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GROWTH THROUGH GIRLS: VOICES, TRANSFORMATIONS, AND NEW PATHWAYS

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Abstract. This report presents the work developed by the Polytechnic University of Coimbra, via its Coimbra Engineering Institute (ISEC), within the framework of the Erasmus+ project GIRLS: Generation for Innovation, Resilience, Leadership and Sustainability. The initiative seeks to promote inclusive, interdisciplinary, and transformative learning experiences by engaging students in authentic, community-based challenges that foster both academic development and civic engagement. At ISEC, this goal was operationalised through two distinct but complementary educational approaches: the integration of Service-Learning (SL) methodologies into the curriculum of the *Statistical Methods* course, a second-year unit within the Mechanical Engineering degree; and, in the project's second year, the adoption of a research-based methodology exploring the use of ChatGPT as a pedagogical tool in the first-year *Statistical Methods* course for Informatics Engineering students.

These pedagogical approaches were designed to enhance the learning of statistical concepts through socially meaningful tasks aligned with the United Nations' Sustainable Development Goals (SDGs). Students collaborated with peers and community stakeholders, including non-governmental organisations, to address real-world problems through data analysis, critical interpretation, and reflective practice. Beyond the acquisition of technical knowledge, the experience aimed to cultivate ethical awareness, empathy, and critical thinking, competencies increasingly recognised as essential in contemporary engineering education.

Throughout the implementation, students engaged in a series of structured activities, including the co-creation of statistical problems with real data, the development of digital resources, and the production of academic outputs such as conference presentations and scientific papers. Reflection was embedded throughout the process to promote metacognitive awareness and personal growth. The analysis presented in this report draws on qualitative data from student responses to guided reflection prompts, enabling an exploration of their perceptions, challenges, emotional responses, and development of transversal competencies.

The findings indicate that the integration of Service-Learning and research-based methodologies into a core mathematical discipline is not only feasible but also pedagogically enriching. It contributes to a more holistic and socially responsive form of engineering education, bridging academic knowledge with civic responsibility. The outcomes suggest that, when placed in learning environments requiring real engagement and ethical reflection, students deepen their understanding and strengthen their connection to both their discipline and broader society.

This report presents the context, methodology, student experiences, and pedagogical implications derived from these implementations.

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1. Introduction

The *GIRLS – Generation for Innovation, Resilience, Leadership and Sustainability* Erasmus+ project was designed to foster transformative learning by connecting higher education with civic engagement, innovation, and global sustainable development challenges. The project brought together institutions from Europe and Latin America with the objective of developing and testing inclusive, interdisciplinary, and competence-based pedagogical strategies for the development of transversal and civic competencies in STEM and Engineering Education.

This report synthesises the contributions of the Polytechnic University of Coimbra, particularly those developed at the Coimbra Engineering Institute (IPC/ISEC), within the framework of the GIRLS project. Over the course of three academic years, students and educators engaged in a wide range of collaborative and research-informed activities. These included:

- **Curricular Implementations:** Two major pedagogical strategies were implemented at ISEC within the *Statistical Methods* course, targeting different student profiles. First, Service-Learning (SL) projects were embedded in the course for second-year Mechanical Engineering students. These projects involved partnerships with local non-governmental organisations and interdisciplinary teams of students addressing real-world themes such as gender, mobility, education, financial literacy, customer satisfaction, and ethical consumption behaviour in the fast fashion industry. Second, a research-based methodology was introduced in the first-year Informatics Engineering course to explore the educational potential of ChatGPT as a collaborative tool. In this implementation, students engaged in a two-phase process: solving tasks independently and then critically analysing AI-generated responses. This approach aimed to foster critical thinking, conceptual understanding, and epistemic awareness in statistical reasoning.
- **Pedagogical Handbooks:** Four methodological handbooks were developed to support active learning implementation, each focused on a specific pedagogical model: Service-Learning (SL), Competence-Based Learning (CBL), Game-Based Learning (GBL), and Research-Based Learning (RBL).
- **Sustainable Development Goals (SDG) Resources:** A set of four pedagogical resources was created to integrate statistical concepts with real-world issues aligned with the United Nations' Sustainable Development Goals. These resources, designed for higher education contexts, addressed SDG 3 (Good Health and Well-being), SDG 5 (Gender Equality), SDG 6 (Clean Water and Sanitation), and SDG 11 (Sustainable Cities and Communities), and included contextualised problem statements, datasets, and detailed statistical resolutions.
- **Reflection Moments:** Structured reflection activities were conducted during the international mobility to Mexico, guided by the Think–4–Share method. These moments included individual, small group, and collective reflection, supported by presentation materials to scaffold students' ethical, emotional, and cognitive processing of the experience.
- **Scientific Publications:** Several peer-reviewed publications were produced as part of the GIRLS project. These include:

