

Study of the impact of a Teaching–Learning Sequence on marine plastic pollution: Transformative Environmental Education and serious games in initial teacher education

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INTRODUCTION & AIM

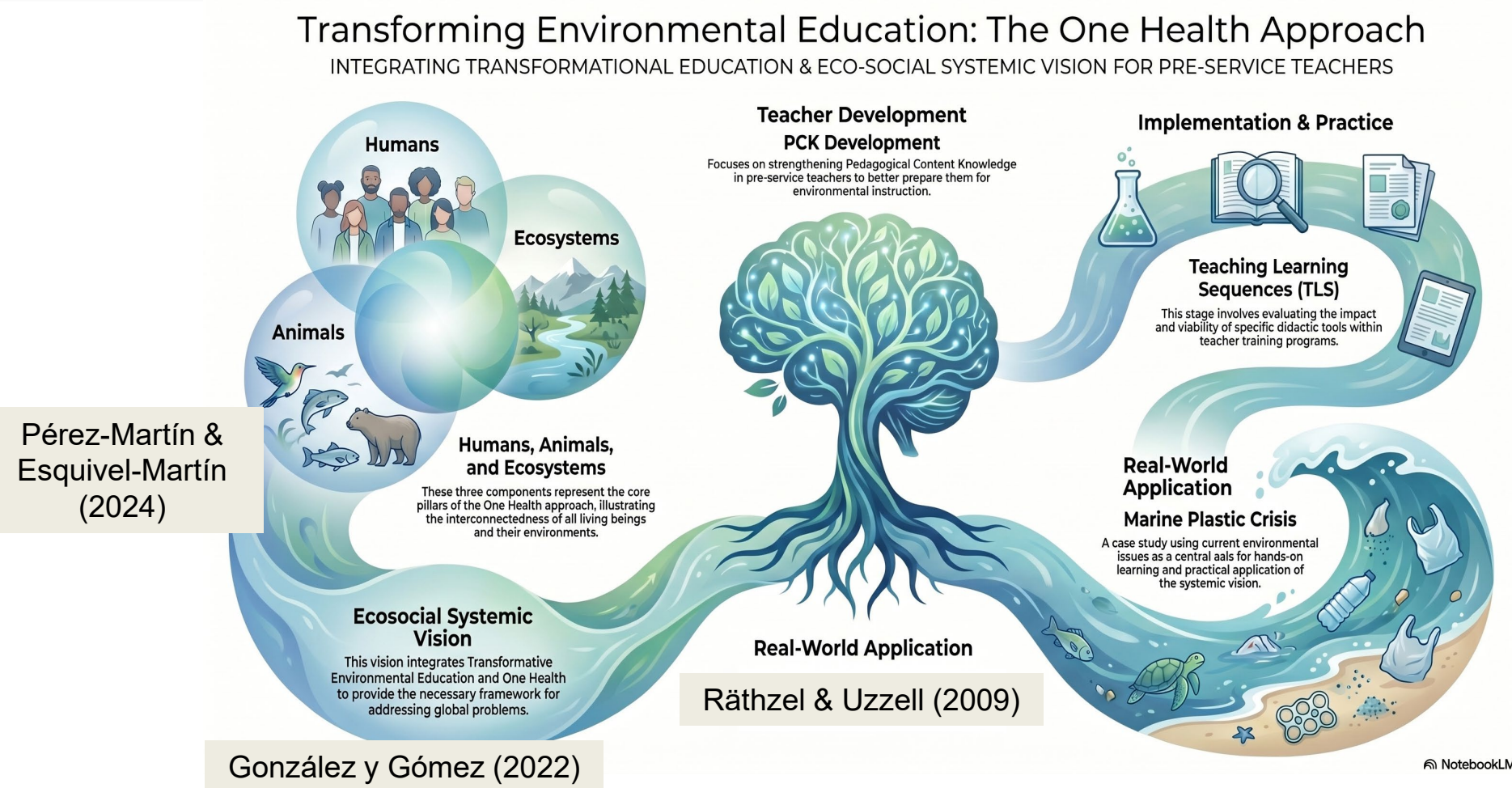


Figure 1. Theoretical principles underlying the work presented (Generated by NotebookLM)

This study aims to evaluate the impact of a TLS that employs a serious game (Escape Box) as the central didactic tool to address marine plastic pollution, targeted at pre-service teachers.

