidently for measuring cognitive autonomy among diverse groups of learners.

The validity of the instrument was confirmed through Exploratory Factor Analysis and Confirmatory Factor

Analysis. The six-factor structure identified in the study matched the theoretical framework. This confirms that cognitive autonomy is not a single ability but a combination of related cognitive capacities.

Table 4

Construct Validity Results

Test / Index	Obtained Value	Interpretation
KMO Value	0.92	Excellent sampling adequacy
Bartlett's Test	$p < 0.001$	Significant
Total Variance Explained	72%	Strong explanatory power
CFI	0.95	Good model fit
TLI	0.94	Good model fit
RMSEA	0.05	Acceptable fit
SRMR	0.04	Acceptable fit

The KMO value of 0.92 confirmed that the sample size was suitable for factor analysis. Bartlett's Test was significant, indicating that the variables were sufficiently correlated. The six factors explained 72% of the total variance, which demonstrates strong construct validity. The confirmatory factor analysis indices also showed a good model fit, establishing that CAAD is a valid instrument for cognitive autonomy assessment.

5.4 Diversity-Based Analysis

A major aim of the study was to examine whether cognitive autonomy differs across diverse learner groups. The analysis considered gender, rural and urban background, first-generation learner status, and language background.

Table 5

Cognitive Autonomy across Learner Groups

Learner Category	Mean Score	Interpretation
Male Students	3.86	Moderate to High
Female Students	3.94	Moderate to High
Rural Learners	3.72	Moderate
Urban Learners	4.02	High
First-Generation Learners	3.65	Moderate
Continuing-Generation Learners	4.01	High
Multilingual Learners	3.98	Moderate to High
Monolingual Learners	3.78	Moderate

The findings show that female students scored slightly higher than male students in overall cognitive autonomy. This may be due to greater reflective engagement, academic discipline, and careful decision-making tendencies. However, the difference was not very large, indicating that gender alone is not a strong determinant of cognitive autonomy.

Urban learners scored higher than rural learners. This difference may be linked to greater access to digital resources, exposure to diverse learning environments, academic support systems, and opportunities for independent learning. Rural learners, though capable, may face limitations related to educational infrastructure, technological access, and academic exposure.

Continuing-generation learners scored higher than first-generation learners. This finding suggests that students whose parents or family members have prior educational experience may receive more academic guidance and motivational support. First-generation learners may possess strong potential, but they may require additional mentoring, confidence-building, and institutional support to develop autonomous learning habits.

Multilingual learners scored higher than monolingual learners. This indicates that exposure to multiple languages may strengthen cognitive flexibility, comparative thinking, and adaptability. Multilingual learners often negotiate meaning across linguistic systems, which may enhance their ability to analyze, interpret, and respond to complex situations.

5.5 Cognitive Analytics-Based Findings

The integration of cognitive analytics provided deeper insights into learners' response patterns and cognitive profiles. Cognitive analytics helped identify not only the score levels but also the nature of learners' cognitive behavior.

Table 6

Cognitive Autonomy Profiles Identified through Analytics

Profile Type	Characteristics	Percentage of Learners
Highly Autonomous Learners	Strong independent thinking, self-regulation, and reflective judgment	28%
Reflective but	Good reflection but require	32%

Dependent Learners	external guidance	
Decision-Oriented Learners	Strong in decision-making but moderate in reflection	18%
Assisted Learners	Depend heavily on teachers and peers	14%
Low-Autonomy Learners	Weak self-regulation and limited independent judgment	8%

The cognitive analytics findings revealed that learners do not belong to one uniform category. A significant group of students were reflective but dependent learners. They were capable of thinking deeply but still relied on teachers, peers, or structured guidance before making academic decisions. This finding is important because it shows that reflection alone does not guarantee cognitive autonomy. Learners must also develop confidence, initiative, and self-regulation.

Highly autonomous learners represented 28% of the sample. These students showed strong scores across all six dimensions and demonstrated the ability to manage learning independently. Assisted learners and low-autonomy learners require special academic support, including mentoring, guided practice, reflective exercises, and learner-centered pedagogy.

5.6 Discussion of Major Findings

The findings of the study confirm that cognitive autonomy is a vital construct in diversity research. In diverse educational settings, learners differ not only in language, culture, gender, and socio-economic status but also in how they think, regulate learning, solve problems, and make decisions. Therefore, diversity research must move beyond demographic analysis and include cognitive dimensions of learner development.

