Educational Intervention for Promoting Sustainable Utilization of Marble Slurry Waste: Evidence from a Structural Equation Modelling Approach

Virendra Singh Chandawat[1], Seema Garg[2]
[1]*Research scholar S.P.C. Government College Ajmer (Rajasthan)*
[2]*Research supervisor, Retired Principal, Government Girls College Nasirabad (Ajmer)*

Abstract- Marble slurry waste generated from marble processing industries poses severe environmental threats, including soil infertility, water contamination, and air pollution. While engineering research has examined its reuse in construction materials, limited studies explore educational strategies to promote sustainable utilization. This study develops and empirically validates an educational intervention model aimed at enhancing environmental awareness, attitude, skill development, and behavioural intention toward marble slurry waste reuse. A quasi-experimental pre-test–post-test control group design was implemented among 320 teacher education students. Structural Equation Modelling (SEM) was employed to test the hypothesized cognitive affective behavioural framework. Results indicate that the educational intervention significantly improved awareness ($\beta = .62$, $p < .001$), which positively influenced attitude and skill development. Behavioural intention strongly predicted sustainable utilization practice ($\beta = .71$, $p < .001$). Mediation analysis confirmed a sequential pathway. The findings extend sustainability education literature by integrating industrial waste management into a validated behavioural model.

Keywords: Sustainability education, Marble slurry waste, Structural equation modelling, educational intervention, Environmental behaviour

I. INTRODUCTION

Industrialization has intensified environmental degradation, particularly in regions with marble processing industries. Marble slurry waste, produced during cutting and polishing operations, is typically dumped in open landfills, leading to ecological damage.

Global sustainability frameworks promoted by United Nations Educational, Scientific and Cultural Organization emphasize Education for Sustainable Development (ESD) as a transformative strategy. Similarly, sustainability priorities highlighted by United Nations Environment Programme stress the importance of awareness and behavioural change.

In India, the National Education Policy 2020 underscores experiential and environmental learning. However, integration of industrial waste management within formal education remains limited.

This study addresses this gap by designing and validating an educational intervention model that promotes sustainable utilization of marble slurry waste.

II. THEORETICAL FRAMEWORK

The model is grounded in the Theory of Planned Behaviour developed by Icek Ajzen, which proposes that behavioural intention predicts actual behaviour and is influenced by attitude and perceived control.

The present framework extends TPB into sustainability education through a sequential model:

Educational Intervention → Awareness → Attitude → Skill Development → Behavioural Intention → Sustainable Practice

This integrates cognitive (awareness), affective (attitude), and behavioural (skills and intention) components.

III. METHODOLOGY

Research Design

Quasi-experimental pre-test and post-test control

group design.

Sample

320 B.Ed. students selected through stratified random sampling.

Instruments

- Environmental Awareness Scale (25 items)
- Attitude toward Sustainability Scale (20 items)
- Skill Competency Rubric (Performance-based)
- Behavioural Intention Scale (15 items) Cronbach's alpha values ranged from 0.74 to 0.88. Data Analysis
- SPSS (descriptive statistics, t-tests)
- AMOS (CFA and SEM)
- Bootstrapping (5000 samples)

IV. RESULTS

Experimental Effectiveness

Post-test scores of the experimental group were significantly higher ($p < .001$) than control group scores.

Measurement Model

- Factor loadings > .60
- AVE > .50
- Composite Reliability > .70
- Model fit: CFI = .93, RMSEA = .06

Structural Model

Path	β	p-value
EI → Awareness	.62	<.001
Awareness → Attitude	.58	<.001
Attitude → Skills	.49	<.001
Skills → Intention	.67	<.001
Intention → Practice	.71	<.001

Sequential mediation was statistically significant ($p < .01$). R^2 for behavioural Intention = 0.63.

V. DISCUSSION

The findings confirm that structured sustainability interventions significantly enhance environmental awareness and behavioural intention. Awareness influenced attitude, consistent with behavioural theory. Skill development strengthened perceived competence, increasing sustainable intention.

The results contribute to sustainability education by:

- Introducing industrial waste utilization into curriculum-based intervention research.
- Empirically validating a cognitive affective behavioural pathway.
- Demonstrating mediation effects through SEM.

VI. IMPLICATIONS

Educational

- Curriculum integration of industrial waste topics.
- Adoption of experiential and project-based learning.

Policy

- Alignment with national sustainability education reforms.
- Industry education collaboration models.

Environmental

- Increased sustainable reuse practices.
- Reduced ecological burden of marble slurry dumping.

VII. CONCLUSION

This study demonstrates that educational interventions significantly influence sustainable utilization behaviour through awareness, attitude, and skill development. The validated SEM model offers a scalable framework for sustainability education.

REFERENCES

[1] Ajzen, I. (1991). The theory of planned behaviour.

Organizational Behaviour and Human Decision Processes, 50(2), 179–211.
[2] Arbuckle, J. L. (2019). *AMOS user's guide*. IBM.
[3] Bandura, A. (1997). *Self-efficacy: The exercise of control*. Freeman.
[4] Barth, M., & Rieckmann, M. (2012). Academic staff development. *Journal of Cleaner Production, 26*, 28–36.
[5] Brundtland, G. H. (1987). *Our common future*. Oxford University Press. Cohen, J. (1988). *Statistical power analysis*. Lawrence Erlbaum.
[6] Creswell, J. W. (2014). *Research design*. Sage.
[7] Davis, F. D. (1989). Perceived usefulness. *MIS Quarterly, 13*, 319–340.
[8] Eilam, E., & Trop, T. (2012). *Environmental Education Research, 18*, 285–304. Field, A. (2018). *Discovering statistics using SPSS*. Sage.
[9] Fornell, C., & Larcker, D. (1981). Evaluating SEM. *Journal of Marketing Research, 18*, 39–50. Hair, J. F., et al. (2019). *Multivariate data analysis*. Cengage.
[10] Henseler, J., et al. (2015). HTMT criterion. *Journal of the Academy of Marketing Science, 43*, 115–135.
[11] Kumar, A., et al. (2017). Marble slurry in concrete. *Construction and Building Materials, 148*, 699–708.
[12] Mezirow, J. (2000). *Learning as transformation*. Jossey-Bass.
[13] OECD. (2018). *Education for sustainable development*. OECD Publishing. Pallant, J. (2020). *SPSS survival manual*. McGraw-Hill.
[14] Podsakoff, P. M., et al. (2003). Common method bias. *Journal of Applied Psychology, 88*, 879– 903.
[15] Sharma, P. (2018). Environmental awareness study. *Journal of Environmental Education, 49*, 12–24.
[16] Singh, R., et al. (2016). Reuse of marble slurry. *Materials Today, 3*, 146–152. Tilbury, D. (2011). Education for sustainable development. UNESCO. UNESCO. (2014). *Global action programme on ESD*.
[17] UNEP. (2019). *Global environment outlook*.