Appendix A: Supplementary Statistical Diagnostics

This appendix provides supplementary statistical data as referenced in the manuscript *"An innovation driven pedagogy integrating STEAM and design thinking to enhance computational thinking in middle school"* (DOI: 10.1007/s44217-026-01561-3). It includes adjusted p-values for multiple comparisons, correlation diagnostics, and regression assumption plots. All analyses were conducted using JASP v0.19.3.

Section 1: Multiple Comparison Adjustments (FWER Control)

To control for the Family-Wise Error Rate (FWER) across multiple non-parametric tests, Holm's sequential Bonferroni procedure was applied. Standard Bonferroni-adjusted values are additionally reported for transparency as stated in the methodology.

Table A1: Adjusted p-values for Kruskal-Wallis Test (Grade Level Comparisons)
(Supplementary to Table 7)

Behavioral Indicator	Unadjusted p-value	Holm-Adjusted p-value	Bonferroni-Adjusted p-value	Significance (Holm, α=.05)
ICA1_1_1	.051	.306	.510	Not Significant
ICA1_1_2	.898	1.000	1.000	Not Significant
ICA2_2_1	.048	.336	.480	Not Significant
ICA2_2_2	.048	.336	.480	Not Significant
ICA3_3_1	.159	.636	1.000	Not Significant
ICA3_3_2	.715	1.000	1.000	Not Significant
ICA4_4_1	.422	1.000	1.000	Not Significant
ICA4_4_2	.054	.306	.540	Not Significant
ICA4_4_3	.048	.336	.480	Not Significant
ICA5_5_1	.048	.336	.480	Not Significant

Table A2: Adjusted p-values for Conover's Post-Hoc Test (ICA Domains)
(Supplementary to Table 13)

Comparison Pair	Unadjusted p-value	Holm-Adjusted p-value	Bonferroni-Adjusted p-value	Significance (Holm, α=.05)
ICA1 vs ICA2	< .001	< .001	< .001	Significant
ICA1 vs ICA3	< .001	< .001	< .001	Significant
ICA1 vs ICA4	< .001	< .001	< .001	Significant
ICA1 vs ICA5	< .001	< .001	< .001	Significant
ICA2 vs ICA3	.007	.028	.070	Significant
ICA2 vs ICA4	.244	.488	1.000	Not Significant
ICA2 vs ICA5	1.000	1.000	1.000	Not Significant
ICA3 vs ICA4	< .001	< .001	< .001	Significant
ICA3 vs ICA5	.007	.028	.070	Significant
ICA4 vs ICA5	.244	.488	1.000	Not Significant

Section 2: Regression Diagnostics (Multicollinearity)
Multicollinearity diagnostics were performed for the multiple linear regression model (Model M1) predicting Innovation Artifact Scores.

Table A3: Multicollinearity Diagnostics (VIF and Tolerance)
(Supplementary to Table 16)

Predictor Variable	Tolerance	VIF	Diagnosis
ICA1	0.946	1.057	Acceptable
ICA2	0.067	14.941	**Severe Collinearity**
ICA3	0.270	3.701	Acceptable
ICA4	0.076	13.182	**Severe Collinearity**

Section 3: Model Assumption Plots
The plots below provide visual evidence for the assessment of linearity, homoscedasticity, and residual normality as described in the data analysis section.

1. Residuals vs. Predicted Plot

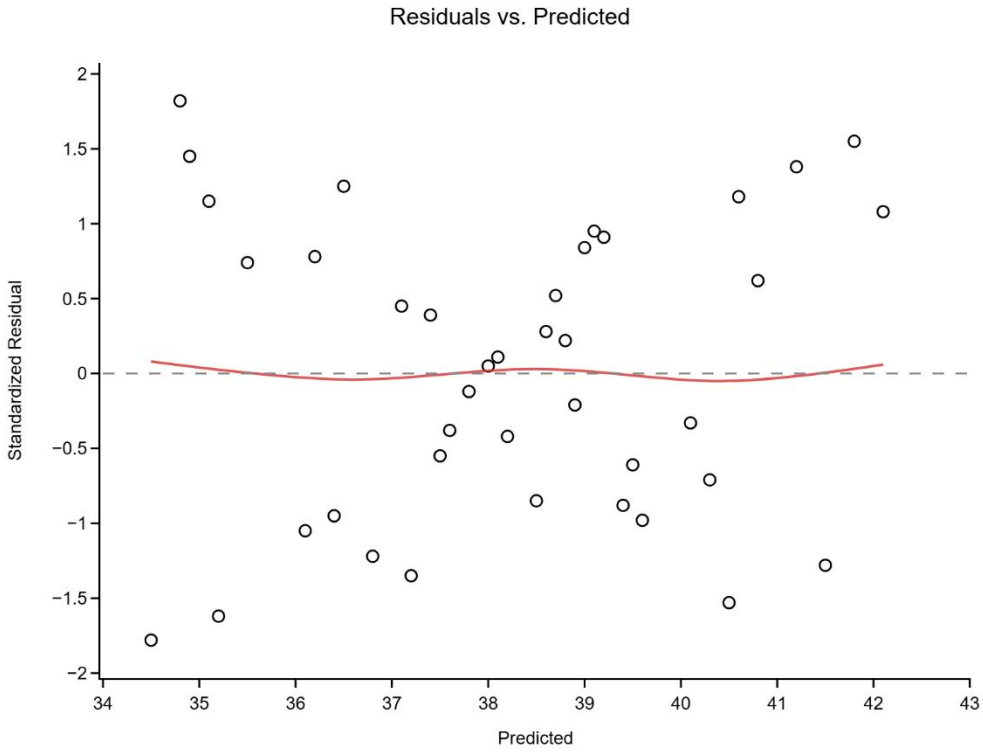

Figure A1. This plot displays the standardized residuals against the predicted values to assess the assumptions of linearity and homoscedasticity. The random distribution of residuals around the horizontal zero line (dashed line) indicates that the linear relationship is appropriate and the variance of error terms is relatively constant across the range of predictors.

