Applying a Model-Driven Gamification Metamodel to Nursing Education: An Agile MDE Perspective Integrated with Behavior Change Techniques

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Abstract

Model-Driven Engineering (MDE) has been widely adopted to simplify the development of complex systems by raising the level of abstraction and enabling automated transformations. In parallel, gamification has proven effective in enhancing learner engagement, motivation, and learning outcomes across educational domains. This paper explores the application of an existing model-driven gamification metamodel to the domain of nursing education within an Agile MDE context. A novel contribution of this work is the systematic integration of Behaviour Change Techniques (BCTs) from the BCT Taxonomy v1 [1] with the metamodel's structural components. By aligning specific BCTs such as goal setting, self-monitoring, social comparison, and feedback on outcomes with corresponding metamodel elements, this paper proposes a theoretically grounded framework for designing gamified nursing education that is structurally coherent and behaviourally motivated. The gamified prototype 'Get Me Out of the Evidence Jungle' serves as a conceptual case study to illustrate this framework.

Keywords

Model-Driven Engineering, Gamification Metamodel, Nursing Education, Agile MDE, Behaviour Change Techniques, BCT Taxonomy

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1. Introduction

The transformation of healthcare education through digital technologies has accelerated considerably over the past decade. Nursing education faces the dual challenge of equipping students with technical clinical competencies and the metacognitive skills required for evidence-based practice (EBP). Traditional didactic methods have shown limitations in sustaining student motivation and facilitating the complex reasoning required in clinical environments [2]. Recent systematic reviews confirm this pattern, showing that nurse education programs relying solely on lectures underperform on learner engagement and knowledge retention compared to active, technology-enhanced alternatives [3, 4].

Gamification defined as the application of game design elements in non-game contexts has emerged as a powerful pedagogical strategy [5]. When integrated with structured software engineering approaches, it offers repeatable, scalable, and theoretically grounded mechanisms for designing engaging learning environments [6, 7]. A 2024 meta-analysis of 22 experimental studies demonstrated a significant positive effect of gamification on academic performance across educational settings (Hedges' g = 0.78) [7]. In nursing specifically, recent evidence confirms that gamified interventions improve knowledge acquisition, motivation, and clinical skill development [8, 9, 10]. Model-Driven Engineering (MDE) provides the abstraction and automation capabilities necessary to realize such systems in a reusable and domain-independent manner [11]. Despite significant progress in metamodel-based gamification frameworks, a critical gap persists: the lack of integration with established behavioural science theories. Gamification without a behaviour change foundation risks producing superficially engaging but educationally shallow experiences [12].

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The BCT Taxonomy v1 [1] provides a hierarchical, standardized vocabulary of 93 techniques organized into 16 clusters, enabling precise identification of the mechanisms through which game elements exert their effects on learner behaviour. In digital health, BCTs have been shown to be the active components driving engagement in mHealth applications [13, 14]. This paper addresses the gap by: (1) demonstrating the cross-domain reuse of an existing gamification metamodel in nursing education; (2) proposing an Agile MDE development process tailored to healthcare education; and (3) introducing a novel BCT-metamodel mapping framework that grounds each metamodel construct in validated behaviour change science.

2. Background and Related Work

2.1. Gamification in Nursing and Health Professional Education

The evidence base for gamification in nursing education has grown substantially since 2021. Nylén-Eriksen et al. [3] conducted a comprehensive systematic review and meta-analysis of 70 studies, finding that both serious games and gamification positively impacted academic achievement in 83–85% of included studies. Similarly, Seo et al. [8] performed a meta-analysis of randomized controlled trials (RCTs) and quasi-experimental studies, concluding that gamification significantly improves academic motivation and confidence among undergraduate nursing students. Sanz-Martos et al. [4] reported that a single gamified session increased learning satisfaction by five points on a 50-point scale and enhanced knowledge acquisition. The most recent meta-analysis by Luo et al. [10], covering 19 studies with 1,712 nursing students, confirmed that game-based teaching improves learning satisfaction, critical thinking, clinical decision-making, and clinical skills.

