2 Game-Based Learning Models and the Architecture of Play

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2.1 A Structural Model of Game-Based Learning: Variables and Their Effects on the Learning Process

This chapter moves from general theory to the internal architecture of games, examining rules, feedback, interaction, uncertainty, and the cognitive mechanisms through which play becomes a learning system.

Before presenting the table, it is worth stating clearly what the model proposes and what it does not. The framework builds on Garris, Ahlers, and Driskell (2002), whose influential research and practice model identified the structural variables through which games motivate and shape learning, and integrates them with the design principles articulated by Salen and Zimmerman (2004) in their foundational work on game mechanics and rules. It does not propose

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that all fifteen variables must be present in every instructional game, or that their effects on learning are uniform across all learners and all domains. It proposes something more modest and more useful: that these fifteen variables are the primary structural dimensions along which any game-based learning experience can be analysed, and that understanding the effect of each variable on the learning process gives the designer, the teacher, and the researcher a coherent framework for making and evaluating instructional decisions. The variables are grouped into four clusters: Rule Structures, Uncertainty and Decision-Making, Objectives and Outcomes, and Player Experience, each of which captures a distinct dimension of how games work on the mind. Within each cluster, the variables are related to one another, and those relationships are noted where they are most important. The table that follows maps each variable to its primary effect on learning, stated as directly as possible.

The model rests on a single foundational claim: that learning in games is not produced by any single feature of game design but by the interaction of multiple structural variables operating simultaneously on the learner's cognition, motivation, and social experience. A game that is strong on operational clarity but weak on meaningful uncertainty will produce procedural compliance without real thinking. A game that generates deep immersion but lacks clear goals will produce engagement without direction. A game that creates productive conflict but withholds the feedback needed to learn from it will produce frustration rather than understanding. The variables are interdependent, and the quality of the learning experience depends on how well they are balanced against one another, which is to say, on the quality of the design.

Table 1 Structural model of game-based learning: variables and their effects on the earning process

Rule Structures	Operational Rules	The explicit, stated instructions that govern what players can and cannot do during play	Establish procedural knowledge and enable action within the game world; reduce cognitive overload at entry by providing a clear behavioural framework; when well-designed, allow the learner to focus attention on decision-making rather than on decoding the game's basic mechanics
	Constitutive Rules	The underlying formal or mathematical logic that the operational rules express; the deep structure of the game's system	Develop structural and relational understanding of the domain the game represents; when grasped through play, produce knowledge that is closer to disciplinary understanding than to game knowledge; the primary mechanism by which games teach the logic of a field rather than merely its surface procedures

	Implicit Rules	The unwritten social norms and expectations that govern how the game is actually played in its social context	Shape the quality of collaborative and competitive interaction; determine whether the game functions as a productive social learning environment or degrades into conflict and disengagement; require explicit teacher management to align social behaviour with instructional purpose
Uncertainty and Decision-Making	Hidden Information	The deliberate withholding from one or more players of information that exists within the game world	Develops probabilistic reasoning and inference under incomplete information; trains the learner to act decisively on the basis of partial evidence; replicates the epistemic conditions of real professional practice more faithfully than any fully transparent problem set
	Randomness	The introduction of outcomes not fully determined by player decisions, through dice, cards, or algorithmic processes	Forces the learner to evaluate decisions by the quality of the reasoning that produced them rather than by their outcomes alone; develops probabilistic thinking and the capacity to distinguish good decisions from lucky ones; builds tolerance for uncertainty as a permanent condition of complex domains
	Opponent Behaviour	The uncertainty produced by the presence of other players whose decisions are not known in advance and whose goals may conflict with one's own	Develops strategic thinking and the capacity to reason about the intentions and likely responses of others; produces the adversarial cognitive demand that single-player environments cannot replicate; directly trains the interpersonal and competitive reasoning required in negotiation, clinical, legal, and market contexts
	Complex Decision Spaces	Game situations in which multiple options are available simultaneously, none obviously superior, each carrying consequences that extend beyond the immediate moment	Trains judgment under genuine uncertainty; develops the capacity to evaluate competing options with incomplete information and real consequences; produces the kind of decision-making demand that examinations, which present pre-specified problems with known correct answers, structurally cannot
	Conflict	The structural tension built into the game – against another player, against the system, or against the constraints of limited resources and capability	Generates the cognitive and motivational pressure without which engagement collapses and learning loses direction; when well-designed, mirrors the genuine tensions of the domain the game represents and produces understanding of how those tensions are navigated in practice
Objectives and Outcomes	Goals	What the player is trying to achieve; the game's explicit statement of success conditions	Provide direction and motivational structure; align the learner's effort with the instructional objective; when well-calibrated to the learner's level of prior knowledge, produce the challenge-competence balance that sustains productive engagement throughout play