METHOD

A quasi-experimental design was implemented in the Environmental Education course, using pre- and post-questionnaires administered to 27 4th year students, aged between 22 and 23, enrolled in the Primary Education degree at the University of Cádiz (Spain). The Teaching–Learning Sequence was designed following a learning cycle grounded in socioconstructivist principles, integrating Ocean Literacy and the One Health approach (Aragón & Brenes-Cuevas, 2025) (Figure 2).



Figure 2. Some activities within the TLS: (A) mural visualizing One Health dimensions, and (B) escape box

RESULTS & DISCUSSION

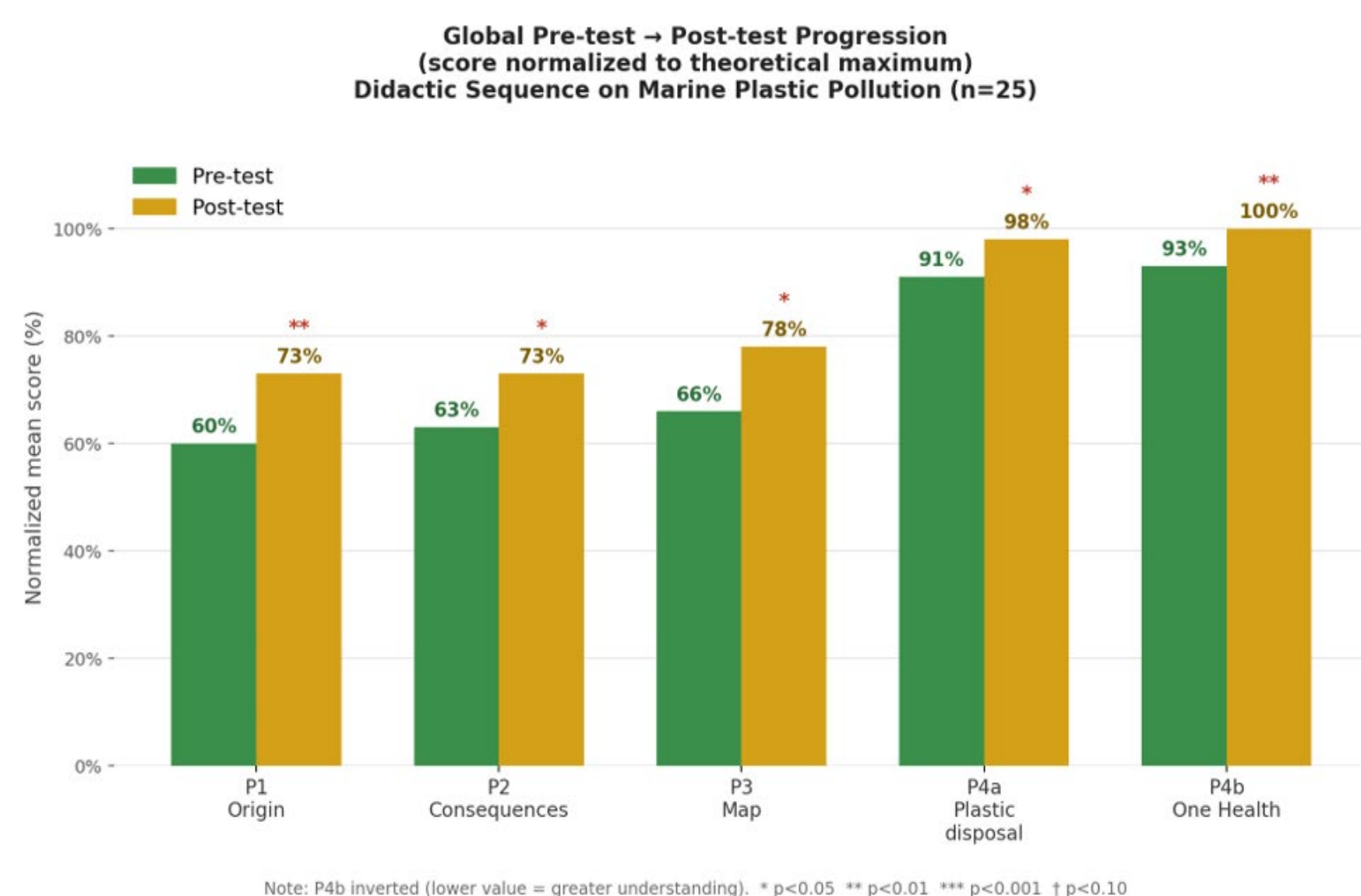
Table 1 presents the descriptive statistics and Wilcoxon signed-rank test results for the six dimensions assessed. Five variables showed statistically significant improvements following the implementation of the Teaching–Learning Sequence (TLS), with $p < 0.05$.

