



Determinants of Nursing Education Resilience in Master of Science in Nursing Programs: Fixed-Effects Panel Evidence from Pakistan, 2014-2024

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ABSTRACT

Background: The transformation of health professions education by artificial intelligence and digital tools places increased pressure on postgraduate nursing programs to demonstrate institutional resilience. Despite this urgency, empirical determinants of Nursing Education Resilience (NER) at the institutional level are largely unmeasured, particularly in lower-middle-income country settings.

Aim: The study designed to identify and measure institutional predictors of NER in accredited Master of Science in Nursing (MSN) programs in Pakistan, 2014-2024.

Method: A balanced panel data was constructed from accredited MSN institutions of Pakistan. The pooled ordinary least squares, random effects and fixed effects (FE) models were estimated using EVIEWS 10. Model selection was based on the Hausman specification test. Six institutional predictors were investigated: adoption of AI curriculum, digital infrastructure, faculty digital competency, student engagement, research output and policy support. The pre-estimation diagnostics were the panel unit root tests and the inter-predictor correlation analysis.

Results: The random effects specification was rejected by the Hausman test ($p = 0.0003$). It was determined that the main source of NER change over time is attributable to changes that occur within institutions. Faculty digital competence and the lead time in the adoption of AI curriculum were the most significant positive predictors of NER in the preferred FE model. Each expressed digital infrastructure, student engagement, research outputs, and policy support as positive effects that reached levels of statistical significance. The confirmed stationarity and the moderate inter-predictor correlations confirmed the econometric specification.

Conclusion: The main factor behind the resilience of nursing education is the development of institutional capacity manifested through faculty development, curriculum integration of AI and support of governance. This finding provides evidence for nurse educators and accreditors as well as health workforce policy makers of Pakistan and other similar resource constrained settings.

Keywords: Nursing Education Resilience · Master of Science in Nursing · Artificial intelligence in nursing education · Faculty digital competency · Panel data · Fixed effects model · Health professions education · Pakistan

KEY HIGHLIGHTS

1. Faculty digital competency most strongly predicts Nursing Education Resilience.
2. Hausman test ($p = 0.0003$) confirms fixed effects as the optimal specification.
3. All six institutional predictors positively affect NER in Pakistan MSN programs.
4. Within-institution variation over 2014–2024 drives resilience gains.
5. Findings inform nursing education policy in resource-constrained settings.

INTRODUCTION

There is an increasing emphasis on how nursing education systems need to prepare graduates for health care that is mediated by technology, data-driven, and characterized by disruption (Ali, et al., 2023). In low- and middle-income countries, resource scarcity, uneven infrastructure and policy fragmentation may lead to fragility in institutional continuity and adaptation within graduate programs in nursing (Ching et al., 2023). In this context, resilience is not just about continuing to operate when things go wrong, but it is also about the institutional capacity to maintain pedagogical quality, modify curricula and innovate as a result of technological and organizational evolution (De Gagne et al., 2022).

This is increasingly apparent as digital and AI enabled teaching tools have made their way into nursing and medical education (Garrison wet al., 2023). We found that the feasibility, usability and satisfaction of using VR communication training was high among 268 students from six universities in five European countries (Qayyum, A., & Zawacki-Richter, 2019), and the mean usability score was 78.46 whilst the mean feasibility score was 86.44 (Saab et al., 2026). The study has demonstrated that advanced educational technologies can be accepted by learners in various contexts, but it has also indicated that the success of the implementation depends on the careful design, facilitation, and support structures.

Pakistan the focus is on the question of institutions, asking: What organizational and policy factors create greater long-term resilience in nursing education? (Zhou et al., 2024). Specifically, this study explores how the

adoption of AI curriculum, digital infrastructure, faculty digital competency, student engagement, research output and policy support contribute to the changes in NER among MSN institutions from 2014 to 2024 (Zhu et al., 2022). This orientation dovetails with the Journal of Nursing Education, which publishes high-quality studies that have implications for both undergraduate and graduate nursing programs and values research that has clear implications for education policy and practice (Saab et al., 2026; Rana et al., 2026).