	Procedures	The actions the player is permitted to take in pursuit of goals; the operational range of the game	Define the cognitive and strategic space within which learning occurs; procedures that are too narrow constrain learning to a single pathway; procedures that are too broad produce decision paralysis; well-designed procedures create a space that is open enough to require genuine thinking and constrained enough to keep that thinking productive
	Outcomes	How success or failure is measured and communicated within the game	Function as the game's primary evaluative feedback; when outcomes are clearly connected to the decisions that produced them, they support learning by closing the loop between action and consequence; when outcomes are poorly calibrated – too harsh, too forgiving, or insufficiently differentiated – they undermine the learning process by severing the connection between decision quality and result
Player Experience	Pleasure	The positive affective experience produced by the game, including aesthetic enjoyment, humour, social connection, and the satisfaction of competent performance	Reduces affective barriers to engagement; increases willingness to persist through difficulty; creates the emotional conditions under which risk-taking – the cognitive behaviour most productive of genuine learning – becomes possible; pleasure that is disconnected from learning content is motivating but not instructive
	Engagement	The sustained direction of attention and effort toward the game's demands	The necessary condition for all other learning effects; no variable in this model produces learning in the absence of engagement; engagement is produced by the interaction of challenge, meaning, and the player's sense that their decisions matter; it is the most important single predictor of whether the game will teach anything at all
	Challenge and Flow	The dynamic balance between the difficulty of the game's demands and the competence of the player meeting them; the state of absorbed, effortless attention that optimal challenge produces	When the balance is correct, produces the state of flow in which learning is most efficient and durable; when the balance is wrong – too easy or too hard – produces boredom or anxiety, both of which suppress learning; maintaining this balance across a heterogeneous learner population is the central practical challenge of instructional game design
	Immersion	The degree to which the player experiences the game's world as present and real; the suspension of awareness of the external environment	Deepens the transfer of learning by strengthening the connection between the game's scenarios and the real-world situations they simulate; high immersion increases the likelihood that knowledge developed during play will be accessible in non-game contexts; immersion is most educationally productive when the game's scenario is structurally faithful to the domain it represents, not merely visually convincing

Several relationships between variables deserve to be made explicit, because they are not fully captured by reading the rows of the table independently.

The relationship between operational rules and flow is direct and consequential. A game whose operational rules are unclear or inconsistently applied places a cognitive burden on the learner that competes with the cognitive work the game is designed to produce. The learner who is still trying to understand what they are allowed to do cannot simultaneously be exercising the judgment the game was designed to develop. Operational clarity is therefore not merely a matter of usability; it is a precondition for the flow state that makes learning efficient.

The relationship between constitutive rules and transfer is equally important and less commonly discussed. A learner who has understood a game's constitutive logic, who has grasped, through play, the formal relationships that the game's operational rules express, is in a position to transfer that understanding to new contexts, because constitutive logic is abstract and therefore portable. A learner who has mastered only the operational rules has acquired context-specific procedural knowledge that may not transfer beyond the specific game that produced it. The depth of learning a game is therefore closely related to the degree to which the learner has penetrated from the operational surface to the constitutive depth.

The relationship between hidden information and opponent behaviour creates, in combination, the conditions for the most demanding form of strategic reasoning that games produce: the reasoning of a player who must act on incomplete information in a situation where another intelligent agent is actively working against them. This combination, present in negotiation simulations, competitive market games, legal advocacy exercises, and a wide range of other knowledge-dependent instructional games, produces cognitive demands that are, in both their structure and their difficulty, closely analogous to the demands of professional practice in complex domains. It is the combination, not either variable alone, that generates this effect.