Table 1. Descriptive statistics and Wilcoxon signed-rank test results for the five dimensions assessed ($n = 25$)

Variable	M Pre	SD	M Post	SD	Δ	W	p / Sig.
P1 – Responsibility attribution (1–4)	2.40	0.80	2.92	0.74	+0.52	12.0	0.007 **
P2 – Consequences / One Health (1–3)	1.88	0.52	2.20	0.69	+0.32	5.5	0.011 *
P3 – Map trajectory (1–4)	2.64	0.62	3.12	0.65	+0.48	12.0	0.030 *
P4a – Plastics home→ocean (1–5)	4.56	0.70	4.92	0.27	+0.36	0.0	0.024 *
P4b – Only affects animals (1–5)	1.28	0.45	1.00	0.28	-0.28	0.0	0.008 **

Note: M = mean; SD = standard deviation; Δ = Post–Pre difference; W = Wilcoxon statistic; ** $p < 0.01$; * $p < 0.05$; n.s. = not significant. For P4b, lower scores indicate greater One Health understanding.

Figure 3 provides an overall view of change by expressing each variable as a percentage of the theoretical maximum score. All statistically significant dimensions show increases of between 7 and 10 percentage points, with the most notable gains in responsibility attribution (P1: 60%→73%) and the One Health perspective (P2: 63%→73%; P4b: 93%→100%). A significant improvement was observed in the sophistication of causal reasoning (M Pre = 2.40 vs. M Post = 2.92; $W = 12.0$, $p = 0.007$). At pre-test, 56% of participants ($n = 14$) attributed the problem to the 'general population' in a diffuse way (Level 2). After the TLS, this group decreased to 32% ($n = 8$), while Levels 3 (multiple sources including industry and consumerism) and 4 (systemic vision) increased jointly from 36% to 68%. Notably, the two participants who at pre-test limited the cause to specific external agents (Level 1) progressed by at least one level, and no student regressed.



Note: P4b inverted (lower value = greater understanding). * $p < 0.05$ ** $p < 0.01$ *** $p < 0.001$ † $p < 0.10$

Figure 3. Overall pre-test–post-test progression expressed as a percentage of the theoretical maximum. Red markers indicate statistical significance (* $p < 0.05$; ** $p < 0.01$). P4b is reversed (lower original score = greater comprehension).

In the pre-test (A), the network core was occupied by a specific mitigating action, "Reusing bottles" ($M=191$, $FMG=100\%$), followed closely by reduction (76%) and recycling (71%) concepts. This proximity in Semantic Distance (FMG) suggests that students assigned a similar weight to the different actions without a clear impact hierarchy (Figure 4). Post-intervention (B), the core underwent a radical transformation, shifting to "Reducing consumption" ($M=197$, $FMG=100\%$). The post-intervention FMG analysis reveals a remarkable percentage gap regarding essential and secondary attributes: "Reusing" and "Recycling" dropped to 59% and 58%, respectively.

For the variable P5 – Complexity of actions (1–3), this provides quantitative evidence of the educational sequence's effectiveness; students abandoned a view based on mechanical and palliative actions to internalize a more preventive and systemic environmental perspective, correctly prioritizing consumption reduction as the fundamental priority over waste generation.

