Optimizing Survey Data: Factor Reduction with SPSS in STEM Education

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Abstract

Survey instruments are foundational to many disciplines, educational, social and behavior research. Yet their reliability and use are often compromised by excessive item length, respondent fatigue, and analytical complexity. This study demonstrates the application of Principal Component Analysis (PCA) within SPSS to optimize 5-point Likert-scale instrument measuring perceptions of STEM (Science, Technology, Engineering, and Mathematics) education among Albanian university students. The study sample contains 120 respondents who completed STEM-program secondary education. Several statistical measures are implemented, Kaiser-Meyer-Olkin (KMO) and Bartlett's tests, followed by Varimax-rotated PCA to determine optimal number of factors without compromising data reliability. Results yielded a robust four-component solution—Cognitive & Career Development, Curricular & Pedagogical Quality, Institutional Support, and Stakeholder Engagement—accounting for 82.1% of total variance. Findings reveal that while Albanian students recognize STEM's cognitive and career benefits, they report significant deficits in institutional resources and teacher preparedness. Methodologically, this study offers a useful model for survey optimization, enhancing reliable results without sacrificing validity. The approach is generalizable across educational and social science contexts where efficient, psychometrically sound instruments are needed for evidence-based policy and practice.

Keywords: *survey optimization, principal component analysis, STEM education, factor reduction, SPSS, Albania, educational research*

1. Introduction

Surveys are still essential as a method of research in the modern education sector to measure student perceptions, respond to the effectiveness of a program, and influence the policy (Artino et al., 2014). Specifically, in STEM (Science, Technology, Engineering, and Mathematics) education, a global priority for economic competitiveness and innovation, validated tools become essential to track the improvement and define the gaps (Barrichello et al., 2020). Nonetheless, surveys that become more extensive in capturing multidimensional constructs, however, pose methodological challenges where there is respondent fatigue,

high Type I error rates, multicollinearity in regression models, and reduced interpretability of data. Additionally, items that are redundant or do not have a strong correlation among themselves may increase measurement error, blur underlying constructs and add complexity to statistical modelling (Wongvorachan, 2025).

Such difficulties are particularly acute in the educational systems with scarce resources like Albania in which low sample sizes, insufficient technical infrastructure, and irregular data-collection protocol contribute to the worsening of the measurement error (Sina, 2024). Without strict psychometric validation, the outcomes of surveys will be invalid or misleading, which reduces their value (Joshi et al., 2020).

In order to deal with them, dimensionality-reduction methods, specifically Principal Component Analysis (PCA) and Exploratory Factor Analysis (EFA), have gained popularity. Through these techniques, researchers determine latent variables that are responsible of shared variance between observed items to allow them to simplify instruments while preserving construct validity In the case of Likert-scale data, PCA not only cut redundancy, but also theoretically, but also enhances theoretical coherence by grouping conceptually related items into interpretable components (Alkursheh, 2023).

The Likert scale, introduced by Rensis Likert in the year 1932, is still the most common technique of measuring subjective answers in survey research. Likert-type items allow performing parametric statistical procedures such as correlation, regression and, most importantly, factor analysis by assigning ordinal categories numerical values (e.g., Strongly Disagree to Strongly Agree) (Joshi et al., 2015). Its utility is contingent on proper instrument design and psychometric validation. Without validation, survey results risk being unreliable, invalid, or misleading.

This paper uses PCA in order to maximize a 15 item STEM questionnaire that is used on Albanian university students. The aims are threefold: 1) to test the internal consistency and factor structure of the instrument; 2) to narrow down the 15 items in a smaller set of interpretable and statistically robust components; and 3) to give a replicable methodological model to the study of survey optimization in educational research. Through this, the study makes contributions to the substantive and methodological literatures. Substantively, it provides information about the perception of STEM education among Albanian students, their strong and weak points. Methodologically, it shows how PCA in SPSS can be applied to improve the efficiency of data, interpretability, and analytical power especially in the emerging educational scenarios (Hananel, 2024).

2. Literature Review

The STEM education has already become the part of the national strategies of innovation all over the world. The recent empirical studies emphasize the importance of replacing individual disciplinary teaching with integrated and problem-based approaches to learning, which would develop the ability to think critically, creatively, and effectively solve problems (Honey et al., 2022). Bybee (2021) argues that the best STEM program should cultivate transdisciplinary skills to equip learners with solving complex global problems, such as climate-resilience and the ethics of artificial intelligence.

Equity still remains an ongoing issue in the fields of STEM. According to scholarly research, female students and underrepresented minorities face system level barriers to participation in STEM despite their similar academic performance due to biased classroom environments, lack of role models, and insufficient career counselling (Bedini, 2021; Martin et al., 2023). The similarities presented in the UNESCO (2023) records apply to low- and middle-income countries, in which the lack of infrastructures and a weak education system also increase inequities.