Finally, the relationship between immersion and transfer deserves emphasis because it runs counter to an assumption that is sometimes made in educational technology: the assumption that the more realistic a game's visual environment, the more effective it will be as a learning tool. Immersion that is produced by visual fidelity alone, by the convincing representation of a surface scenario, does not reliably produce the transfer of learning. Immersion that is produced by structural fidelity, by a game whose internal logic really mirrors the logic of the domain it represents, does. A visually simple game whose constitutive rules accurately represent the dynamics of a real-world system will produce more durable and more transferable

learning than a visually spectacular game whose mechanics bear only a superficial relationship to the domain it claims to simulate. The map is not the territory, and the simulation is not the domain. But a simulation whose structure faithfully replicates the domain's structure is, for the purposes of learning, close enough to matter. There is a temptation, when thinking about games in educational contexts, to focus on the surface features, the points, the scenarios, the competitive dynamics, the narrative wrapping, and to treat these as the substance of what games are. This temptation should be resisted. The surface features of a game are real and they matter, but they are effects rather than causes. They are produced by something deeper and more structural: the system that lies beneath the surface and generates, through the interaction of its parts, everything the player encounters during play. To understand how games teach, one must understand how games work, and games work as systems. This is not a metaphor. It is a precise description of their architecture.

A system, in the sense relevant here, is a set of elements whose relationships with one another produce behaviour that none of the elements could produce alone. Wardaszko (2018) has examined this interdisciplinary challenge directly, arguing that simulation game design requires the integration of systems theory, complexity science, and learning theory into a coherent design methodology, a demand that distinguishes serious game design from both conventional instructional design and commercial game development. The elements of a game, its pieces, its rules, its players, its resources, its spaces, are not interesting in isolation. A chess piece standing alone on a table is an object. A chess piece on a board, in relation to other pieces, governed by rules that specify what it can and cannot do, is a participant in a system whose complexity vastly exceeds the sum of its components. This excess, the gap between the simplicity of the parts and the complexity of the behaviour they produce together, is what game designers and systems theorists alike call emergence, and it is one of the most important concepts in understanding both how games function and why they are educationally powerful.

2.2 Elements, Relationships, and the Logic of Interaction

To analyse a game as a system is to ask, first, what its elements are, and second, how those elements relate to one another. These are not the same question, and the second is more important than the first. A game's elements, the pieces, the cards, the spaces, the players, the resources, can be enumerated straightforwardly. But the relationships between those elements, the ways in which a change in one part of the system propagates through the others and produces consequences that were not specified in advance, are where

the game's actual behaviour lives. A change in the value of a single resource in a strategy game does not merely affect the decisions that involve that resource directly. It ripples through the entire system, altering the relative value of every other resource, shifting the balance of strategies available to each player, and changing the conditions under which every subsequent decision will be made. The system is not a collection of independent parts. It is a web of interdependencies, and its behaviour at any given moment is the product of all those interdependencies operating simultaneously.

This structural fact has a direct implication for learning. When a student interacts with a game, they are not interacting with a series of isolated problems, each presenting a question and waiting for an answer. They are interacting with a system, and the understanding they develop through that interaction is, at its best, systemic understanding: the capacity to see how parts relate to wholes, how local decisions produce global consequences, how changes in one element of a complex structure ripple through the others in ways that are not always predictable and not always intended. This kind of understanding is precisely what the most demanding educational objectives require and what formal instruction, with its tendency toward the sequential presentation of isolated concepts, finds most difficult to produce. The system does not teach its parts one at a time. It teaches their relationships, all at once, through the experience of navigating them.