The study makes a contribution to Nursing education in 3 ways. First, it provides a concrete measure of the institutional result of NER, as opposed to merely a general conceptual aim. Second, it implements panels econometric techniques, which are still less widely used in the research of nursing education. Third, it situates the Pakistan case in a wider international context of digital learning, which makes the findings applicable to a wider context than the national one (Güney et al., 2026; (Rana et al., 2024).

METHOD

Design

The study employed a quantitative panel data approach that focused on the accredited MSN institutions in Pakistan between 2014 and 2024. This was chosen to reflect cross-institutional and over-time variation while holding constant unobserved institutional factors that are constant throughout the study period. Estimation is performed in EViews 10 using the pooled ordinary least squares, fixed effects and random effects specifications of Hausman (1978).

Variables

NER was the dependent variable, and was measured through indicators of continuity of operations, curriculum adaptability, and institutional performance. The independent variables were: AI curriculum adoption (AICURR), Digital infrastructure (DIGINFRA), Faculty digital competency (FACCOMP), Student engagement (STUDENG), Research output (RESOUTPUT), and Policy support (POLSUPPORT). The variables are indicators of how the Technology-Organization-Environment model and Resilience Theory (Soharwardi at al., 2025; Rana et al., 2025).

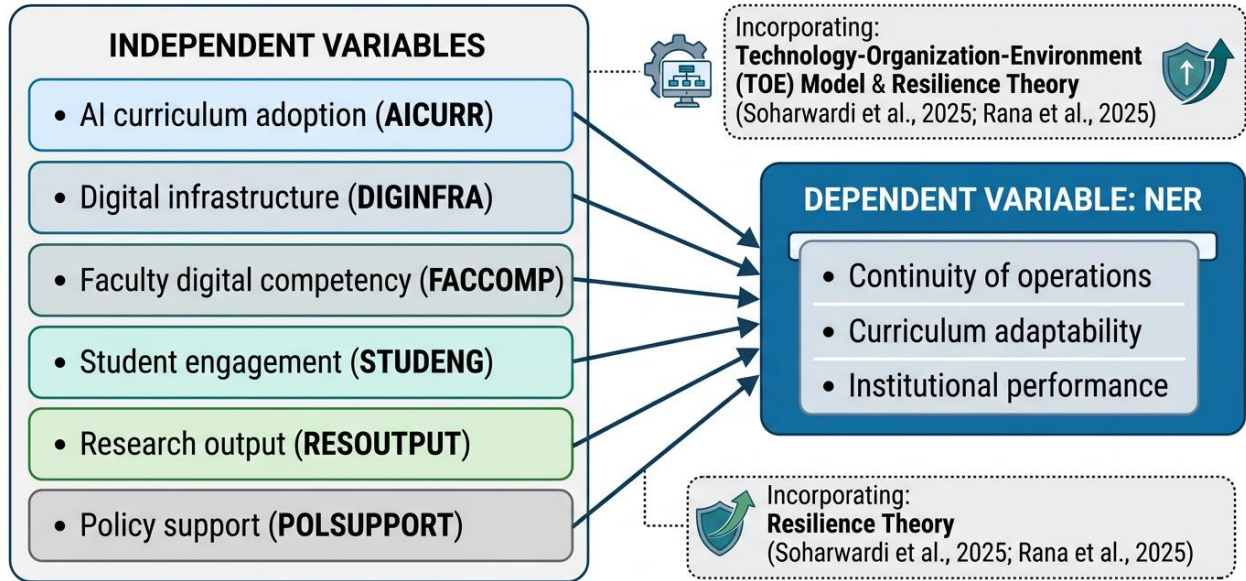


Fig 1. To integrate Technology-Organization–Environment and Resilience Theory in the theoretical framework to explain Nursing Education Resilience (NER) in MSN programs.

Analysis

Descriptive statistics, correlation analysis, Augmented Dickey-Fuller and Phillips-Perron stationarity tests are

presented as well as comparative panel regression models (Hausman, 1978). One can write the baseline model as follows:

$$NER_{it} = \beta_0 + \beta_1 AICURR_{it} + \beta_2 DIGINFRA_{it} + \beta_3 FACCOMP_{it} + \beta_4 STUDENG_{it} + \beta_5 RESOUTPUT_{it} + \beta_6 POLSUPPORT_{it} + \mu_i + \varepsilon_{it}$$

where *i* represents institution and *t* is the year. The Hausman test was used to determine the preferred model.