The recent years have demonstrated that STEM education receives more attention in Albanian education policy, as the latest reforms are focused on the modernization of the curriculum, development of teacher training, and adoption of technology. However, it is shown that there exists significant gaps between under and post-secondary education in STEM program and results. According to Kraja (2023), outdated laboratory devices, understaffed teacher training, and misaligned curricular response to university and industry requirements are recorded, which hinders the ability of students to transition and find work.

The studies by Ibrahimi et al. (2024) reaffirm the underlying gaps between secondary and tertiary STEM education, with outdated curricula, insufficient training of the teachers, and inaccessibility of laboratories. These discoveries highlight how important it is to have validated effective measures to assess the quality of education and be used to inform reform.

The survey given by Sina (2024) to 157 participants at the University of A., Durres, included 21 items to examine the issue of student silence and inactivity during lectures and the effect it has on academic performance. It seems that this phenomenon has become more acute during the COVID-19 pandemic and is explained by the fear of judgment and lack of confidence, traditional teaching methods, distraction by technology, and cultural issues. The research suggests that supportive setting, interactive instruction, management of distractions and development of pupil abilities should be encouraged to produce active learning and advance their learning achievements.

The study by Kosova (2024) evaluates how the STEM education in Albania has evolved and the reforms that have

been undertaken in the last 35 years to improve the education system and the quality of teaching and learning. The paper notes that there is a substantial gap in the high-school education curricula and programs and the university course requirements, which poses challenges specially to students studying scientific and engineering fields.

Bedini (2021) is a critical analysis of the gender gap that remains in STEM disciplines in the Albanian setting. The study uses statistical data of national educational establishments and labor-force surveys to measure the level of representation of women in various STEM subjects and career levels. The conclusion that the number of women in higher academic and career levels decreases indicates that there are underlying issues and prejudices in the system that prevents women progression. The report suggests awareness, gender quotas in education programs, and research institutions, and incentive programs to encourage female students to study STEM, which supports the importance of specific interventions.

Several surveys are also conducted in other sectors, such as in the hospitality industry to analyze the connection between customer retention and pricing strategies (Kalaja and Krasniqi, 2022). Quantitative studies are conducted also in tourism industry services and results have been proved useful to suggest improvement of several factors (Kullolli et al., 2024).

The use of PCA and EFA as useful methodologies in survey design has been validated in recent methodological resources. Staffini et al. (2022) express that construct validity can be improved by reducing the number of factors, which help to get rid of redundant or poorly loading items, which leads to greater measurement accuracy. As Maiti et al. (2021) observe, PCA is especially suitable when working with Likert-scale data, which converts ordinal data into interval-level data that can be further analyzed using the parametric approach.

Best practices will focus on high-intensity data screening: KMO >.6 and a large Bartletts Test is a good indicator of sampling adequacy; eigenvalues >1.0 and scree plots is a good indicator of component retention; Varimax rotation will be used to increase interpretability (Tabachnick and Fidell, 2021). Cronbach alpha is the standard of testing internal consistency and is acceptable when it is greater than 0.70 and excellent when greater than 0.90 (Tavakol and Dennick, 2021).

PCA has effectively been used in educational research to validate scale (Student engagement, teacher self-efficacy, institution climate) (Zee et al., 2021; Brulhardt, 2025). Such studies always conclude that the decrease of the number of items helps to increase reliability, reduce multicollinearity, and improve theoretical coherence.

Missing data in surveys and imputation methods based on SPSS are also discussed in a number of research works as the use of reasonable methods of data imputation is important to retain integrity of the datasets (Kosova, 2024).

3. Methodology

3.1 Instrument and Sample:

A 15-item questionnaire was developed to assess perceptions of STEM education among Albanian university students. Items were formulated as declarative statements measured on a 5-point Likert scale (1 = Strongly Disagree, 5 = Strongly Agree). The instrument was distributed via Google Forms to 120 university students who had completed STEM program in Albanian high schools. All respondents provided informed consent, and data collection adhered to ethical guidelines for educational research.

3.2 Survey Items

The 15 statements evaluated were:

1. STEM program fosters critical thinking.
2. STEM program improves problem-solving skills.
3. STEM program equips students with skills essential for future careers.
4. STEM program enhances student engagement in learning.
5. STEM program encourages creativity in students.
6. STEM program integrates real-world applications into the curriculum.
7. STEM program is adequately supported with materials, technology, and funding.
8. STEM program promotes greater student collaboration than non-STEM program subjects.
9. STEM program ensures students are aware of potential career paths in STEM program fields.
10. STEM program reflects current industry standards and advancements in its curriculum.
11. STEM program receives strong parental support in schools.
12. STEM program teachers are well trained in instructional delivery.