  - *Is Collaborative Learning a Voluntary Process?* (ICMASE 2023) https://doi.org/10.1007/978-3-031-49218-1_9
  - *Service-Learning: As a Way to Enhance Students' Competencies* (SEFI 2024) — describing the CASPAE project https://doi.org/10.5281/zenodo.14256917
  - *Descriptive and Inferential Analysis of Renal Health and Patterns of Water Consumption: A Case Study of Ciudad Hidalgo* https://doi.org/10.1007/978-3-031-84151-4_30
  - *Bridging Academic Learning and Community Service* https://doi.org/10.1007/978-3-031-84151-4_28
  - SEFI MSIG 2025 paper on interdisciplinary Service-Learning and inclusive teaching practices *(forthcoming)*
  - Mexico qualitative study entitled *Transformative Learning through International Service (forthcoming)*
  - *Critical Thinking and AI – Construction of Statistical Knowledge* (ICMASE 2025) *(forthcoming)*
- **Chapters in Springer Volume:** Two chapters were written for the Springer book *Education for Sustainability and SDGs in Engineering*:
  - One chapter addresses SDG 10 (Reduced Inequalities) and presents an SL project in which students analysed wage disparities.
  - The other focuses on SDG 12 (Responsible Consumption and Production), centred on the assessment of material waste in Engineering contexts.
- **Gramma's Stuff:** Additional outputs include the collaborative journal *Gramma Things*, which aims to promote intergenerational communication and dialogue across age groups through shared narratives.

This comprehensive ecosystem of activities reflects a systematic and holistic approach to integrating Service-Learning, civic engagement, and the Sustainable Development Goals into Engineering Education. It also seeks to promote inclusive, interdisciplinary, and emotionally meaningful learning environments capable of equipping students with both academic knowledge and social awareness.

2. Methodology

2.1. **Pedagogical Context.** The SL initiatives described in this report were integrated into a second-year Statistical Methods course for engineering students. The seven-step model (Observation, Preparation, Action, Reflection, Data Registration, Evaluation, and Recognition) structured the SL activities. This approach enabled students to apply theoretical statistical knowledge in real contexts.

2.2. **Community Engagement.** The non-profit organisations CASPAE and Academia Negócio e Turismo da Empresa Dcanjamba from Angola served as the community partners in the 1^{st} and 2^{nd} project years, respectively. One of the students was from Angola and the fruitful collaboration was proposed by him to the remaining group colleagues. Students worked on analysing data relevant to organisations' operations, including service characterisation, project assessment, and technological needs analysis. Groups of students were tasked with identifying problems, collecting data, and conducting analyses with tools such as Excel and SPSS.

2.3. **Evaluation Tools.** Students completed pre- and post-questionnaires assessing competencies in areas such as teamwork, leadership, cultural awareness, critical thinking, and problem-solving. The evaluation instrument used a 7-point Likert scale.

2.4. **Case Study 1: CASPAE Collaboration (2023/2024).** The initial implementation of the SL initiative took place in partnership with CASPAE, a social support non-profit organisation in Coimbra. Engineering students worked in small groups to address real needs identified by the NPO. Projects included service usage profiling, gender-based digital inclusion gaps, and evaluation of CASPAE's expansion strategies. Students conducted interviews, developed and distributed surveys, and analysed data using Excel and SPSS. The experience was framed within a structured SL cycle.

2.5. **Case Study 2: Ethical Consumption, Financial Literacy and Service Quality (2024/2025).** In the following academic year, the SL initiative evolved into a deeper interdisciplinary collaboration between Statistical Methods and Linear Algebra students. Thirteen students, including one with Asperger syndrome, formed three groups. Their projects addressed:

- Ethical consumption behaviour in fast fashion;
- Financial literacy among engineering students;
- Customer satisfaction for an Angolan company (Dcanjamba).

