Science Diplomacy Education through Serious Games – Toward Evidence-Based Simulation Design

Claudia Alarcón-López[a,b,*], Luisa Echeverria King[c], Rafael Pineros[d]
[a]Northwest Higher Education Center, Mexico
[b]Monterrey Institute of Technology and Higher Education, Mexico
[c]Universidad Simón Bolívar, Colombia
[d]Universidad Externado de Colombia, Colombia
**Corresponding author: claudia.alarconlpz@gmail.com*

Introduction

Science diplomacy (SD) is increasingly recognised as a crucial field at the intersection of scientific advancement and international cooperation, addressing global challenges, such as climate change, public health, and technological governance. As the field gains prominence, so does the need for effective capacity-building educational strategies.

One promising pedagogical tool in SD education is the use of serious games—interactive, experiential learning tools designed for purposes beyond entertainment. Among these, simulation games have become popular tools in professional educational training programs, offering experiential learning to develop critical skills such as agency in role-playing, multilateral negotiation, critical thinking, time management, and strategic decision-making.

However, despite their widespread use, many simulation games prioritise immersive experiences over structured learning. They often lack mechanisms to measure learning, self-perceived skill development, or alignment with SD competencies. This paper critically examines the current use of simulation-based serious games in SD education, highlighting their constructivist, experience-focused design and identifying key limitations, including limited instructional time and insufficient theoretical scaffolding.

We propose a conceptual shift in how serious games in SD, specifically simulation games, are ideated and evaluated in SD capacity building. These should be embedded in meaningful case studies (real or fictional), supported by validated assessment tools that measure learning outcomes and reinforce core SD dimensions. Theory-informed serious game design can transform simulation games in SD from descriptive activities into powerful tools that consolidate knowledge, strengthen competencies, and advance the strategic goals of SD.

Serious Games as Pedagogical Tools in Science Diplomacy

Serious games represent a promising avenue for advancing SD education by offering immersive, interactive learning experiences that simulate real-world challenges. Defined as games designed specifically for education or training[1], serious games are increasingly used to train professionals across various sectors, including diplomacy.[2-5] These games can take several forms, including simulation games, role-playing games, strategy games, and game-based learning platforms, each providing unique learning opportunities depending on the training objectives.

Simulation games, broadly defined as structured, rule-based environments replicating real-world systems to foster experiential learning, are particularly effective for short-term educational interventions.[5] They have been a key tool for training in diplomacy and are emerging in SD capacity-building training.[6,7] These games enable participants to engage in scenario-based exercises where they can assume roles such as negotiators, diplomats, or scientists and make decisions based on the dynamics of global challenges. These interactive learning tools offer immersive environments where practitioners can develop skills such as strategic thinking, negotiation, multilateralism, and time management.[5-7] These games provide a constructivist learning experience that can complement traditional training methods.[8]

Validated simulation tools include those by Kriz (2010)[9], which explore best practices for evaluating educational games through empirical and theoretical models. Additionally, the Diplomacy Lab framework[10] provides insights into measuring the impact of simulation exercises in international relations training. These findings support the development of scalable and adaptable frameworks that meet the needs of diverse geopolitical contexts and disciplines.

Despite their potential, there is limited research on the effectiveness of simulation games in fostering measurable learning outcomes, particularly in terms of skill acquisition and alignment with SD competencies. While these simulations are powerful tools for experiential learning, their primary focus is often on providing a negotiation experience rather than explicitly reinforcing the core concepts of SD, such as multilateral cooperation, science-policy interfaces, evidence-based decision-making, science anticipation, and the role of diplomacy in global scientific collaboration. As a result, the educational impact of these games remains difficult to assess, and their ability to build SD-specific competencies is unclear.

To bridge this gap, we propose a conceptual shift that aims for SD simulations to be based on both learning science and a structured SD taxonomy. Additionally, embedding case studies (either real or fictional) into simulations, combined with validated tools to measure learning outcomes, can enhance the educational value of these games and ensure that they contribute effectively to SD capacity building. By integrating learning science principles and developing tools to assess the effectiveness of simulations, the educational value of these games can be significantly enhanced.