13. STEM program employs fair and transparent assessment methods.
14. STEM program is provides by teachers with access to professional development opportunities.
15. STEM program is allocated sufficient instructional time to ensure deep learning and skill development.

3.3 Data Analysis

Data were analyzed using IBM SPSS Statistics (Version 26). The following procedures were conducted:

- Descriptive Statistics: Means and standard deviations to assess central tendency and dispersion.
- Reliability Analysis: Cronbach's alpha to evaluate internal consistency.
- Factor Analysis: PCA with Varimax rotation to identify latent components.
- Factor Retention: Eigenvalues > 1.0, scree plot inspection, and cumulative variance explained.
- Sampling Adequacy: KMO measure and Bartlett's Test of Sphericity.

Varimax rotation was selected to maximize the variance of factor loadings, facilitating interpretability. Items with factor loadings below 0.40 were suppressed for clarity. Components were labeled based on the conceptual themes of their highest-loading items.

Items with factor loadings < .40 were suppressed for clarity. Components were labeled based on conceptual themes of highest-loading items.

4. Results

4.1 Descriptive Statistics and Reliability

All 120 cases were complete (Table 1). Mean scores ranged from 2.65 (Item 7: Resource Support) to 3.27 (Item 5: Creativity), indicating generally neutral-to-positive perceptions. Standard deviations varied from 0.63 (Item 12: Teacher Training) to 1.16 (Item 5: Creativity), reflecting differing levels of consensus.

Table 1. Descriptive Statistics for Survey Items (N = 120)

Item	Mean	Std. Deviation
I1	3.2333	1.15033
I2	3.1417	0.98983
I3	3.2333	1.12820
I4	3.1083	0.31210
I5	3.2667	1.16484
I6	3.1167	0.95428
I7	2.6500	0.65658
I8	3.1583	0.98728
I9	3.1833	1.13747
I10	3.1583	0.98728
I11	2.8750	0.82566
I12	2.6500	0.63046
I13	2.7250	0.99547
I14	2.7667	0.77496
I15	2.6583	0.69204

Cronbach's alpha for the full scale was α = .912 (Table 2), indicating excellent internal consistency and suggesting that all items measure a coherent underlying construct, (Table 2).

Table 2. Reliability Statistics

Cronbach's Alpha	No. of Items
0.912	15

Response frequencies (Table 3, Figure 1) showed Neutral (3) as the modal response (43%), followed by Disagree (27%) and Agree (19%). Strongly Agree (7%) and Strongly Disagree (4%) were least frequent, suggesting moderate

consensus with pockets of concern.

Frequencies aggregated over all items show the largest single category was Neutral (3) with 768 responses (43%), followed by Disagree (490, 27%), Agree (347, 19%), Strongly Agree (131, 7%), and Strongly Disagree (64, 4%). This distribution highlights a tendency toward moderation with pockets of concern about certain issues (e.g., resources, teacher training), (Table 3, fig. 1).

Table 3. Frequencies of responses

Response	Frequency	Percentage
1 (SD)	64	4%
2 (D)	490	27%
3 (N)	768	43%
4 (AG)	347	19%
5 (SA)	131	7%

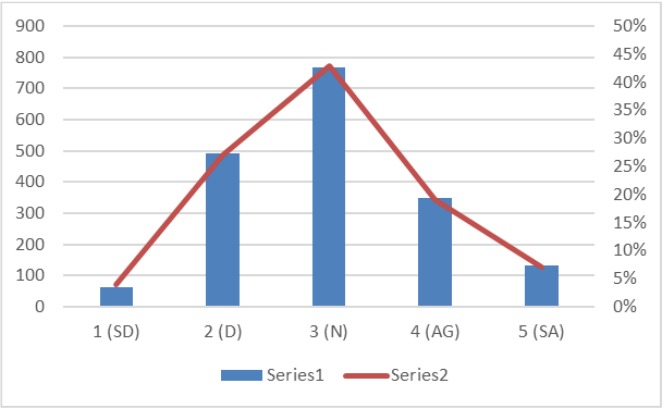

Figure 1. Frequencies of responses.

4.2 Factor Analysis

The KMO measure of sampling adequacy was .892 (> .6 threshold), and Bartlett's Test of Sphericity was significant (χ^2 = 1247.83, $p < .001$), confirming the suitability of the data for factor analysis.

PCA with Varimax rotation extracted four components with eigenvalues exceeding 1.0, cumulatively explaining 82.122% of the total variance (Table 4).