The high reliability and validity values of CAAD demonstrate that the device is scientifically suitable for assessing cognitive autonomy. The six identified dimensions offer a comprehensive framework for understanding autonomous cognition. Independent thinking emerged as the strongest dimension, suggesting that learners increasingly value personal judgment and intellectual freedom. This is a positive sign in higher education, where students are expected to become active participants in knowledge construction.

However, the relatively lower score in self-regulated learning highlights an important pedagogical concern. Many students may express independent opinions but may not have adequate strategies to plan, monitor, and evaluate their learning. This gap suggests that institutions should focus on teaching learning strategies, time management, goal setting, reflective writing, and self-assessment techniques.

The diversity-based findings also have important implications. The lower scores of rural and first-generation learners do not indicate lack of ability; rather, they point to unequal access to academic resources and support systems. These learners may benefit from bridge courses, mentoring programmes, digital literacy training, peer learning groups, and counseling support. Similarly, the higher scores of multilingual learners suggest that linguistic diversity can be viewed as a cognitive strength rather than a barrier.

The cognitive analytics component added depth to the study by identifying learner profiles. Traditional assessment may only classify learners as high, moderate, or low achievers. However, cognitive analytics revealed more meaningful categories such as reflective but dependent learners, decision-oriented learners, and assisted learners. This profiling can help teachers design targeted interventions. For example, reflective but dependent learners may need confidence-building activities, while low-autonomy learners may require structured guidance and gradual exposure to independent tasks.

5.7 Educational Implications

The study has several educational implications. First, cognitive autonomy should be included as an important outcome of higher education. Institutions should not focus only on examination performance but also on independent thinking, reflective judgment, and problem-solving ability. Second, the CAAD can be used by teachers, counselors, and researchers to identify learners who need academic support. Third, curriculum designers should include activities that promote learner autonomy, such as problem-based learning, project work, case analysis, reflective journals, peer discussions, and decision-making tasks.

The findings also support the need for inclusive pedagogy. Learners from rural, first-generation, and less privileged backgrounds should be provided with additional learning support without labeling them as weak. Cognitive autonomy can be developed through proper educational

exposure, encouragement, and guided practice. Therefore, the study emphasizes the role of institutions in creating supportive learning environments that enable all learners to develop intellectual independence.

The research analysis confirms that the Cognitive Autonomy Assessment Device is a reliable, valid, and useful instrument for measuring cognitive autonomy among diverse learner populations. The findings show that cognitive autonomy is multidimensional and influenced by educational, linguistic, and socio-cultural factors. While many learners demonstrated moderate to high levels of autonomy, specific areas such as self-regulated learning and decision-making require further strengthening.

The study establishes that cognitive analytics can significantly advance diversity research by providing deeper insights into learner behavior and cognitive development. By identifying learner profiles and group-based variations, the CAAD offers a practical framework for inclusive educational planning. Overall, the findings highlight the importance of developing cognitive autonomy as a central goal of contemporary education and as a meaningful indicator of equity, diversity, and learner empowerment.

6. Recommendations for Future Research

The present study successfully developed and validated a Cognitive Autonomy Assessment Device (CAAD) for measuring cognitive autonomy among diverse learner populations. While the findings contribute significantly to diversity research and educational assessment, several avenues remain open for further investigation. Future studies can expand the scope, applicability, and analytical potential of the instrument in various educational and social contexts.

One important direction for future research is the longitudinal examination of cognitive autonomy development. The current study adopted a cross-sectional approach, providing a snapshot of learners' cognitive autonomy at a particular point in time. Future researchers may conduct longitudinal studies to investigate how cognitive autonomy evolves across different stages of education and how factors such as age, academic experience, and learning environments influence its growth over time. Such studies would provide valuable insights into the

developmental trajectory of autonomous cognition.

Future research may also explore the application of the Cognitive Autonomy Assessment Device across different educational levels, including school education, postgraduate programmes, and professional training contexts. The present study focused primarily on undergraduate students; therefore, extending the instrument to other learner populations would help establish its broader applicability and generalizability.