The inclusive pedagogical design supported neurodiverse participation and cross-course collaboration. All projects involved full SL cycles: autonomous survey design, field data collection, statistical analysis using SPSS, and structured group reflections.

The comparison between pre- and post-questionnaires demonstrated substantial gains in students':

- Teamwork and collaboration skills,
- Leadership and responsibility,
- Appreciation of cultural and racial diversity,
- Problem analysis and critical thinking,
- Ability to connect theory to practice.

These findings suggest that SL activities positively impacted both academic and transversal competencies.

The pre- and post-questionnaires were completed by all 13 students involved in the second-year implementation. The instrument used was adapted from validated tools and included items grouped into key transversal competencies. Data analysis revealed statistically significant improvements in students' self-assessed competencies, particularly in teamwork (mean increase of 1.2 points), leadership (1.1 points), and the ability to relate academic content to real-life contexts (1.3 points), as previously reported in [1] and further discussed in [2].

Reflections were collected in two ways: through individual written forms completed at key stages of the SL cycle, and through guided oral sessions using the Think–4–Share method. These reflections were structured along three axes: emotional, cognitive, and ethical, and provided rich qualitative data for analysis, later used to inform the Mexico case study publication (*forthcoming*).

In terms of inclusivity, special attention was given to neurodiverse participation. One of the students involved in the second-year projects had Asperger syndrome, and adjustments were made to support his engagement. These included assigning roles that matched his strengths, adapting group timelines, and ensuring clear communication within the team. The positive

outcomes of this inclusive practice were noted in the students' reflections and reinforced by teachers' observations, as documented in [2].

2.6. **Case Study 3: Research-Based Use of AI in Statistical Methods (2024/2025).** In the second year of the GIRLS project, a research-based pedagogical approach was implemented in the first-year *Statistical Methods* course for Informatics Engineering students. This initiative aimed to explore the educational potential of AI (ChatGPT, Claude, Deepseek, etc) as a collaborative tool to support statistical reasoning and critical thinking.

The activity was structured in two phases. In the first phase, students individually solved a set of open-ended statistical problems without external assistance, using only their course materials and calculators. In the second phase, they were presented with AI-generated solutions to the same problems. Students were asked to critically evaluate these AI-generated responses, comparing them to their own, identifying errors or inconsistencies, and justifying whether they would accept, reject, or revise either solution. They then submitted written reports articulating their reasoning and the learning process.

This dual-phase methodology was designed to foster epistemic awareness by engaging students in reflective judgement and the evaluation of multiple representations of knowledge. It activated all stages of the research cycle: problem formulation, analytical procedure selection, interpretation of results, and reflective communication of findings. The pedagogical design was aligned with principles of Research-Based Learning (RBL), as described in the project's methodological handbook.

Qualitative analysis of student reports revealed meaningful learning outcomes. Students expressed increased awareness of conceptual subtleties in statistical reasoning and demonstrated improved capacity to identify logical flaws or misapplications of formulas. Many reported surprise at the persuasive yet incorrect nature of some AI-generated responses, highlighting the importance of human oversight in automated contexts. Preliminary observations suggest that the use of ChatGPT served as a catalyst for metacognitive engagement, encouraging students to examine their own problem-solving processes with greater depth.

This implementation also laid the groundwork for a forthcoming peer-reviewed publication presented at ICMASE 2025, entitled *"Critical Thinking and AI – Construction of Statistical Knowledge"*, which will further detail the research findings and implications for AI-supported learning in Engineering Education.

3. A Story of Learning, Service, and Transformation in Morelia

In June 2024, twenty students from across Europe, studying engineering, health sciences, and languages, embarked on a journey to Morelia, Mexico. They travelled not as tourists or researchers, but as learners and guests, prepared to serve and to grow. This international mobility was part of the GIRLS Erasmus+ project - Generation for Innovation, Resilience, Leadership, and Sustainability. The game is on!, KA220-HED-285023E0, an European initiative grounded in the belief that education reaches its full potential when it extends beyond the classroom into society.