Consider a game like *SimCity* or its educational variants, in which the player manages the development of an urban environment. The game presents decisions about zoning, infrastructure, taxation, and public services, and each of those decisions feeds back into every other. A decision to reduce taxation increases residential development but reduces public revenue, which degrades infrastructure, which reduces property values, which reduces taxation further, a feedback loop that, if not managed, produces a cascade of consequences that no single decision, considered in isolation, would have predicted. The student who plays this game long enough to recognise this loop has learned something that no amount of instruction about urban economics can teach as directly: the felt sense of how systemic interdependence works, the visceral understanding that local decisions have global consequences, and that consequences loop back to alter the conditions under which future decisions will be made. This is not a metaphor for systems thinking. It is systems thinking, experienced from the inside.

2.3 Feedback Loops and the Mechanism of Learning

The concept of the feedback loop is central to both systems theory and learning theory, and the fact that games are structured around feedback loops is one of the primary reasons they are effective as learning environments. A feedback loop exists whenever the output of a system influences its subsequent input, whenever consequences circle back to alter the conditions that produced them. Games are built from feedback loops at every level of their design, from the immediate tactical feedback of a single decision to the long strategic arcs that shape the entire course of play.

In a zero-entry game, feedback loops are the primary mechanism by which knowledge is constructed. The player acts, receives feedback, adjusts their mental model of the game's logic, acts differently, receives different feedback, and gradually refines their understanding of the system's behaviour. This is the inductive learning process described in the preceding section, but it is worth examining its systemic dimension more carefully. The feedback loop in a well-designed game is not merely informative; it is also motivating. It tells the player not only what happened but, implicitly, that what happened was a consequence of what they did. This implicit attribution of causality, the sense that outcomes are connected to decisions, and that better decisions will produce better outcomes, is what sustains engagement through the difficulty of early play, when the player is still constructing the mental model that will eventually allow them to perform well.

The distinction between reinforcing and balancing feedback loops, familiar from systems theory, maps onto the learning process with some precision. A reinforcing feedback loop is one in which a change in one direction produces further change in the same direction: early success leads to resources that enable further success, or early failure leads to conditions that make further failure more likely. A balancing feedback loop is one in which a change in one direction produces pressure toward change in the opposite direction: a player who accumulates too many resources triggers responses from other players or the system that constrain further accumulation. Both kinds of loop are present in well-designed games, and both produce specific learning effects. Reinforcing loops teach the logic of momentum and compounding advantage, the understanding that early decisions shape the conditions of all subsequent decisions in ways that are not linear. Balancing loops teach the logic of equilibrium and constraint, the understanding that systems resist extreme states and that sustainable strategies are frequently those that work with the system's tendency toward balance rather than against it.

These are not trivial lessons. They are among the most important structural insights that any learner in any complex domain,

economics, ecology, political science, medicine, engineering, needs to develop. And they are lessons that games teach not through explanation but through the repeated experience of navigating systems that are governed by precisely these dynamics. Empirical research supports this point: Reese, Tabachnick, and Kosko (2015) have shown that video game learning dynamics can be measured as multidimensional trajectories, capturing precisely the kind of iterative, feedback-governed development that static assessments cannot detect.

Perhaps the most intellectually striking feature of games as systems is emergence: the production, by the interaction of simple rules, of complex and often unpredictable behaviour. Emergence is the reason that chess, governed by a small number of rules that can be learned in an afternoon, has sustained centuries of strategic analysis without exhausting its possibilities. It is the reason that the simple rules of *Conway's Game of Life*, a cellular automaton with four rules governing the birth and death of cells, produce patterns of extraordinary complexity and variety. And it is the reason that a well-designed game can, through the interaction of its elements, generate situations that the designer did not specifically anticipate and that the player has never encountered before, but that are nonetheless entirely governed by the game's rules.

For learning, emergence has a specific significance. A game that produces emergent complexity gives the learner something that a static problem set cannot give: the experience of navigating real novelty. The problems the learner encounters in an emergent game are not pre-specified; they arise from the interaction of the game's elements and the choices of its players, and they are, in that sense, new each time. The learner who develops the capacity to handle emergent complexity in a game is developing a capacity that transfers to the handling of emergent complexity in the real domains the game simulates, because the cognitive demand is the same: the ability to reason about a situation that has not been seen before, using principles derived from situations that have. Empirical support for this claim comes from a striking recent study: Van Opheusden et al. (2023) demonstrated, using large-scale behavioural data from online chess, that expertise is associated with increased planning depth, the ability to simulate more moves ahead, a finding that directly links game-based practice to the development of forward-reasoning capacities that are domain-general.