Ethics and reporting

Paper for health science should be written in APA 7th edition style, contain a concise introduction, clearly describe the methods, precisely report statistics, and

include a discussion of significance and implications for nursing education. The current draft therefore provides results in the form of numbered tables, and exact reported values as well as a short and concise interpretation of the nursing education in keeping with the expectations of the journal.

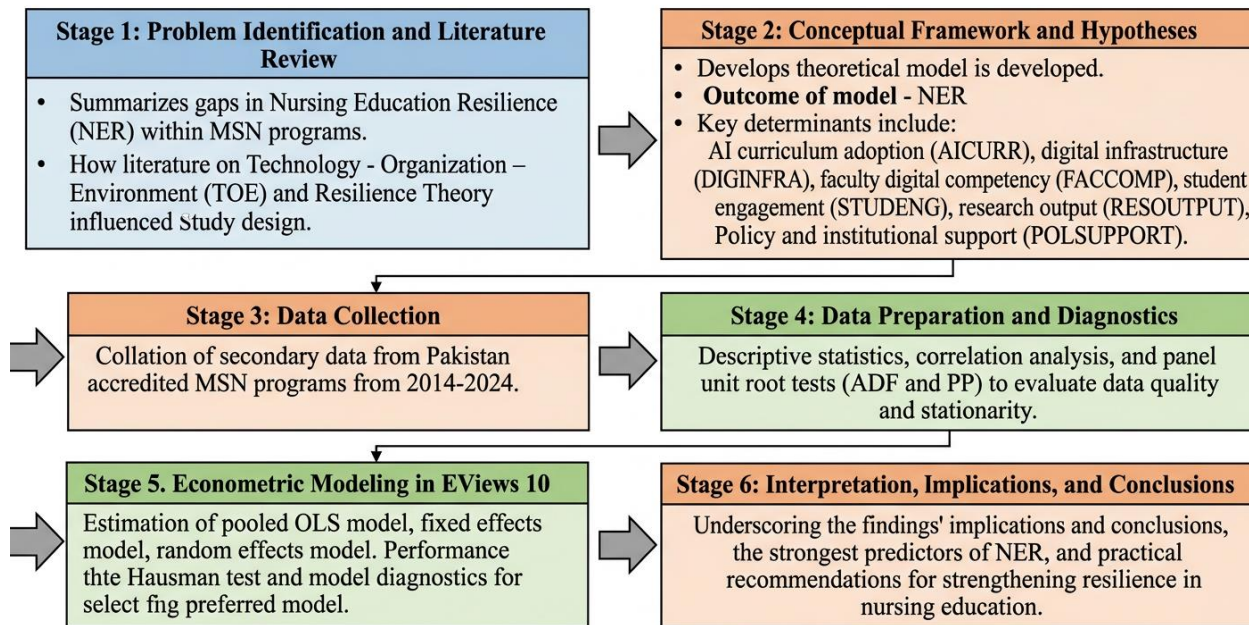


Figure 2. summarized the six-stage study design on nursing education resilience (NER).

Figure 2. In Stage 1 (problem identification and literature review), gaps in Nursing Education Resilience (NER) are summarized in MSN programs along with how the literature on Technology - Organization – Environment (TOE) and Resilience Theory influenced the study design. In stage 2 (conceptual framework and hypotheses), the theoretical model is developed, with the outcome of the model being NER, and the key determinants being AI curriculum adoption (AICURR), digital infrastructure (DIGINFRA), faculty digital competency (FACCOMP), student engagement (STUDENG), research output (RESOUTPUT), and policy and institutional support (POLSUPPORT). Stage 3 (data collection) involves the collation of secondary data from the Pakistan accredited MSN programs from 2014-2024. Stage 4 (data preparation and diagnostics) involves descriptive statistics, correlation analysis and panel unit root tests (ADF and PP) to evaluate data quality and stationarity. Stage 5 (econometric modeling in EViews 10) shows how to estimate the pooled OLS

model, fixed effects model, random effects model, and perform Hausman test and model diagnostics for the selection of the preferred model. Stage 6 (interpretation, implications, and conclusions) underscores the findings' implications and conclusions, specifically the strongest predictors of NER, and practical recommendations for strengthening resilience in nursing education.