Escape rooms represent a prominent gamification modality in nursing education. A 2024 systematic review by González-de la Torre et al. [15] found consistent improvements in knowledge, satisfaction, and attitudes across escape room interventions. Yilmaz and Bayram [16] demonstrated in an RCT that nursing students participating in patient safety-themed escape rooms showed significantly higher post-test knowledge scores and cooperation skills compared to controls. The ONCEM quasi-experimental study (2024) reported high motivation, satisfaction, and self-confidence among oncology nursing students following escape room participation. Furthermore, Ghiamikeshtgar et al. [17] found that 80% of students rated escape room-based clinical evaluation as satisfactory or highly satisfactory, and 72% reported it as effective for clinical preparedness.

Beyond escape rooms, gamification has been applied through serious games, simulation, and digital platforms. Lee et al. [9] conducted a meta-analysis of RCTs in nursing education, reporting significant improvements in knowledge (Hedges' g = 0.75), confidence (g = 0.73), and performance (g = 0.49). Damaševičius et al. [18] conducted a meta-review of 50+ serious game and gamification studies across healthcare, concluding that well-designed gamified interventions outperform traditional education on most cognitive and affective outcomes. A 2025 JMIR Nursing study explored gamification for mental health nursing education, finding enhanced student engagement and reduced stigma through interactive card-based games [19]. Bai et al. [20] further demonstrated that gamified disaster nursing training improved 16 distinct effectiveness indicators across interventional studies published through 2024.

2.2. Model-Driven Engineering and Gamification Frameworks

Metamodel-based approaches to gamification provide a layer of abstraction between high-level pedagogical intent and low-level implementation detail. Herzig et al. [21] proposed GaML, one of the earliest modeling languages for gamification. More recent work by Mora et al. [22] and Garaccione et al. [23] refined these foundations by introducing domain-specific constraints and tool-supported model transformations. Garaccione et al. [23] described UMLegend, a gamified modeling tool empirically evaluated with 280 participants, demonstrating that gamification of conceptual modelling education significantly increases both productivity and competence. Mousavi et al. [24] presented a full MDE framework for

gamifying introductory programming education, validating the generalizability of metamodel-based approaches across technical domains.

Agile Model-Driven Engineering combines the flexibility of agile methodologies iterative delivery, stakeholder collaboration, and adaptive planning with the rigor of model-driven development [25, 26]. Di Nardo et al. [27] demonstrated in the context of software engineering education that gamification should be treated as a supplementary, not replacement, tool within structured development workflows, a principle well-aligned with the Agile MDE paradigm.

2.3. Behaviour Change Techniques in Digital Health and Education

The BCT Taxonomy v1 [1] defines behaviour change techniques as 'the active ingredients of behaviour change interventions.' In digital health, BCTs have been mapped to app features [28] and gamification mechanisms [29]. Mair et al. [14] conducted an umbrella review of BCT effectiveness in digital health interventions, finding that self-monitoring, goal setting, and feedback on behaviour are the most consistently effective BCTs across non-communicable disease management. Milne-Ives et al. [13] reviewed 28 studies examining BCT-engagement associations in mobile health, identifying six BCTs repeatedly associated with sustained user engagement: goal setting, self-monitoring, feedback, prompts/cues, rewards, and social support. Zhu et al. [30] further examined BCT implementation in digital behaviour change interventions, mapping 32 habit-formation design strategies to specific BCT categories. These findings directly support the BCT-metamodel alignment proposed in the present paper. However, no prior work has mapped BCTs specifically to gamification metamodel constructs within an MDE framework — which is the central contribution of this paper.

3. The Gamification Metamodel and Nursing Domain Mapping

The gamification metamodel proposed by Mousavi et al. [24] defines all primary metaclasses, formally introduced here in hierarchical order. GamificationSystem is the root aggregate of the entire model, registering all users, courses, and teams within a single gamified environment. Course represents an institutional learning unit (e.g., a clinical rotation module) composed directly under GamificationSystem as a shared curriculum artefact independent of any individual student. User represents a learner or educator registered within the system, associating with Course through an enrolment relationship (0..*). Team groups users for interprofessional collaboration and is ranked via LeaderBoard (team and individual rankings), which supports social comparison mechanisms. Activity encapsulates individual learning tasks typed by TrialType enumerations (e.g., diagnosis, drug calculation, literature review) and is governed by exactly one ActCondition (1..1), which enforces completion thresholds and win/fail logic. Each Activity may trigger zero or more Reward instances (points and badges) and Feedback instances (formative and summative assessment responses). Learner progress is monitored through the accumulation of reward scores, feedback outcomes, student performance indicators, and leaderboard rankings across activities. The metamodel was implemented using EMF/Ecore, with nursing scenarios represented as XMI model instances. In the current implementation, model-to-model transformations and code generation pipelines (e.g., using ATL or Acceleo) have not yet been applied; these are identified as a direct next step within the Agile MDE roadmap. The EMF/Ecore foundation nonetheless provides a concrete infrastructure for future automated validation, transformation, and tool-supported co-design with educators. Figure 1 illustrates the metamodel architecture and its nursing-specific instantiations.