Alignment with global development agendas, including the SDGs, is also critical. By incorporating the SD Taxonomy, a framework that organises SD concepts into interconnected categories[11], serious games can be better designed to address the complexities of SD and ensure that the learning experience aligns with the real-world needs of science diplomats, including meta-cognition, critical thinking, and inference awareness.[12]

Rethinking Simulation Games in Science Diplomacy Education

Despite their appeal, many SD simulations struggle to translate immersive experiences into durable theoretical insights. Without prior orientation—whether via concise preparatory modules or in-game pause points—participants too often enact diplomatic scenarios without internalising the theoretical underpinnings of SD. Moreover, many current designs sacrifice pedagogical clarity for narrative richness, leaving learners adrift in complex storylines without explicit objectives and guided debriefs that translate experience into transferable SD insight. Without scaffolding, assessment, or theoretical grounding,

these tools risk delivering engaging but fragmented learning experiences, constraining accountability and continuous improvement.

To enhance educational coherence, it is crucial that game mechanics are closely connected to both (1) conceptual taxonomies of SD, such as the frameworks of diplomacy for science, science for diplomacy, and science in diplomacy[13], or even regional taxonomies such as the one described by Echeverria-King (2024)[11] for Latin America or the European Commission framework (2025)[14], and (2) educational learning theories such as transformative learning theory[15], Bloom's taxonomy for serious games[16], or systems thinking.[17] When incorporated into the game's ideation, narrative, and debriefing structures, they could provide clarity regarding the specific competencies and concepts learners are expected to engage with and internalise.

Instead of advocating for a specific game design, we propose a conceptual shift in how simulation games in SD are ideated and evaluated in SD capacity building as theory-informed interventions that facilitate both cognitive and socio-emotional learning. This approach involves several key components:

- Usage of Conceptual Taxonomies of SD

  Conceptual taxonomies could provide a structured context for serious games. The organisation and classification of scientific knowledge have been a historical constant that has allowed for greater specialisation and development. This process is dynamic and includes overcoming old disciplinary boundaries to advance toward transdisciplinary methodologies that contribute to a better understanding of a problem from different levels of governance and with the inclusion of actors beyond the State.[18] Therefore, SD is embedded in a complex dynamic of knowledge creation (interdisciplinary), an encounter transmitted through experience in solving complex problems (evolutionary), and an expression that links different actors (perspectives)[19], which generates specific forms of classification according to the perspective or influence being applied. In this sense, the classification of knowledge through a conceptual taxonomy is aimed at forming and building a consensus that is accepted by the scientific community that uses it so that, at the same time, it becomes an incentive for its development and subsequent evolution.[11]

- Educationally Grounded Game Design

  Simulation games should be designed with clear educational principles, informed by learning science theories.[5] This includes understanding how learners acquire, apply, and retain knowledge, as well as how to foster deeper cognitive engagement. Games must be structured to promote critical thinking, problem-solving, and concept integration related to SD (e.g., science-policy interfaces, evidence-based decision-making, and negotiation dynamics). Games should be pedagogically intentional with clear learning goals.

- Clear and Measurable Learning Outcomes

  Clearly articulated learning outcomes are essential to guide both the game design and evaluation.[8-10] These should address not only cognitive dimensions—such as comprehension of key SD concepts and proficiency in negotiation—but also socio-emotional competencies, including empathy and emotional self-regulation. In the absence of explicit objectives, any systematic evaluation of a game's educational value is rendered methodologically unsound.