RESULTS

Descriptive findings

There were 150 observations made by the panel. The mean NER was 0.684 of the standard deviation 0.157 suggesting moderate resilience with meaningful institutional variation. The institutional investment in infrastructure was more advanced (AICURR mean = 2.45) than the AI curricular integration (AICURR mean = 75.34).

Table 1

The descriptive statistics of the study variables are shown below.

Variable	Mean	SD	Min	Max	Observations
NER	0.684	0.157	0.400	0.920	150
AICURR	2.45	1.10	1.00	5.00	150
DIGINFRA	75.34	8.92	50.00	90.00	150
FACCOMP	0.622	0.152	0.30	0.88	150
STUDENG	0.710	0.170	0.35	0.95	150
RESOUTPUT	4.21	1.83	1.00	8.00	150
POLSUPPORT	0.73	0.44	0.00	1.00	150

Note. the acronyms in the brackets are: Nursing Education Resilience (NER); AI curriculum adoption (AICURR); digital infrastructure (DIGINFRA); faculty digital competency (FACCOMP); student engagement

(STUDENG); research output (RESOUTPUT); and policy support (POLSUPPORT).

Correlation and stationarity

All independent variables were positively correlated with NER; the highest bivariate correlation was the one between FACCOMP and NER which was 0.537. The paper also provides the results of the ADF and PP test which indicated that all the variables were stationary at

level with p values < 0.05. The results of this analysis justified the use of level-form panel regression.

Table 2

The correlation matrix and stationarity summary are provided. The correlation matrix and stationarity summary are included.

Variable	Correlation With NER	ADF p-value	PP p-value	Stationary
AICURR	0.503	0.033	0.021	Yes
DIGINFRA	0.456	0.001	0.002	Yes
FACCOMP	0.537	0.010	0.017	Yes
STUDENG	0.498	0.044	0.036	Yes
RESOUTPUT	0.442	0.029	0.026	Yes
POLSUPPORT	0.298	0.038	0.042	Yes

Note. All variables reported were stationary at level

Main regression results

The ordinary least squares, fixed effects, and random effects models were all positive for all the coefficients. In the preferred fixed effects model, the coefficient for FACCOMP was the largest (0.250), followed by STUDENG (0.172), AICURR (0.132), POLSUPPORT

(0.097), RESOUTPUT (0.083), and DIGINFRA (0.016). The Hausman test statistic was 18.6 (p-value = 0.0003) and the fixed effects specification was favored.

Table 3

Results of the panel regression predictions of nursing education resilience.

Predictor	Pooled OLS B (t)	Fixed Effects B (t)	Random Effects B (t)
AICURR	0.145 (3.85)	0.132 (3.47)	0.140 (3.69)
DIGINFRA	0.018 (2.22)	0.016 (1.95)	0.017 (2.01)
FACCOMP	0.279 (4.11)	0.250 (3.90)	0.263 (4.02)
STUDENG	0.195 (2.70)	0.172 (1.95)	0.180 (2.12)
RESOUTPUT	0.090 (1.80)	0.083 (1.75)	0.085 (1.77)
POLSUPPORT	0.106 (2.30)	0.097 (2.02)	0.100 (2.15)
Constant	0.281 (6.23)	0.299 (5.90)	0.287 (6.01)
Observations	150	150	150
R-squared	0.612	0.644	0.627

Note. Hausman test = 18.6 and p = 0.0003, thus fixed effects model preferred.

Diagnostic results

There was no serious autocorrelation in the Durbin-Watson statistics between 1.85 and 1.90. All models had Jarque-Bera p values > 0.05, which indicated no

deviations from normal residuals. White and Breusch-Godfrey test values also confirmed the overall appropriateness of the specifications.