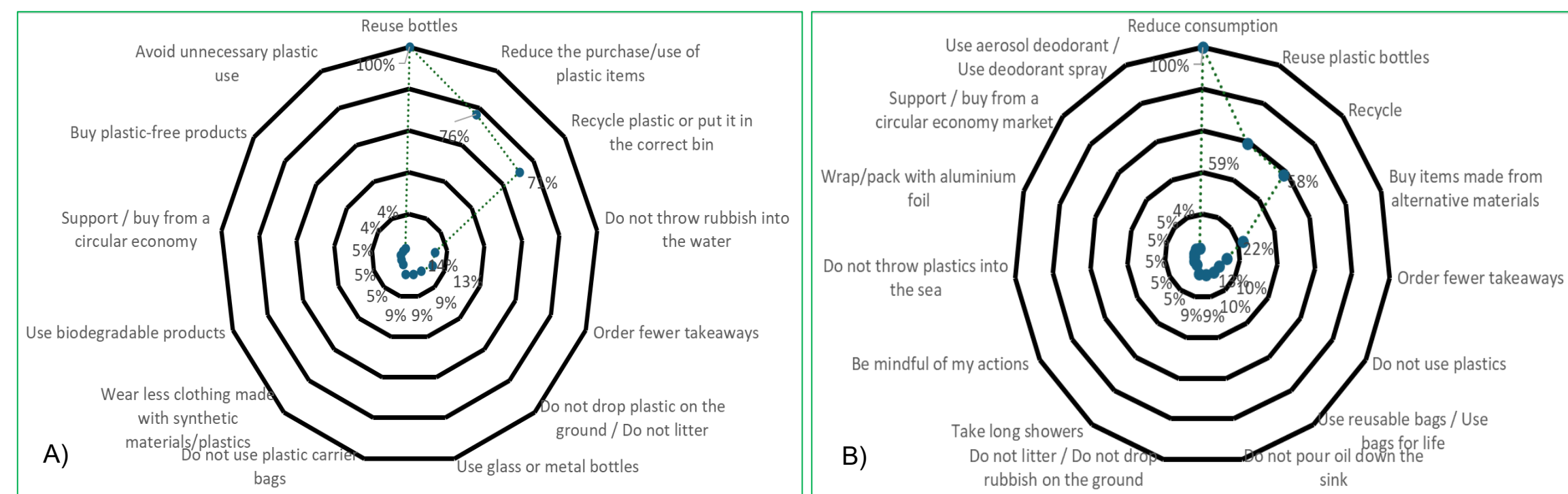


Figure 4. Semantic network formed by the FMG value of "actions that can help reduce plastic pollution," applied to the 4th-year student group of the Bachelor's Degree in Primary Education ($n=25$, 22–23 years old) A) pretest and B) post-test.

CONCLUSION

- The innovative TLS successfully shifted students' initial conceptions toward complex, systemic environmental understanding.
- It effectively promoted a critical One Health perspective linking human and ecosystem health while,
- The experiential Escape Box format proved highly valid and engaging across distinct educational levels, robustly confirming a meaningful and progressive conceptual change.

REFERENCES

- Aragón, L. & Brenes-Cuevas, C. (2025). A Gamified Teaching Proposal Using an Escape Box to Explore Marine Plastic Pollution. *Sustainability*, 17, 7528. <https://doi.org/10.3390/su17167528>
- González, L. & Gómez, C. (2022). La competencia ecosocial en un contexto de crisis multidimensional. *Revista Internacional de Educación para la Justicia Social*, 11(2), 29–43. <https://doi.org/10.15366/riejs2022.11.2.002>
- Pérez-Martín, J.M. & Esquivel-Martín, T. (2024). New Insights for Teaching the One Health Approach: Transformative Environmental Education for Sustainability. *Sustainability*, 16, 7967. <https://doi.org/10.3390/su16187967>
- Räthzel, N., & Uzzell, D. (2009). Transformative environmental education: a collective rehearsal for reality. *Environmental Education Research*, 15(3), 263–277. <https://doi.org/10.1080/13504620802567015>