- Mixed-Methods Evaluation

  A robust evaluation framework should combine quantitative (e.g., pre/post-game surveys) and qualitative (e.g., interviews, focus groups) methods to assess knowledge retention and emotional engagement. This combination allows for assessing cognitive gains and affective responses, providing a nuanced understanding of how participants internalise concepts and shift their attitudes or behaviours. Such an approach has been shown to effectively capture learning outcomes that singular evaluation methods might overlook.[20]

- Time-Bound Evaluation

  Longitudinal studies may be impractical due to the short-term nature of most simulation games. Therefore, time-bound evaluations should focus on immediate learning outcomes and reflection. Prompt post-simulation debriefings enable participants to reflect critically, link experiences to real-world SD concepts, and consolidate knowledge. Research highlights that such timely reflection maximises educational impact by transforming experience into meaningful learning.[21,22]

- Reflexivity and Metacognitive Debriefing

  Reflexive practices and metacognitive debriefing are critical for helping learners understand the implications of their decisions during the game. These structured reflections enable participants to evaluate their actions, consider alternative strategies, and relate their experiences to broader SD frameworks. In particular, science anticipation and inference awareness are recommended in SD capacity-building exercises. Science anticipation involves adopting a long-term, sustainability-oriented strategic mindset—envisioning the future impact of decisions made during the simulation. Inference awareness requires recognising one's own cognitive biases and understanding how they can influence negotiations within SD simulation games.[12]

- Peer and Expert Feedback

  Structured peer review combined with expert evaluation can deepen learning in SD simulations by blending collaborative reflection with disciplinary insight. Peer feedback fosters diverse interpretations and mutual sense-making, encouraging participants to critically examine their reasoning and explore alternative approaches.[23] Expert feedback, in turn, situates in-game decision-making within authentic diplomatic contexts, helping learners connect their actions to real-world policy challenges and navigate complex normative frameworks.[24] When thoughtfully balanced, this interplay between participant agency and authoritative input can avoid both over- and under-structuring, supporting engagement while maintaining conceptual rigour.

Conclusion

Simulation games have great potential to transform SD education when designed with a clear pedagogical intent, grounded in conceptual frameworks, evaluated rigorously, and designed with an understanding of both SD and learning science principles. This paper advocates for a shift toward theory-informed design that draws on educational frameworks to ensure simulations contribute meaningfully to cognitive and socio-emotional development. By prioritising clear learning outcomes, mixed-methods evaluation, and time-bound assessments, simulations can offer a more rigorous, critical evaluation of their impact, allowing for deeper insights into knowledge transfer and emotional engagement. Moreover, incorporating reflexive debriefing and peer/expert feedback can transform the post-game phase into an essential learning tool that deepens the intellectual and emotional understanding of SD challenges. Ultimately, serious games in SD need to be more than engaging or entertaining experiences—they must be part of a coherent learning ecosystem that integrates theory, assessment, and reflective practice. With these considerations, simulation games can play a more integral role in developing the critical competencies required for the complex, interdisciplinary nature of SD.