Table 4

Model diagnostics

Model	Durbin-Watson	Breusch-Pagan p	Breusch-Godfrey p	White p	Jarque-Bera p
Pooled OLS	1.85	0.041	0.231	0.143	0.598
Fixed Effects	1.90	0.050	0.221	0.130	0.561
Random Effects	1.87	0.045	0.211	0.118	0.585

DISCUSSION

The key result is that the most important predictor of NER is faculty digital competency in the preferred fixed effects model. This indicates that the institutional resilience of nursing education is not solely related to technology but also on the educator's skill in using technology in curriculum designing, teaching, and adaptation (Ching et al., 2023). In the context of graduate nursing education, this directly impacts the

way AI, simulation, and digital platforms are applied to real-world education opportunities (Tan et al., 2023).

There was also a strong positive link between the adoption of AI curriculum and resilience. The results suggest that there is increased resilience when digital innovation forms part of the formal curriculum as opposed to being an isolated or short-term project. For nursing education, the suggestion is that nursing education modernization is not a simple supplement but a process integrated into nursing educational

institutions. For nursing education, the suggestion is that the nursing education modernization is not a simple supplement, but a process that is integrated into nursing education institutions.

These results align with the global trend in the education of nurses and doctors using digital technologies. In the accompanying multi-country virtual reality study, students expressed high usability, feasibility and satisfaction with VR and highlighted its value of realistic, immersive and guided communication practice (De Gagne et al., 2022). While the study above did not deal with institutional econometrics, it is consistent with the overall finding: digital innovations work best when they are structured, supported and even guided by educational intent (Saab et al., 2026).

Other factors that positively influenced resilience were student engagement, digital infrastructure, research output, and policy support. This pattern indicates that it is not only about infrastructure; it is about innovative infrastructure, capable faculty, active learners, and supporting governance structures that go together with the innovation of MSN programs. The leadership of nursing education requires the development of the faculty, the formulation of institutional policies, and the investment in technology to be developed as a unified strategy (Qayyum, A., & Zawacki-Richter, (2019).

The Journal of Nursing Education requests that the author(s) comment on the implications of findings, but refrain from unsupported speculation. In that spirit, the current results have led to three concrete implications based on the evidence: improve faculty digital competency, formalize efforts to integrate AI in the curriculum, and match policy support with the implementation of educational technology. These are some non-financial levers that institutions can work on even if budgets are limited (Güney et al., 2026; (Rana et al., 2024).

Limitations

The paper presented here is based on secondary data from institutional panels and hence cannot directly capture the perceptions of students and faculty. Thus, the estimates reveal institutional associations, but do not fully explain the lived mechanisms that build resilience in practice. Our findings are also specific to the MSN institutions in Pakistan, which may limit direct generalizability to other countries, or to undergraduate programs.

A second limitation is that policy support is discussed conceptually as both a direct and moderator, but the main table in the attached paper presents the direct coefficients more clearly than the formal interaction estimates. A supplementary table explicitly reporting the interaction term would improve consistency between the conceptual framework and the empirical presentation for a final journal submission.

CONCLUSION

This panel study finds that faculty digital competency and AI curriculum adoption have the most significant impact on NER in Pakistan's MSN programs, and student engagement, digital infrastructure, research output, and policy support also have positive effects. The results support a nursing education perspective where resilience is built by the interplay of pedagogy, organizational capacity and governance, rather than solely by technology acquisition.

The practical suggestion is plain. To foster resilient graduate nursing education, institutions should invest in digitally capable faculty, deliberately modernized curricula, and supportive policy environments that allow innovation to be sustained over time. This is a direction supported by the broader international digital learning literature which suggests that technology can be educationally valuable when embedded in sound instructional design and institutional support.

5.1 Nursing Student, Faculty, or Public Contribution

The paper lacks a section describing the role of nursing students, faculty, or the public in the design, conduct, analysis, or preparation of the paper. The authors of Nursing should revise this statement before submission to reflect the actual contributions made during the study, since such a statement is expected to be included in the chapter on methods.