In collaboration with the Universidad Vasco de Quiroga and local organisations in Ciudad Hidalgo, the students participated in an intense, emotionally charged week of community-based engagement. The central theme of the initiative was health education, with a particular focus on kidney health and the promotion of safe water consumption. However, the experience evolved into far more than a conventional public health campaign.

Armed with surveys, lesson plans, and an open mind, students visited schools, health centres, and homes. They listened to families, identified community concerns, and collaboratively designed engaging interventions to communicate essential health messages. Engineering students worked alongside their peers in health sciences to analyse data and deliver content, while language students translated materials and facilitated intercultural dialogue. Together, they navigated cultural differences, logistical constraints, and unfamiliar health practices. For many participants, this was their first time outside Europe, and their first experience of working within such a different social and cultural environment.

Central to this initiative was a carefully designed Service-Learning (SL) framework, rooted in experiential education theories ([3], [4]) and aligned with the GIRLS pedagogical foundations. Preparatory sessions were held prior to departure, guided by the GIRLS project handbooks. Upon arrival in Mexico, students were not assigned predefined roles; instead, they were encouraged to observe, to listen, and to reflect. Daily reflection practices helped scaffold their learning and emotional processing. Students wrote extensively about their experiences, what they saw, how they felt, and what they learned. These written reflections served as a powerful lens through which their personal and collective transformations became visible.

Some students wrote about learning to be more efficient and empathetic listeners; others expressed the emotional difficulty of confronting poverty and systemic inequality firsthand. Several reported discomfort with leading health workshops in a culture they were still striving to understand. Yet, within this discomfort emerged deep learning. One student reflected, "Everything. I feel like a completely different person now." Another wrote, "It is important to help people without expecting anything in return."

As the week progressed, students began to shift their self-perception. They no longer saw themselves merely as learners completing an assignment but as actors of social change. They questioned assumptions, discovered strengths, and built cross-cultural relationships. The word "transformation" appeared repeatedly in their reflections, alongside terms such as "people", "help", "life", and "motivation".

By the end of the mobility, students had not only conducted health interventions and statistical analyses but had also produced multilingual educational materials and engaged in real-world problem-solving. More importantly, they had internalised what it means to learn with purpose and to serve with humility. Educators, community partners, and students alike reported that the experience left a lasting impression, both academically and personally.

This international SL case illustrates the holistic learning model promoted by the GIRLS project. It exemplifies how civic engagement, interdisciplinary collaboration, and structured reflection can converge to promote transformative educational outcomes that reach far beyond traditional classroom boundaries.

3.1. **Structured Reflection and the Think–4–Share Methodology.** A core pedagogical component of the Morelia experience was the implementation of structured daily reflection using the *Think-4-Share* methodology. Developed and facilitated by one of the GIRLS educators, this approach enabled participants to engage in introspection, collective meaning-making, and synthesis at the community level.

Each session followed a three-phase progression:

- **Individual Moment (15 minutes):** Students revisited the day's experiences as if replaying a mental film, reflecting on actions, emotions, knowledge shared, and lessons

learned. They wrote personal insights on colour-coded post-its and placed them on a board titled *Individual Reflection*.

- **Group Moment (20 minutes):** Small working groups exchanged their reflections without interruption. A designated spokesperson synthesised common ideas and recorded them under the heading *Group Reflection*.
- **Community Moment (25 minutes):** Representatives from each group shared their conclusions with the full cohort. The collective listened attentively, and final insights were compiled as a *Community Reflection*.

This methodology is conceptually aligned with Kolb's experiential learning cycle, [3], concrete experience, reflective observation, abstract conceptualisation, and active experimentation, and honours the emotional, ethical, and interpersonal dimensions of learning. It also fosters inclusive participation and supports students in recognising their own growth and positioning within a community context.

The layered structure of Think-4-Share not only amplified students' voices but also generated valuable qualitative data for subsequent analysis, supporting the integration of reflective tools within the broader GIRLS pedagogical framework.