Figure 2 presents the gamification metamodel architecture in standard UML class notation, adapted for the nursing education context. The diagram shows all primary metaclasses with attributes, association types, and multiplicities: GamificationSystem serves as the root aggregate composing one or more Course instances (1..*), each containing one or more Activity elements (1..*); each Activity is governed by exactly one ActCondition (1..1), enforcing completion and success logic, and may trigger zero or more Reward and Feedback instances (0..*); User instances participate in Team groups (0..*), which are ranked via LeaderBoard; and ProgressTracker aggregates performance data across all activities. Notably, Course instances are composed directly under GamificationSystem rather than under User,

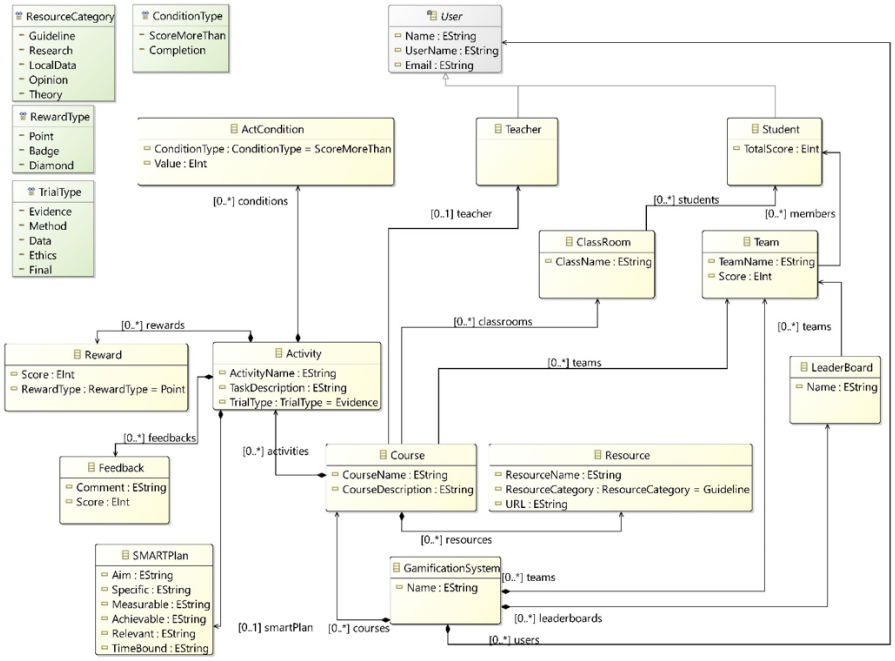


Figure 1: Gamification Metamodel Core Metaclasses with Nursing-Specific Instantiations [24].

reflecting the institutional reality that a course exists as a shared curriculum artefact independent of any individual student; User instances associate with Course through an enrolment relationship (0..*), consistent with standard learning management system architectures and established educational metamodel conventions. This metamodel extends established gamification design frameworks [22, 24] by incorporating elements specifically tuned to evidence-based learning contexts: SMARTPlan for structured objective setting, TrialType enumerations for differentiated challenge types, and ResourceCategory to classify clinical evidence sources. Each metaclass accommodates domain-specific instantiation through attribute extension rather than structural modification. The Activity metaclass, which in the original programming context represented coding challenges [24], is instantiated in nursing education as clinical tasks, procedural simulations, and case-based reasoning exercises — a flexibility central to the metamodel's cross-domain applicability [23, 24]. TrialType constrains the nature of each activity through enumeration (e.g., diagnosis, drug calculation, literature review), ensuring challenge types align with the NMC Standards for Proficiency [31]. Each metaclass is further annotated with its corresponding BCT from the BCT Taxonomy v1 [1]: for example, Reward and LeaderBoard operationalise Material Reward (BCT 10.2) and Social Comparison (BCT 6.2), while Feedback simultaneously activates Feedback on Behaviour (BCT 2.2) and Feedback on Outcome (BCT 2.7), confirming that gamification elements operationalise theoretically differentiated behaviour change mechanisms. Table 1 summarises the complete mapping alongside BCT linkages.