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APPENDIX TABLES FOR THE NURSING EDUCATION RESILIENCE PAPER**Appendix Table A1:** Operational definitions, measurement, and expected directions of study variables

Variable	Type	Operational definition	Measurement/proxy	direction with NER
NER	Dependent	Nursing Education Resilience across MSN institutions	Continuity of operations, curriculum adaptability, and institutional performance metrics	Positive
AICURR	Independent	Extent of artificial intelligence integration in curricula	Number of AI modules and AI-related teaching activity	Positive
DIGINFRA	Independent	Institutional digital and ICT readiness	LMS usage frequency, bandwidth, and device support	Positive
FACCOMP	Independent	Faculty digital competency and AI readiness	Faculty trained in digital pedagogy and AI-enabled teaching	Positive
STUDENG	Independent	Student engagement in online and digital learning	LMS logins, submissions, and participation measures	Positive
RESOUTPUT	Independent	Innovation-oriented scholarly productivity	Number of innovation-focused publications	Positive
POLSUPPORT	Moderator / institutional factor	Policy and institutional support for digital transformation	Binary or formal policy support indicator	Positive

Appendix Table A2: Descriptive profile of panel variables

Variable	Mean	Median	Standard deviation	Minimum	Maximum	Observations
NER	0.684	0.710	0.157	0.400	0.920	150
AICURR	2.45	2.00	1.10	1.00	5.00	150
DIGINFRA	75.34	76.00	8.92	50.00	90.00	150
FACCOMP	0.622	0.600	0.152	0.30	0.88	150
STUDENG	0.710	0.700	0.170	0.35	0.95	150
RESOUTPUT	4.21	4.00	1.83	1.00	8.00	150
POLSUPPORT	0.73	1.00	0.44	0.00	1.00	150

Appendix Table A3: Correlation matrix of the main study variables

Variables	NER	AICURR	DIGINFRA	FACCOMP	STUDENG	RESOUTPUT	POLSUPPORT
NER	1.000						
AICURR	0.503	1.000					
DIGINFRA	0.456	0.522	1.000				
FACCOMP	0.537	0.470	0.385	1.000			
STUDENG	0.498	0.413	0.391	0.475	1.000		
RESOUTPUT	0.442	0.385	0.349	0.330	0.411	1.000	
POLSUPPORT	0.298	0.221	0.209	0.310	0.253	0.195	1.000

Note. All reported correlations are below 0.80, supporting the paper conclusion that severe multicollinearity is not evident.

Appendix Table A4: Panel unit root test results (ADF and PP)

Variable	ADF probability	PP probability	Decision
NER	0.014	0.009	Stationary
AICURR	0.033	0.021	Stationary

DIGINFRA	0.001	0.002	Stationary
FACCOMP	0.010	0.017	Stationary
STUDENG	0.044	0.036	Stationary
RESOUTPUT	0.029	0.026	Stationary
POLSUPPORT	0.038	0.042	Stationary

Note. All variables were stationary at level in the attached paper, supporting direct estimation in panel regression form.

Appendix Table A5: Pooled OLS, fixed effects, and random effects estimates

Predictor	Pooled OLS coefficient	Pooled t-stat	Fixed effects coefficient	Fixed effects t-stat	Random effects coefficient	Random effects t-stat
AICURR	0.145	3.85	0.132	3.47	0.140	3.69
DIGINFRA	0.018	2.22	0.016	1.95	0.017	2.01
FACCOMP	0.279	4.11	0.250	3.90	0.263	4.02
STUDENG	0.195	2.70	0.172	1.95	0.180	2.12
RESOUTPUT	0.090	1.80	0.083	1.75	0.085	1.77
POLSUPPORT	0.106	2.30	0.097	2.02	0.100	2.15
Constant	0.281	6.23	0.299	5.90	0.287	6.01
Observations	150		150		150	
R-squared	0.612		0.644		0.627	
Adjusted R-squared	0.595		0.621		0.608	
F-statistic	32.11		29.43		30.72	

Appendix Table A6: Model selection and specification diagnostics

Statistic	Value	Interpretation
Hausman statistic	18.6	Supports choosing fixed effects over random effects
Hausman p-value	0.0003	The preferred specification is fixed effects
Institution fixed effects included	Yes	Within-institution variation is modeled explicitly
Year dummies included	Yes	Common time shocks are controlled in all models

Appendix Table A7: Residual diagnostics across model specifications

Model	Durbin-Watson	Breusch-Pagan p-value	Breusch-Godfrey p-value	White test p-value	Jarque-Bera p-value
Pooled OLS	1.85	0.041	0.231	0.143	0.598
Fixed effects	1.90	0.050	0.221	0.130	0.561
Random effects	1.87	0.045	0.211	0.118	0.585

Note. The paper interprets these diagnostic values as supporting acceptable residual behavior and reliable model inference.