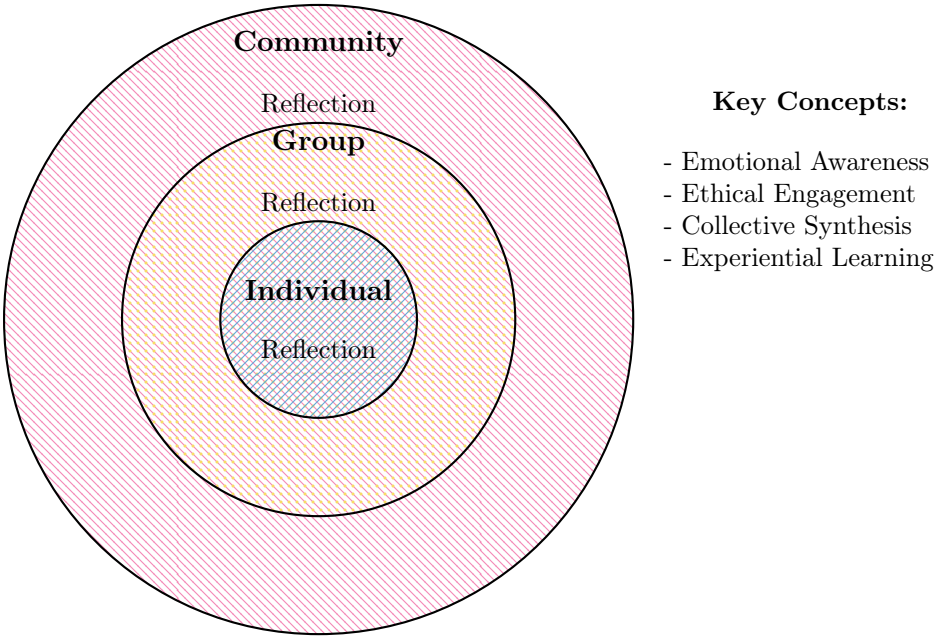

FIGURE 1. The Think–4–Share reflection cycle: expanding from individual to community-level insight. Visual accessibility is ensured by combining colour and pattern: **blue + diagonal lines** for Individual Reflection, **gold + dots** for Group Reflection, and **pink + crosshatch** for Community Reflection. In greyscale or for colour-blind readers, the pattern distinguishes the layers.

4. Discussion

The results across the Service-Learning (SL) and research-based implementations demonstrate that both methodologies effectively supported the development of mathematical and transversal competencies in authentic, socially meaningful contexts. In the SL case studies, the integration

of statistical methods with real-world themes, such as ethical consumption, financial literacy, and the evaluation of community service, significantly enhanced:

- Students' perception of the relevance and applicability of mathematics;
- Engagement with civic and societal challenges;
- Critical and ethical reflection on their future professional roles as engineers.

The 2024/2025 interdisciplinary implementation added further pedagogical value by fostering collaboration between students from the *Statistical Methods* and *Linear Algebra* courses. Joint problem-solving encouraged the articulation of algebraic reasoning and improved mathematical communication. Notably, the inclusion of a student with Asperger syndrome, supported through differentiated strategies (e.g., clearly defined roles, structured mediation, and asynchronous reflection), demonstrated the inclusive potential of SL when aligned with universal design principles. This confirms previous findings that SL can promote both academic learning and social belonging among neurodiverse learners.

SL integration also led to broader educational benefits:

- Students reported a stronger sense of purpose in applying theoretical knowledge to community challenges;
- Motivation and engagement increased as students faced complex, real-life scenarios requiring both analytical and interpersonal skills;
- Structured reflection activities promoted the development of ethical awareness, empathy, and civic responsibility.

However, some limitations were observed. Not all students experienced progress in every transversal competence, indicating the need for more differentiated and personalised feedback mechanisms. Additionally, during the initial SL implementation, there were occasional mismatches between students' expectations and the actual needs of the community partners (CASPAE and Dcanjamba), particularly in terms of project scope and available data. These challenges highlight the importance of early and transparent dialogue between academic teams and community organisations.

Regarding the research-based implementation using AI, preliminary findings suggest that AI-supported learning can serve as a catalyst for critical thinking. Students not only identified computational errors or logical inconsistencies in the AI-generated responses but also demonstrated increased metacognitive awareness in evaluating their own reasoning. The iterative comparison between human- and machine-generated solutions encouraged reflective judgement and epistemic agency, core goals of research-based learning. While the novelty of the tool contributed to initial enthusiasm, sustained learning gains were linked to structured guidance and clearly defined evaluation criteria.