The gamification layer comprises Reward (points and badges), LeaderBoard (team and individual rankings), and ActCondition (completion and success logic). Feedback connects assessment outcomes to learner responses in real time, while SMARTPlan supports structured project planning in EBP. This architecture aligns with findings from Nylén-Eriksen et al. [3] who identified that gamification interventions that combine points, badges, leaderboards, and feedback mechanisms produce the strongest results in nursing education contexts.

This mapping demonstrates that the metamodel is sufficiently abstract to accommodate nursing-specific semantics without structural modification. All primary metamodel classes were instantiated with nursing-specific values without requiring new class creation or inheritance extension. This finding aligns with evidence from Seo et al. [8] showing that gamification elements when properly aligned to pedagogical objectives significantly enhance nursing student motivation and confidence regardless of the technical platform used.

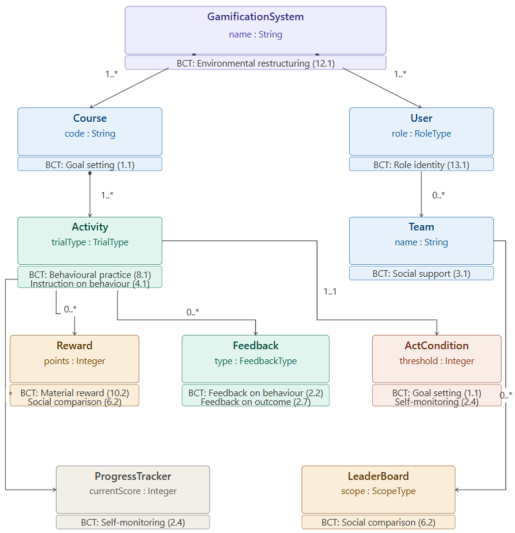


Figure 2: Gamification metamodel in UML class notation with BCT annotations per metaclass, showing Material Reward (BCT 10.2), Feedback on Behaviour (2.2), Social Comparison (6.2), and Goal Setting (1.1).

Table 1
Metamodel Elements Mapped to Nursing Education Applications and BCT Linkages.

Metamodel Element	Game Concept	Nursing Application	BCT Linkage
GamificationSystem	Whole Game / GameManager	'Evidence Jungle' root	Environmental restructuring
Course	Level / Scenario	Clinical rotation modules	Graded tasks, Goal setting
Activity / TrialType	Quest / Game Screen	Clinical case study & EBP quests	Behavioral practice, Instruction on behavior
Resource / ResourceCategory	Evidence Cards	NICE guidelines, Cochrane reviews	Credible source (BCT 9.1)
Reward / LeaderBoard	Badge / Score / Ranking	Performance indicator badges	Material reward (BCT 10.2), Social comparison (BCT 6.2)
Feedback / ActCondition	UI Message / Validation	Clinical evaluation response	Feedback on behavior (BCT 2.2) & outcome (BCT 2.7)
SMARTPlan	Final Task / Form	Structured EBP project plan	Action planning (BCT 1.4), Self-regulation

4. Integrating Behaviour Change Techniques with the Metamodel

BCT Taxonomy v1 comprises 93 discrete techniques grouped into 16 hierarchical clusters. For this framework, eight clusters were identified as directly relevant based on a systematic review of BCT-gamification alignment studies [14, 29, 32]: Goals & Planning, Feedback & Monitoring, Social Support, Reward & Threat, Shaping Knowledge, Associations, Identity, and Repetition & Substitution. BCTs were selected based on three criteria: operationalizability within a digital learning environment, established evidence of effectiveness in health professional education, and direct structural correspondence with at least one metamodel element. This selection process aligns with the approach recommended by Milne-Ives et al. [13], who identified that BCTs associated with goal setting, self-monitoring, and social comparison are most robustly linked to sustained engagement in digital interventions.

Table 2 presents the full BCT-metamodel mapping which is the primary novel contribution of this paper. Mair et al. [14] demonstrated across 86 systematic reviews that self-monitoring, feedback on outcomes, and goal setting are the most effective BCTs in digital health interventions. Each of these maps directly to a core metamodel element in our framework, providing strong empirical grounding for the

design choices. Zhu et al. [30] additionally demonstrated that digital interventions combining explicit goal setting with personalized feedback produce the most durable habit-formation outcomes, a pattern operationalized in the SMARTPlan and Feedback metaclasses of this framework. BCT–metamodel mapping was derived through iterative author consensus using the definitions from the BCT Taxonomy v1, while acknowledging that independent expert validation and inter-rater reliability assessment remain future work.

