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HOW TO (RE)INSPIRE THE NEXT GENERATION OF SIMULATION MODELERS

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ABSTRACT

Despite the rising relevance of simulation in the twin transformation of sustainability and digitalization, simulation education often struggles to attract and retain learners. We introduce a generic, adaptable Constructive Alignment Simulation Framework that supports instructors in designing motivating, learner-centered, and coherently structured simulation courses. The framework emerged from the collective teaching experience of the authors in Austria, the UK, and the USA, covering a broad range of student profiles, institutional contexts, and educational levels. Building on key principles such as constructive alignment, revised Bloom's Taxonomy, and blended learning, the framework includes structured learning objectives, modular teaching formats, and a portfolio of assessment methods. We show how individual components of the framework have already been implemented across different simulation courses and demonstrate its flexibility and modular applicability for gradual and context-sensitive adoption.

1 INTRODUCTION

Discrete Event Simulation and Agent-Based Simulation are powerful methods for analyzing complex systems, and they offer increasing integration opportunities with machine learning (Kogler and Maxera 2025). Teaching simulation remains a pedagogical challenge because instructors face heterogeneous learner profiles from diverse disciplinary backgrounds, constrained curricular time, and a lack of structured pedagogical guidance. Literature on simulation education has highlighted the potential of grading contracts (Liu et al. 2024), gamified teaching formats (Kogler and Rauch 2020), experiential learning (Martin 2018), conceptual modeling (Robinson 2017), simulation life cycle (Tako 2015), educational frameworks (Garcia and Centeno 2009), and constructive alignment (Skoogh et al. 2012). However, a generalizable framework integrating those separate approaches for structuring simulation courses across disciplines has been lacking. We address this gap by presenting a framework developed from extensive international teaching experience and anchored in current pedagogical theory. Our framework is grounded in constructive alignment (Biggs, 1996) to integrate these theoretical foundations into a cohesive structure explicitly operationalized to the field of simulation education.

2 THE CONSTRUCTIVE ALIGNMENT SIMULATION FRAMEWORK

The Constructive Alignment Simulation Framework supports the design of coherent, motivating, and outcome-oriented simulation courses based on modular building blocks for simulation theory (i.e., modeling theory, simulation types, randomness), simulation life cycle (i.e., structuring the modeling process), conceptual modeling (i.e., abstraction and focus with process diagrams, event graphs, BPMN), and experiential learning (i.e., case studies, serious gaming, hackathons, competitions). It systematically links three pedagogical pillars:

- **Intended learning outcomes** are formulated based on the revised Bloom's Taxonomy (Anderson and Krathwohl 2001), distinguishing factual, conceptual, procedural, and metacognitive knowledge. The framework proposes 24 generic learning goals across six cognitive levels (i.e., remember, understand, apply, analyze, evaluate, create).
- **Teaching and learning activities** are structured into a blended learning environment that balances autonomy and guidance. Units combine asynchronous e-learning (e.g., screencasts, tutorials, quizzes), synchronous sessions (e.g., interactive modeling, peer discussions), and project-based experiential tasks. This structure allows differentiated learning paces while fostering engagement and depth of understanding.
- **Assessment methods** are explicitly aligned with outcomes and activities to ensure coherence and reward iteration, critical reflection, and real-world relevance. The framework emphasizes formative, process-oriented evaluation formats, including simulation portfolios, oral model defenses, reflective journals, peer assessments, and grading contracts.

3 IMPLEMENTATION IN INTERNATIONAL CONTEXTS

The Constructive Alignment Simulation Framework originated from practical experience across nine simulation courses in Austria, the UK, and the USA. Instructors implemented selected components based on disciplinary focus, student experience, and institutional setting. In Austria, students in wood logistics and biotechnology developed simulation models in AnyLogic and conceptual models with BPMN. Applied projects addressed sustainability and operational resilience, embedded in portfolio-based assessment structures. In the UK, courses in business and computing used Simul8, NetLogo, and process modeling tools to support practice-based learning in undergraduate, postgraduate, and doctoral settings. In the USA, students in business and engineering were introduced to simulation via SIGMA and Arena, guided by grading contracts and peer-reviewed simulation projects.

These varied implementations show that the framework can be adopted incrementally and flexibly, tailored to course scope, student background, and institutional constraints. Across all settings, its structured yet adaptable approach has helped instructors improve learner motivation, methodological clarity, and modeling competence. We therefore invite the simulation education community to iteratively adopt and further develop this framework to inspire and equip the next generation of simulation modelers.

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