Appendix Table A8: Rank ordering of predictors in the preferred fixed effects model

Rank	Predictor	FE coefficient	Interpretation
1	FACCOMP	0.250	Strongest positive predictor of NER
2	STUDENG	0.172	Strong positive contribution to resilience
3	AICURR	0.132	Substantial curricular effect on resilience
4	POLSUPPORT	0.097	Institutional support strengthens resilience
5	RESOUTPUT	0.083	Positive but smaller innovation-related contribution
6	DIGINFRA	0.016	Positive but comparatively smaller infrastructure effect

Appendix Table A9: Linkage between research questions and empirical findings

Research question	Main variable(s)	Empirical finding
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RQ1: How does AI curriculum adoption influence NER?	AICURR	Positive and statistically meaningful association across all reported models
RQ2: What is the impact of digital infrastructure and faculty digital competency?	DIGINFRA, FACCOMP	Both are positive, with FACCOMP the strongest predictor in the fixed effects model
RQ3: How does student engagement affect resilience?	STUDENG	Positive and meaningful association with NER
RQ4: What role does research output play?	RESOUTPUT	Positive but smaller contribution compared with faculty and curricular drivers
RQ5: To what extent does policy support matter?	POLSUPPORT	Positive contribution and conceptually treated as a resilience-strengthening factor

Appendix Table A10: Recommended supplementary

Supplementary table	Purpose	Status
Table S1. Data source and coding sheet	Shows source, scale, and coding rule for each variable	Recommended for submission
Table S2. Robustness checks	Adds alternative specifications and interaction estimates for policy support	Recommended for submission
Table S3. Sensitivity analyses	Tests whether results hold under restricted years or alternative samples	Recommended for submission
Table S4. Software output summary	Reports EViews commands or reproducibility notes for estimation flow	Recommended for submission

Appendix Table A11: Panel Data Overview and Study Characteristics of MSN Nursing Education Programs in Pakistan (2014-2024)

Study Title	Nursing Education Resilience in MSN Programs: Panel Evidence from Pakistan
Time Range	2014-2024
Generated	2025-12-12
Source	Derived from paper variables and appendix structure

Appendix Table A11a: Operational Definitions and Measurement of Study Variables for Nursing Education Resilience Model in MSN Programs (Pakistan, 2014-2024)

Variable Code	Variable Name	Category	Role in Model	Operational Definition	Measurement / Proxy	Scale / Unit	Expected Sign	Source / Basis	Notes
NER	Nursing Education Resilience	Outcome	Dependent	Institutional resilience in MSN programs	Continuity of operations, curriculum adaptability, institutional performance metrics	Index / ratio	Positive	Paper design study	Primary dependent variable
AICURR	AI Curriculum Adoption	Technology	Independent	Extent of AI integration in nursing curricula	Number of AI modules, AI training hours, AI-enabled teaching activities	5-point scale / count	Positive	Paper operationalization	Technological readiness indicator
DIGINFRA	Digital Infrastructure	Technology	Independent	Institutional digital and ICT readiness	LMS usage frequency, bandwidth, device-student ratio	Index / score	Positive	Paper operationalization	Infrastructure support variable
FACCOMP	Faculty Digital Competency	Human Capital	Independent	Faculty readiness in digital pedagogy and AI use	Faculty trained in digital pedagogy / AI tools	Proportion / index	Positive	Paper operationalization	Strongest predictor in FE model

STUDENG	Student Engagement	Learning Process	Independent	Student participation in digital learning environments	LMS logins, submissions, forum participation	Index / proportion	Positive	Paper operationalization	variable	Adaptive learning indicator
RESOUTPUT	Research Output	Innovation	Independent	Institutional research productivity linked to innovation	Number of innovation-focused publications	Count	Positive	Paper operationalization	variable	Innovation-oriented variable
POLSUPPORT	Policy and Institutional Support	Governance	Moderator / Institutional Factor	Formal support for digital transformation and AI adoption	Binary policy presence, formal institutional or governmental support	Binary / index	Positive	Paper operationalization	variable	Conceptually treated as moderator