Table 2
BCT Taxonomy v1 Mapped to Gamification Metamodel Elements and Nursing Instantiations

BCT Technique	BCT Cluster	Metamodel Element	Nursing Example
Goal Setting (Behavior)	Goals & Planning	SMARTPlan, ActCondition	Student sets clinical competency targets per rotation
Self-Monitoring	Feedback & Monitoring	Feedback, ProgressTracker	Real-time clinical assessment score dashboard
Instructions on Behavior	Shaping Knowledge	Activity, TrialType, Resource	Guided evidence-based case study quests
Material Reward	Reward & Threat	Reward, LeaderBoard	Badges awarded on completing procedural skills
Social Comparison	Social Support	Team, LeaderBoard	Interprofessional team leaderboard rankings
Credible Source	Associations	Resource, ResourceCategory	NICE / clinical guideline evidence resource links
Role Identity	Identity	User (Student/Teacher)	Student adopts ‘clinical investigator’ persona
Behavioral Practice	Repetition & Substitution	Activity, Course (iterative)	Repeated procedural simulations across modules

The Capability-Opportunity-Motivation-Behavior (COM-B) model [33] provides the overarching theoretical framework within which these BCTs operate. In nursing education, Capability refers to students’ clinical knowledge and evidence appraisal skills (addressed by Activity, Resource, and TrialType); Opportunity refers to the structured affordances provided by the platform (Course, GamificationSystem); and Motivation refers to the incentive structures sustaining engagement (Reward, LeaderBoard, Feedback, SMARTPlan). By grounding metamodel elements in COM-B, designers gain a principled means of diagnosing engagement gaps. Ratinho and Martins [34] demonstrated in a systematic review that gamified learning strategies focusing on COM-B motivation components particularly autonomy and competence produce the strongest sustained motivational effects in higher education contexts. Figure 3 illustrates this COM-B alignment.

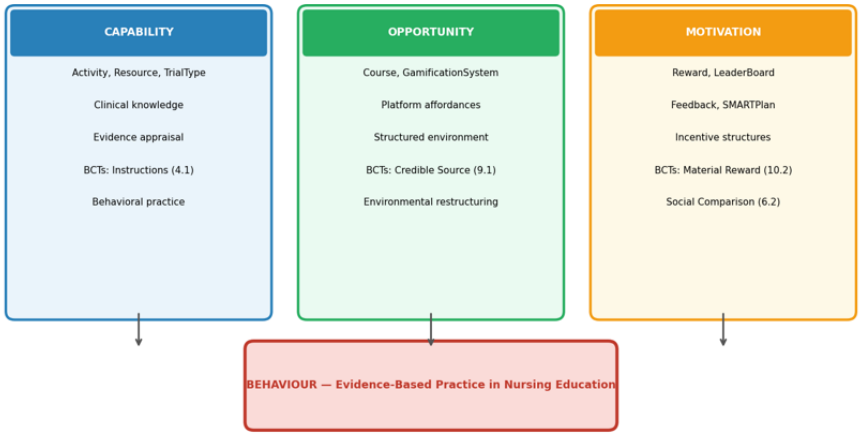


Figure 3: COM-B Model Alignment with Gamification Metamodel Elements and BCT Clusters.

5. Agile MDE Process with BCT Sprint Integration

This paper proposes a novel five-sprint Agile MDE framework that embeds BCT specification into each phase of the development cycle. Unlike conventional Agile MDE processes that treat pedagogical theory as a precondition rather than an active design input, this framework makes BCT selection a sprint artefact, ensuring behavioural objectives remain traceable from metamodel instantiation through prototype evaluation [26]. Table 3 presents the complete sprint framework, and Figure 4 visualizes the sprint timeline.

Table 3
Five-Sprint Agile MDE Framework with BCT Integration per Phase.