Another promising area concerns cross-cultural and international validation studies. Cognitive autonomy may be influenced by cultural norms, educational philosophies, and societal expectations. Researchers can administer the instrument in different countries and cultural contexts to examine the universality and contextual variability of cognitive autonomy. Such comparative studies would contribute to the development of culturally responsive assessment frameworks and strengthen the global relevance of diversity research.

The integration of artificial intelligence and learning analytics represents another significant avenue for future investigation. Emerging technologies offer opportunities to capture real-time learner behaviors, decision-making processes, and cognitive engagement patterns. Future researchers may combine the Cognitive Autonomy Assessment Device with artificial intelligence-based educational platforms, adaptive learning systems, and learning management systems to develop dynamic models of cognitive autonomy. Such integration could facilitate continuous assessment and personalized learning support.

Future studies may also examine the relationship between cognitive autonomy and other educational variables, including academic achievement, creativity, emotional intelligence, leadership skills, digital literacy, critical thinking, and employability competencies. Investigating these relationships would enhance understanding of the broader educational significance of cognitive autonomy and its contribution to learner success in academic and professional settings.

The present study identified differences in cognitive autonomy among diverse learner groups. Future researchers may conduct in-depth investigations focusing specifically on first-generation learners, multilingual learners, learners

from rural backgrounds, students with disabilities, and other underrepresented groups. Such studies would provide valuable insights into the unique challenges and strengths associated with different learner populations and support the development of targeted educational interventions.

Experimental and intervention-based research also offers considerable potential. Researchers may design instructional programmes, mentoring initiatives, reflective learning activities, and technology-enhanced pedagogical strategies aimed at strengthening cognitive autonomy. The Cognitive Autonomy Assessment Device can serve as both a diagnostic and evaluative tool to measure the effectiveness of such interventions.

Furthermore, future studies may refine and expand the cognitive analytics framework employed in the present research. Advanced analytical techniques such as machine learning, predictive modelling, neural network analysis, and cognitive profiling may provide deeper insights into learner behavior and cognitive development. These approaches can help identify hidden patterns and predictors of cognitive autonomy, thereby enhancing educational decision-making.

Finally, future research should continue exploring the role of cognitive autonomy in promoting diversity, equity, and inclusion within educational systems. As contemporary educational institutions increasingly serve heterogeneous learner populations, understanding how cognitive autonomy contributes to learner empowerment, academic resilience, and social participation will remain a critical area of scholarly inquiry. The development of evidence-based strategies for nurturing autonomous cognition among diverse learners can significantly contribute to inclusive and equitable education in the twenty-first century.

In summary, future research should focus on longitudinal investigations, cross-cultural validation, artificial intelligence integration, intervention studies, learner diversity, and advanced cognitive analytics. These directions will not only strengthen the theoretical foundations of cognitive autonomy research but also enhance its practical relevance for educators, policymakers, and researchers committed to advancing diversity and inclusion in education.

7. Conclusion

The present study sought to advance diversity research through the development

and validation of a Cognitive Autonomy Assessment Device (CAAD), a comprehensive instrument designed to measure cognitive autonomy among diverse learner populations. In an era characterized by increasing cultural diversity, technological transformation, and evolving educational demands, the ability to think independently, make informed decisions, solve complex problems, regulate learning processes, and engage in reflective judgment has become an essential educational outcome. The study therefore addressed a significant gap in diversity research by providing a scientifically validated framework for assessing these critical cognitive capacities.

The findings demonstrate that cognitive autonomy is a multidimensional construct comprising independent thinking, critical reasoning, decision-making ability, problem-solving competence, self-regulated learning, and reflective judgment. Through rigorous psychometric procedures, including expert validation, pilot testing, reliability assessment, exploratory factor analysis, and confirmatory factor analysis, the Cognitive Autonomy Assessment Device was found to possess high levels of reliability and validity. The instrument successfully captured meaningful variations in cognitive autonomy across diverse learner groups, confirming its suitability for educational research and practice.

A significant contribution of the study lies in its integration of cognitive analytics with traditional psychometric assessment. By employing cognitive profiling and response pattern analysis, the research moved beyond conventional measurement approaches and provided deeper insights into learners' cognitive behaviors. The identification of distinct learner profiles highlighted the complexity of autonomous cognition and demonstrated the value of cognitive analytics in understanding individual differences. This approach offers educators and researchers a more nuanced perspective on learner development and educational diversity.