In summary, both the SL and RBL approaches, when grounded in well-structured pedagogical models and reflective practices, show strong potential to enrich Engineering Education. They promote a more holistic and engaged learning experience, bridging disciplinary knowledge with ethical and societal awareness.

5. Conclusion: Lessons Learnt, Pedagogical Impacts, and New Pathways

This multi-year, interdisciplinary initiative confirms that Service-Learning (SL), when strategically integrated with Research-Based Learning (RBL), provides a robust pedagogical framework for engineering education. By embedding statistical concepts within socially relevant, community-driven challenges, students experienced mathematics not as an abstract discipline

but as a tool for ethical engagement, civic transformation, and interdisciplinary collaboration. The outcomes validate that such pedagogical innovation can bridge the gap between curriculum and society, fostering not only technical competencies but also personal and civic maturity. The case studies, ranging from local NGO partnerships in Portugal to international mobility in Mexico and collaboration with Angola, demonstrated that students undergo significant transformation when placed in real-world learning environments. Across SL and RBL implementations, students displayed greater self-efficacy, emotional intelligence, critical judgement, and cultural humility. These outcomes were particularly evident in their written reflections, where words like "transformation", "people", "help", and "responsibility" surfaced consistently. This evidence aligns with the theoretical experiential learning and supports the view that learning is most effective when it is active, contextualised, and affective.

Lessons Learnt by Students. Students' reflections and performance across the SL and research-based implementations revealed a wide range of learning outcomes:

- Working with real data is inherently non-linear, requiring adaptability, critical thinking, and tolerance of ambiguity;
- Applying statistical methods in real-world contexts is cognitively demanding but deeply rewarding;
- Mathematical reasoning can serve as a tool for civic engagement and ethical deliberation;
- Interdisciplinary teamwork fosters empathy, communication, and the flexibility needed for post-academic professional environments;
- Leadership and autonomy are not innate, but emerge through scaffolded experience and reflective practice.

Lessons Learnt by Educators. Educators involved in the project identified key pedagogical insights that inform future SL design and implementation:

- Students thrive in structured, socially relevant learning environments that give purpose to mathematical inquiry;
- Inclusive practices, especially for neurodivergent learners, are enhanced through predictable, transparent, and values-driven pedagogy;
- Cross-disciplinary collaboration between curricular units unlocks innovative formats for active learning;
- Effective SL design requires careful alignment between course objectives, community needs, and available resources;
- Student engagement increases when their work is perceived as socially meaningful and contextually impactful;
- Transversal competency evaluation offers a complementary lens to assess student development beyond content mastery.

The experience was equally transformative for educators. The interdisciplinary collaboration between instructors of mathematics, statistics, and engineering challenged traditional disciplinary silos. It also provided a testbed for inclusive practices, particularly in supporting neurodivergent students through transparent roles, scaffolded timelines, and structured reflection. Educators reported increased satisfaction, stronger student engagement, and greater alignment between learning outcomes and social responsibility goals. Importantly, the initiative reinforced the role of educators as facilitators of meaning-making rather than transmitters of abstract content. Beyond classroom practice, this work provides evidence for broader institutional and policy implications. The GIRLS pedagogical model, grounded in SL, RBL, Competence-Based Learning,

and Game-Based Learning, offers a transferable template for other institutions seeking to implement high-impact, inclusive, and SDG, aligned teaching practices. The integration of transversal competencies into curriculum design, assessment, and reflection practices could inform accreditation processes, faculty training, and the development of interdisciplinary modules across Europe. To capitalise on the insights gained, future initiatives should focus on the development of: (1) validated tools for assessing transversal competencies; (2) inclusive SL toolkits with guidelines for neurodiverse engagement; (3) partnerships with international NPOs that extend learning beyond national boundaries; and (4) faculty development programmes that embed the GIRLS framework across disciplines. Moreover, research should continue to explore the intersection of AI tools (e.g., ChatGPT) with ethical and epistemic learning in mathematics and engineering education. Ultimately, this initiative confirms that mathematical and statistical learning, when embedded in community contexts and reflective practice, becomes not only more effective but also more human. As engineering education moves toward complexity, uncertainty, and global interdependence, models such as GIRLS offer a compelling response, one that integrates knowledge, care, and action.

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