No.	Agile MDE Activity	Metamodel Focus	BCT Integrated
1	Domain analysis & metamodel instantiation	GamificationSystem, User, Course	Goal setting, Role Identity, Instruction on behaviour
2	Activity modelling & TrialType configuration	Activity, TrialType, Resource	Credible source, Behavioural practice, Shaping knowledge
3	Gamification layer & reward logic	Reward, LeaderBoard, ActCondition, Feedback	Material reward, Social comparison, Self-monitoring
4	SMART planning module & prototype evaluation	SMARTPlan, Team, Feedback	Action planning, Social support, Feedback on outcomes
5	Cross-domain validation & educator retrospective	Full metamodel re-assessment	No new BCTs introduced; retrospective evaluation and cross-sprint alignment audit of BCTs from Sprints 1–4

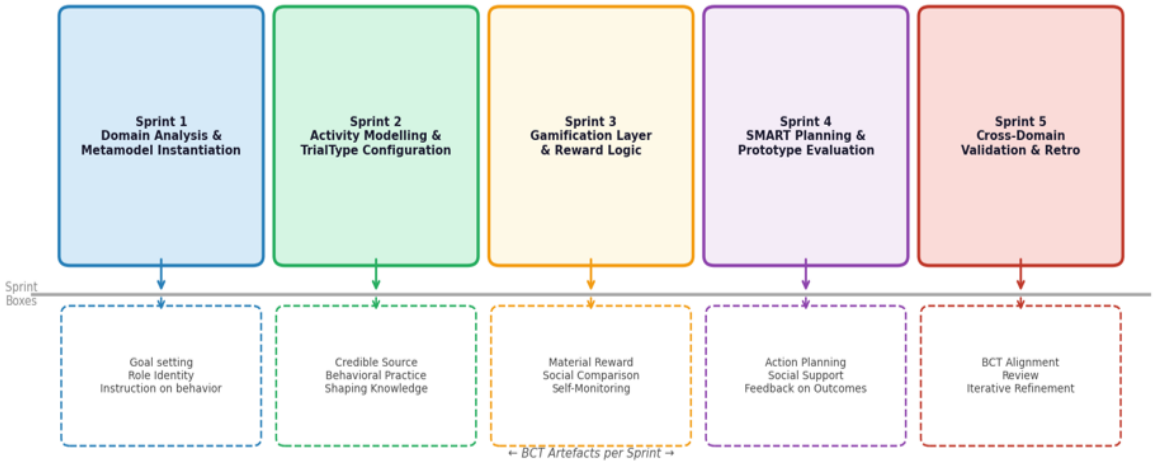


Figure 4: Agile MDE Sprint Timeline with BCT Sprint Backlog Integration per Phase.

A distinctive feature of the proposed framework is the BCT Sprint Backlog. A novel artefact that formalizes the connection between user stories, metamodel elements, and BCT specifications within a single sprint planning document. Each user story is annotated with: (a) the metamodel element(s) it instantiates; (b) the BCT(s) it is intended to activate; (c) the COM-B component targeted; and (d) the expected behavioural mechanism. This approach directly addresses the reproducibility challenge

identified by Michie et al. [35], whereby digital behaviour change interventions often fail to specify their active ingredients with sufficient precision for replication or comparative evaluation.

The metamodel's abstraction layer proved particularly valuable in co-design sessions: educators were able to engage meaningfully with metamodel instance diagrams without requiring software engineering knowledge. This co-design characteristic aligns with the participatory design principles emphasized in recent healthcare education technology research [15, 36], which identifies educator and student co-design as a critical success factor for gamification adoption in clinical curricula.

6. Case Study: 'Get Me Out of the Evidence Jungle'

'Get Me Out of the Evidence Jungle' is a gamified web-based module designed to develop evidence-based research skills among interprofessional healthcare students. The jungle metaphor positions students as 'clinical investigators' navigating an environment populated by evidence resources of varying quality directly activating the Role Identity BCT (BCT 13.1). This identity-based framing aligns with findings from a 2025 JMIR Nursing study which found that nursing students in gamified environments who adopted professional role identities within the game context showed stronger attitudes toward evidence-based practice [19].

The prototype's four screens map directly to metamodel elements: the start screen instantiates GamificationSystem and User; the Evidence Arena instantiates Activity, TrialType, and Resource; the feedback screen instantiates Feedback and ActCondition; and the completion screen instantiates Reward, LeaderBoard, and SMARTPlan. The game logic is governed by the ActCondition metaclass, which evaluates student responses against predefined correctness criteria. Students receive 10 points per correctly ranked evidence source; a minimum threshold of 30 out of 40 points triggers the congratulations screen (win condition), while scores below this threshold redirect to a remediation feedback screen (fail condition). Progression between screens is linear: from the Start screen through the Evidence Arena, to either the Feedback (fail) or Congratulations (pass) screen. LeaderBoard scores are updated at session end, aggregating individual scores into team totals for interprofessional comparison. Figure 5 shows the prototype screens.