References

1. Michael D, Chen S (2006) Serious games: Games that educate, train, and inform. Thomson Course Technology.

2. Bridge D, Radford S (2014) Teaching diplomacy by other means: Using an outside-of-class simulation to teach international relations theory. International Studies Perspectives, 15(4): 423–437. https://doi.org/10.1111/insp.12032
3. Cercel MO (2022) Gamification in diplomacy studies as an effective tool for knowledge transfer: Questionnaire study. JMIR Serious Games, 10(2): e32996. https://doi.org/10.2196/32996
4. Gentry SV, Gauthier A, Ehrstrom BL, Wortley D, Lilienthal A, Car LT, Dauwels-Okutsu S, Zary N, Campbell J, Car J (2019) Serious game is an effective learning method for primary health care education of medical students: A randomized controlled trial. Nurse Education Today, 79: 40–45. https://doi.org/10.1016/j.nedt.2019.05.012
5. Crookall D, Oxford R, Saunders D (1987) Towards a reconceptualization of simulation: From representation to reality. Simulation and Games, 18(2): 147–171.
6. Raji M, Alarcón-López CA, Murphy S (2023) Shaping the Future of Multilateralism through Science Diplomacy: Insights from the GESDA Science Diplomacy Immersion Program. Science Diplomacy, 6(4): 31.
7. Doole FT, Littin S, Myers SA, Somasekhar G, Steyaert JC, Lansey K (2022) Experiential learning for training future science policy and diplomacy experts. Journal of Science Policy & Governance, 21(1): 1–27
8. Mezirow J (1991) Transformative dimensions of adult learning. Jossey-Bass.
9. Kriz WC (2010) A systemic approach to simulation and gaming for learning. Simulation and Gaming, 41(5): 663–680. https://doi.org/10.1177/1046878109352839
10. Oerther DB (2017) Diplomacy Lab Provides Term-Length Group Projects Integrating Policy Analysis and Liberal Arts into the Traditional Engineering Classroom. Proceedings of the 2017 ASEE Annual Conference and Exposition (2017, Columbus, OH), American Society for Engineering Education (ASEE). https://scholarsmine.mst.edu/civarc_enveng_facwork/1327/
11. Echeverría-King LF, Piñeros-Ayala RE, Pantović B, Flores-Zamora AF, Figueroa P (2024) A Taxonomy of Science Diplomacy From a Latin American and Caribbean Perspective. In Developments and Approaches in Science Diplomacy: Latin America and the Caribbean, pp. 26–54. IGI Global.
12. Alarcón-López CA (2024) A critical thinking approach for sustainable and anticipatory science diplomacy. In Developments and Approaches in Science Diplomacy: Latin America and the Caribbean, pp. 1–25. IGI Global.
13. AAAS (2009) Science diplomacy: A key to improving international relations. American Association for the Advancement of Science.
14. European Commission: Directorate-General for Research and Innovation, Gjedssø-Bertelsen R, Bochereau L, Chelioti E, Dávid Á, Gailiūtė-Janušonė D, Hartl M, Liberatore A, Mauduit, J, Müller J, Van-Langenhove L (2025) A European framework for science diplomacy: Recommendations of the EU Science Diplomacy Working Groups. Publications Office of the European Union. https://data.europa.eu/doi/10.2777/9235330
15. Dirkx JM (1998) Transformative learning theory in the practice of adult education: An overview. PAACE Journal of lifelong learning, 7: 1–14.
16. Buchanan L, Wolanczyk F, Zinghini F (2011) Blending Bloom's taxonomy and serious game design. In Proceedings of the International Conference on Security and Management (SAM). The Steering Committee of The World Congress in Computer Science, Computer Engineering and Applied Computing (World Comp), pp. 1).
17. Hofstetter E, Leifler O, Johansson B, Berggren P (2024) Facilitating systems thinking in serious

game design by highlighting inter-player relationships. Proceedings of the European Conference on Cognitive Ergonomics, 2024: 1–8.

18. Klein JT (2017) Typologies of interdisciplinarity. Frodeman R, Klein JT, Pacheco RC (Eds.), The Oxford Handbook Of Interdisciplinarity, pp. 21–39.
19. Manassero-Mas MA, Vázquez-Alonso Á (2019) Conceptualización y taxonomía para estructurar los conocimientos acerca de la ciencia. Revista Eureka Sobre Enseñanza y Divulgación de la Ciencia, pp. 3104–3116.
20. Oberle M, Leunig J, Ivens S (2020) What do students learn from political simulation games? A mixed-method approach exploring the relation between conceptual and attitudinal changes. European Political Science, 19: 367–386.
21. Crookall D (2014) Engaging (in) gameplay and (in) debriefing. Simulation & Gaming, 45(4–5): 416–427.
22. Burns CL (2015) Using debriefing and feedback in simulation to improve participant performance: an educator's perspective. International Journal of Medical Education, 6: 118.
23. Reinholz DL, Dounas-Frazer DR (2016) Using peer feedback to promote reflection on open-ended problems. The Physics Teacher, 54(6): 364–368.
24. Simon A (2020). Teaching and learning about foreign policy decision-making via board-gaming and reflections. European Political Science, 19(1): 9–28.