The diversity-based findings further reinforce the importance of considering cognitive dimensions within inclusion and equity research. Variations observed among rural and urban learners, first-generation and continuing-generation students, and multilingual and monolingual learners indicate that educational experiences and opportunities influence the development of cognitive autonomy. These findings suggest that cognitive autonomy should be recognized as an important indicator of

learner empowerment and educational equity. Educational institutions must therefore create learning environments that support independent thinking, self-regulation, critical inquiry, and reflective practice for all learners, regardless of their backgrounds.

The study also highlights the educational significance of fostering cognitive autonomy in contemporary learning environments. As societies become increasingly dependent on digital technologies and information-rich ecosystems, learners must possess the capacity to evaluate information critically, make informed decisions, and adapt to changing circumstances. Cognitive autonomy equips individuals with the intellectual independence necessary to navigate complex academic, professional, and social contexts. Consequently, educational systems should prioritize the development of autonomy-oriented pedagogies that encourage active learning, inquiry, collaboration, and reflection.

From a practical perspective, the Cognitive Autonomy Assessment Device offers valuable applications for educators, researchers, counselors, curriculum designers, and policymakers. The instrument can be utilized to assess learner needs, design targeted interventions, monitor cognitive development, and evaluate educational programmes. Furthermore, the findings provide evidence-based support for inclusive educational practices that recognize and nurture diverse cognitive strengths among learners.

The study contributes substantially to the growing body of literature on diversity studies, educational assessment, and cognitive analytics. By linking cognitive autonomy with diversity research, it broadens existing understandings of inclusion beyond demographic characteristics and emphasizes the importance of cognitive empowerment. The integration of psychometric assessment and cognitive analytics represents an innovative methodological contribution that may inspire future research in related fields.

In conclusion, the Cognitive Autonomy Assessment Device represents a reliable, valid, and inclusive tool for measuring cognitive autonomy among diverse learner populations. The study demonstrates that cognitive autonomy is a crucial component of learner development and an important factor in promoting educational equity, academic success, and lifelong learning. As educational

institutions continue to serve increasingly diverse populations, the assessment and enhancement of cognitive autonomy will remain essential for fostering inclusive, resilient, and intellectually empowered learners. The findings underscore the transformative potential of cognitive analytics in advancing diversity research and provide a strong foundation for future investigations into autonomous cognition and inclusive educational development.

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ETHICAL DECLARATIONS

Ethics Approval and Consent to Participate

The study was conducted in accordance with the ethical standards and guidelines for educational and social science research. Participation in the study was entirely voluntary. Prior to data collection, all participants were informed about the objectives, procedures, and purpose of the research. Informed consent was obtained from each participant before administering the Cognitive Autonomy Assessment Device (CAAD).

Consent for Publication

All participants provided their consent for the use of anonymized data for academic research and publication purposes. No personally identifiable information was collected, and participants' identities have been fully protected.

Human and Animal Rights

This study involved only human participants and did not involve any animal subjects. The research procedures posed no physical, psychological, social, or academic risk to the participants.

Confidentiality and Anonymity

The confidentiality and anonymity of all participants were strictly maintained throughout the research process. No names, registration numbers, institutional identifiers, or personal details were recorded. All collected data were used exclusively for research purposes and stored securely.

Voluntary Participation

Participation in the study was entirely voluntary. Participants were informed of their right to withdraw from the study at any stage without any penalty or negative consequences.

Data Availability Statement

The data supporting the findings of this study are available from the corresponding author upon reasonable request. Data will be shared only for academic and research purposes while maintaining participant confidentiality.

Conflict of Interest

The authors declare that there are no conflicts of interest regarding the publication of this research.

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Author Contributions

Mr. S. Kumaran Arul Devaram contributed to the conceptualization of the study, literature review, instrument development, data collection, data analysis, interpretation of findings, and manuscript preparation.

Dr. S. Gunasekaran contributed to research supervision, methodological design, validation of the assessment framework, critical review of the manuscript, and overall guidance throughout the study.

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Declaration by the Authors

The authors affirm that this manuscript is original, has not been published previously, and is not under consideration for publication elsewhere. All sources of information have been appropriately acknowledged, and the study complies with accepted ethical standards for academic research.