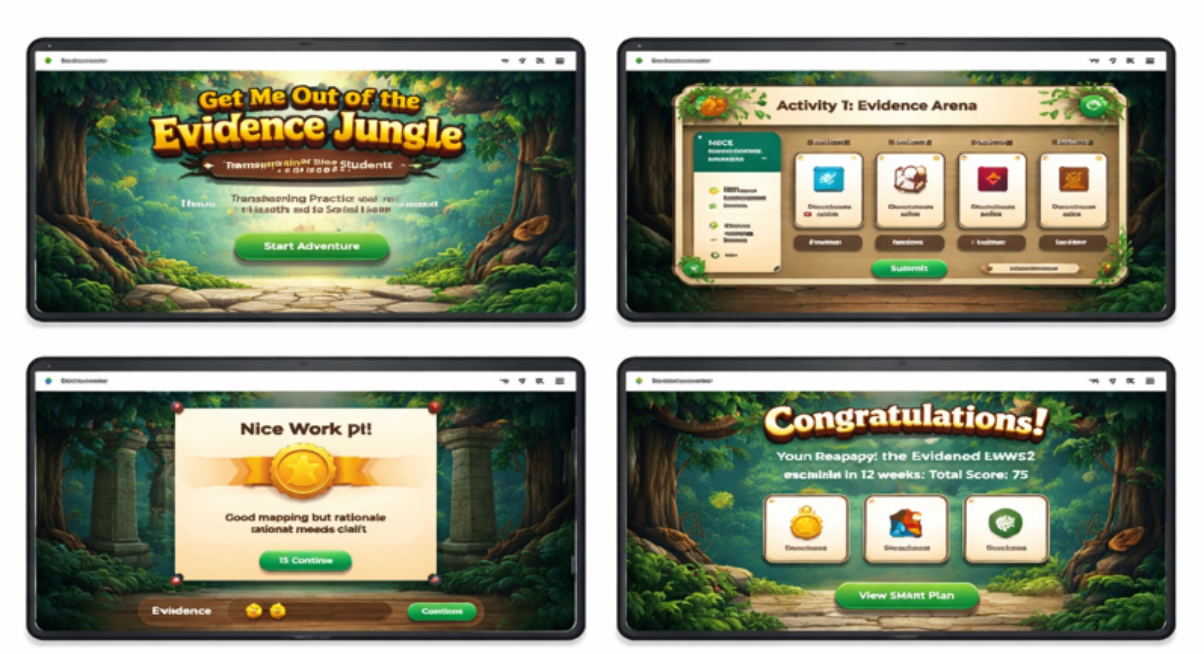


Figure 5: Prototype screens of 'Get Me Out of the Evidence Jungle': (top-left) Start screen; (top-right) Evidence Arena with ResourceCategory cards; (bottom-left) Feedback screen; (bottom-right) Congratulations screen with Reward, LeaderBoard and SMARTPlan prompt.

The Evidence Arena presents students with four evidence sources categorised by ResourceCategory (Systematic Review, RCT, Clinical Guideline, Expert Opinion). Students must select and rank sources according to their relevance to a PICO-formatted clinical question activating Instruction on Behavior (BCT 4.1) and Credible Source (BCT 9.1). This PICO-based evidence ranking task directly mirrors the information literacy competencies targeted in recent nurse education technology studies. Kowitlawakul et al. [36] identified that educational technology tools that combine evidence-based task scaffolding with immediate feedback produce the most significant improvements in undergraduate nursing student engagement.

The feedback screen operationalizes both Feedback on Behaviour (BCT 2.2) and Feedback on Outcome (BCT 2.7) simultaneously. This dual feedback structure is supported by Milne-Ives et al. [13] who found that combining behavioural and outcome feedback is more strongly associated with engagement than in isolation. The congratulations screen integrates Material Reward (BCT 10.2), Social Comparison (BCT 6.2), and Action Planning (BCT 1.4) in a single interface.