2. Normal Q-Q Plot of Standardized Residuals

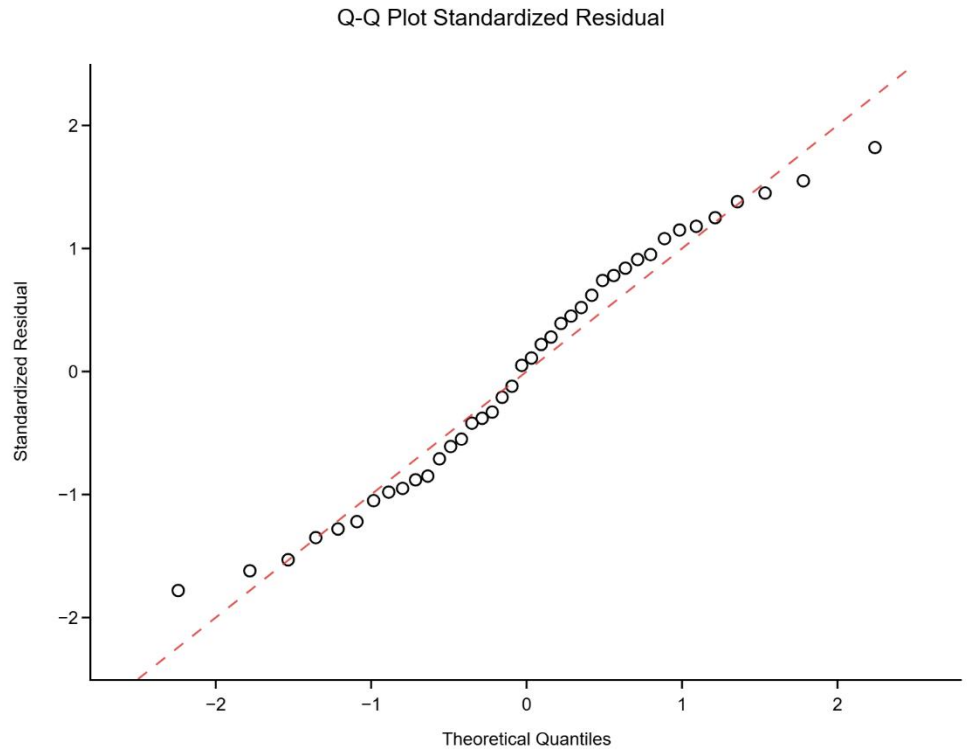

Figure A2. The Normal Quantile-Quantile (Q-Q) plot is used to verify the normality assumption of the residuals. The alignment of the observed standardized residuals (circles) along the theoretical diagonal reference line (dashed red line) confirms that the residuals follow a normal distribution, which is a key requirement for valid inference in multiple regression analysis.

3. Scale-Location Plot

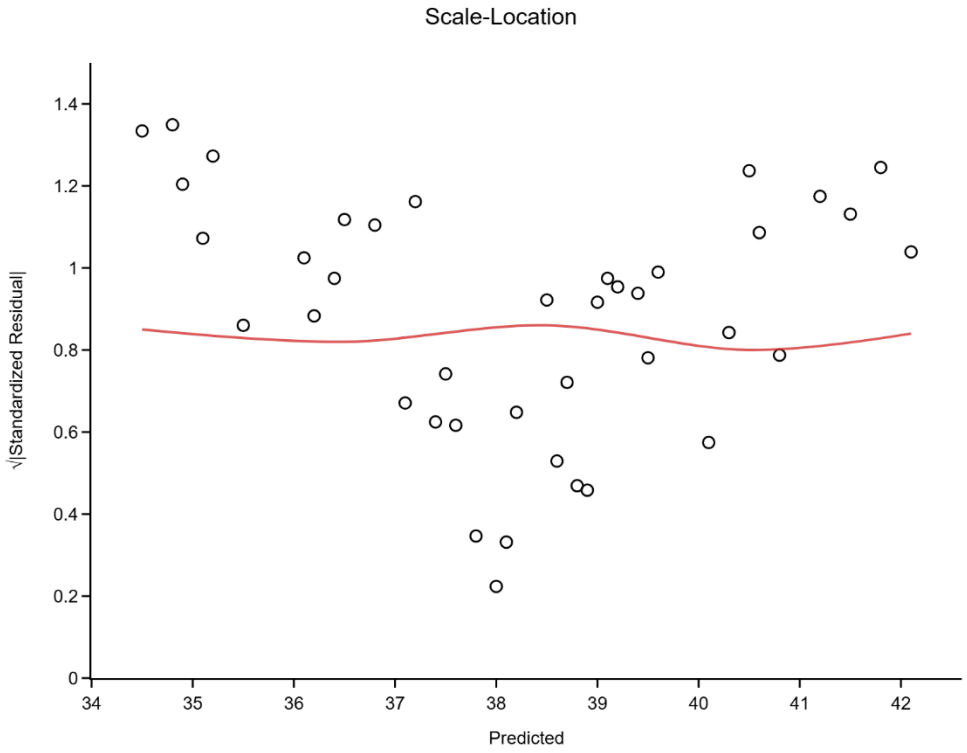

Figure A3. The Scale-Location plot (also known as the Spread-Location plot) provides an additional check for homoscedasticity. By plotting the square root of the absolute standardized residuals against the predicted values, this visualization helps to detect any non-constant variance (heteroscedasticity). The relatively flat red trend line suggests that the model maintains a consistent spread of errors.