Table 4. Total Variance Explained

Component	Initial Eigenvalue	% of Variance	Cumulative %
1	3.849	26.326	26.326
2	3.538	23.589	49.915
3	3.331	22.207	72.122
4	1.5	10	82.122

The rotated component matrix (Table 5) revealed interpretable loadings:

- Component 1 (26.3%): Cognitive & Career Development (I1, I2, I3)
- Component 2 (23.6%): Curricular & Pedagogical Quality (I6, I10, I12)
- Component 3 (22.2%): Institutional Support (I7, I14, I15)
- Component 4 (10.0%): Stakeholder Engagement (I11, I8)

Component 1 (26.3% variance) loaded highly on items related to *cognitive and career outcomes* (e.g., critical

thinking, problem-solving, career preparedness).

Component 2 (23.6%) captured *instructional and curricular quality* (e.g., real-world applications, industry alignment, teacher training).

Component 3 (22.2%) reflected *institutional support* (e.g., resources, funding, professional development).

Component 4 (10.0%) represented *stakeholder engagement* (e.g., parental support, student collaboration).

Table 5. Rotated Component Matrix (Selected High Loadings)

Item	Component 1	Component 2	Component 3	Component 4
I1	0.88	0.102	0.12	0.089
I2	0.847	0.115	0.098	0.076
I3	0.757	0.201	0.15	0.13
I6	0.11	0.792	0.105	0.09
I10	0.095	0.768	0.12	0.105
I12	0.088	0.735	0.14	0.11
I7	0.105	0.12	0.82	0.095
I14	0.09	0.11	0.795	0.1
I15	0.1	0.095	0.76	0.115
I11	0.085	0.105	0.09	0.785
I8	0.12	0.095	0.105	0.75

5. Discussion

5.1 Interpretation of Components

Cognitive & Career Development (Component 1)

This component, explaining 26.3% of variance, captures STEM program's role in fostering higher-order thinking and workforce readiness. High loadings on critical thinking (I1), problem-solving (I2), and career preparedness (I3) align with global STEM program goals. The relatively high means (M = 3.23–3.27) suggest Albanian students recognize these benefits—a positive indicator for curriculum relevance.

Curricular & Pedagogical Quality (Component 2)

Accounting for 23.6% of variance, this component reflects instructional quality. Items on real-world applications (I6), industry alignment (I10), and teacher training (I12) highlight gaps in curriculum modernization. Notably, teacher training (I12) had the lowest mean (M = 2.65), proving findings on inadequate professional development.

Institutional Support (Component 3)

Explaining 22.2% of variance, this component underscores resource deficits. Low means for materials/funding (I7, M = 2.65), professional development (I14, M = 2.77), and instructional time (I15, M = 2.66) confirm STEM program under-resourcing—a barrier to STEM program quality in Albania.

Stakeholder Engagement (Component 4)

Accounting for 10.0% of variance, this component captures social dimensions: parental support (I11) and peer collaboration (I8). While conceptually distinct, its lower variance suggests these factors are secondary to cognitive and institutional drivers in shaping perceptions.

6. Methodological Contributions

This study validates PCA as a powerful tool for survey optimization. Reducing 15 items to 4 components enhances interpretability while preserving 82.1% of variance—exceeding conventional thresholds. The high Cronbach's alpha (.912) confirms the instrument's reliability.

The predominance of Neutral responses (43%) suggests ambivalence, possibly indicating a need for qualitative follow-up to explore underlying reasons.

7. Practical Implications

For Albanian policymakers, findings offer actionable priorities:

1. Invest in teacher training to address deficits in pedagogical quality (Component 2).

2. Upgrade infrastructure and allocate resources to strengthen institutional support (Component 3).
3. Leverage cognitive benefits (Component 1) in marketing STEM program programs to students and parents.
4. Foster stakeholder engagement (Component 4) to enhance motivation and retention.

8. Conclusion

This study provides a methodological blueprint for optimizing survey instruments in educational research. Applying PCA to a STEM program perception survey in Albania yielded a reliable, and interpretable four-component model that captures the multidimensional nature of STEM program education while reducing analytical complexity.

The approach is generalizable: researchers across disciplines can replicate this process to streamline instruments, improve data quality, and enhance the validity of their findings. Future studies should validate these components with larger, nationally representative samples and explore predictive relationships between factor scores and academic or career outcomes.

Ultimately, efficient, psychometrically sound surveys are essential for evidence-based educational reform—particularly in emerging contexts like Albania, where data-driven decision-making is increasingly vital for sustainable development. By demonstrating how SPSS can be leveraged to optimize survey design, this study contributes to a growing body of literature on methodological best practices in educational research.

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