The nursing education instantiation required zero structural modifications to the core metamodel, supporting the metamodel's claim to domain independence. Gamification elements commonly treated as interchangeable such as badges, points, and leaderboards in fact operationalise distinct and theoretically differentiated BCT mechanisms. This distinction has practical consequences: Seo et al. [8] demonstrated that gamification interventions explicitly linking reward elements to specific motivational mechanisms outperform those using game elements instrumentally without theoretical grounding. It should be noted that the absence of structural modifications may also be interpreted as evidence of a relatively high level of abstraction; in model-driven engineering, however, this abstraction is intentional and desirable, since it enables the same metamodel structure to be instantiated across multiple educational domains while preserving domain-specific semantics through model-level customisation rather than metamodel modification. Nonetheless, a more domain-specific extension could capture nursing-specific constraints such as NMC proficiency standards and clinical supervision relationships and is identified as a direction for future metamodel specialisation.

7. Discussion and Conclusion

The findings of this conceptual study suggest that model-driven gamification metamodels possess a degree of domain independence that exceeds what previous literature has demonstrated. This paper crosses a more fundamental domain boundary from a technical vocational domain to a regulated health professional education context. Recent systematic reviews and meta-analyses consistently confirm that gamification positively impacts knowledge, motivation, confidence, and clinical performance in nursing education [3, 8, 9, 10], providing a strong empirical backdrop for the structural claims advanced here. The five-sprint Agile MDE framework demonstrated that iterative co-design with clinical educators is both feasible and productive within a model-driven paradigm.

Three novel contributions are made. First, the BCT-metamodel mapping framework constitutes the first systematic alignment of BCT Taxonomy v1 constructs with a model-driven gamification metamodel, enabling designers to conduct BCT gap analyses of existing platforms. This contribution is particularly timely: Mair et al. [14] have demonstrated that BCT-explicit digital health interventions outperform those that incorporate similar features without theoretical grounding, and Milne-Ives et al. [13] confirm that only six BCTs are robustly associated with sustained engagement. All six of which appear in the present mapping. Second, the BCT Sprint Backlog extends conventional Agile MDE sprint planning by introducing a mandatory behavioural specification layer, addressing the reproducibility crisis in digital behaviour change research [35]. Third, the application of COM-B as a diagnostic framework for metamodel evaluation provides a structured vocabulary for diagnosing engagement failures at the model level rather than the implementation level, an approach validated by Ratinho and Martins [34] who demonstrated the superior motivational outcomes of theory-grounded gamification design.

Limitations include the study's conceptual nature: empirical validation with nursing students and clinical educators has not yet been conducted. Furthermore, this study focuses on a single existing

metamodel [24]; a comparative evaluation across multiple model-driven gamification frameworks [22, 23, 24] would strengthen the generalisability of the BCT-mapping approach and is identified as a priority for future work. To address these limitations, a structured pilot study is planned in collaboration with the Nursing Department at the University of Roehampton. The pilot will deploy the 'Get Me Out of the Evidence Jungle' prototype with undergraduate nursing students in a controlled comparison design, consistent with the BCT methodology employed in escape room gamification studies [9, 16]. Outcomes will be measured across three dimensions: engagement (session completion rate, time-on-task, and voluntary replay rate), learning (pre/post knowledge assessment scores on evidence appraisal), and modelling effort (educator time required to instantiate and adapt the metamodel for a new clinical module). A control group receiving equivalent content without BCT-aligned gamification elements will enable direct comparison, and ethics approval will be sought through the University's institutional review process prior to data collection. Beyond this immediate pilot, future work extend evaluation to additional gamification modalities including escape rooms [15, 37] and disaster nursing training [20], and to incorporate independent expert validation of the BCT-metamodel mapping to establish inter-rater reliability.

In conclusion, 'agile' in this framework refers concretely to the five-sprint iterative structure in which each sprint produces a reviewable artefact: metamodel instance diagrams, BCT Sprint Backlog documents, and prototype screens that clinical educators can evaluate without software engineering expertise. This artefact-driven co-design enables rapid feedback loops between domain experts and modellers, supporting adaptive planning as pedagogical requirements evolve, and directly addresses the reproducibility challenge in digital behaviour change research [35]. Future empirical studies should measure the impact of this co-design process on both modelling effort and educator satisfaction in real institutional settings. Taken together, Agile MDE and behaviour change science are complementary rather than competing frameworks: Agile MDE provides structural rigour and rapid iteration. BCT integration provides theoretical grounding and evaluation vocabulary. Their integration represents a significant methodological advance for both fields.

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Declaration on Generative AI

Generative AI was used for proofreading and language refinement.

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