This is a point of considerable educational importance, because much of what passes for knowledge in formal education is knowledge of anticipated problems: the capacity to recognise a problem type and apply the appropriate procedure. The broader scientific community has begun to recognise the generative potential of games: Long et al. (2023) argue in Nature that games can serve as methodological

platforms for behavioural science, enabling researchers to collect ecologically valid data on decision-making, cooperation, and learning at a scale and with a realism that laboratory paradigms cannot match. This capacity is necessary but not sufficient for competence in complex real-world domains, where problems do not arrive pre-classified and solutions are rarely the straightforward application of a memorised procedure. The emergent game trains a different and, in some respects, more demanding cognitive skill: the ability to construct a response to a situation whose type is not immediately clear, using principles and strategies that must be assembled in real time under conditions of uncertainty and constraint.

2.4 Rules and the Architecture of Play

Rules are the foundation of any game. Without them, there is no game, only a collection of objects and an unstructured situation. But rules are not a single, homogeneous category, and the educational implications of game-based learning cannot be fully understood without a clear account of the different kinds of rules that structure play and the different relationships those kinds of rules bear to the learning process.

The most visible kind of rule is what game design theory calls the operational rule: the explicit instruction that governs play, the statement of what a player can and cannot do, when and under what conditions. Operational rules are what a player learns first, through the rulebook or the tutorial or the instructions of a more experienced player. They are the surface of the game's formal structure, and they are what most people mean when they say they are learning the rules of a game. In educational terms, operational rules function as the procedural knowledge the game requires: the know-how that enables action within the game's world.

But beneath operational rules lie a different and more fundamental kind of structure: what game design theory, drawing on the work of Salen and Zimmerman (2004), calls the constitutive rules. These are not the explicit instructions for play but the underlying formal or mathematical logic that those instructions express. The operational rule that a bishop in chess moves diagonally is an instruction. The constitutive logic beneath it is a set of mathematical relationships between positions on the board that determine, precisely and completely, what the bishop's presence on any given square implies for every other square in its range. Constitutive rules do not appear in rulebooks. They are the formal structure that the operational rules instantiate, and they are typically invisible to the casual player, present in the game's behaviour without being stated in its instructions.

The educational significance of this distinction is substantial. A student who has learned a game's operational rules knows how to play. A student who has grasped, through repeated play and reflection, something of the game's constitutive logic knows something about the formal structure of the domain the game represents. The student who plays a market simulation and learns, through the operational rules, how to buy and sell resources is acquiring procedural knowledge of the game's mechanics. The student who begins to understand, through the experience of play, why certain equilibria emerge, why certain strategies dominate others, and why the system behaves differently under different conditions of supply and demand is approaching the constitutive logic of the game, the formal relationships that the operational rules express. This deeper understanding is closer to disciplinary knowledge than to game knowledge, and its development through play is one of the primary mechanisms by which well-designed games produce real learning rather than merely the illusion of it.

There is a third kind of rule that the game design literature identifies, and it is perhaps the most neglected in educational accounts of game-based learning: the implicit rule. For a comprehensive treatment of how these layers of rule structure interact in game design, see Adams and Dormans (2012) and Fullerton (2024), both of whom offer detailed taxonomies of mechanical and formal game structures from a practitioner's perspective. Implicit rules are not written anywhere. They are the social norms and expectations that govern how a game is actually played in practice, the understandings about what constitutes acceptable behaviour, fair play, appropriate strategy, and the spirit of the game that players bring to any game situation and that shape the experience of play as powerfully as any written instruction. In a classroom game, implicit rules include expectations about how students should treat one another, how competitive behaviour should be modulated, and what kinds of strategic moves are considered legitimate within the social context of the educational setting. These rules are real, and they matter. A student who exploits a loophole in the operational rules to win a classroom game by means that other players experience as unsportsmanlike has technically followed the rules but violated the implicit norms that make the game a productive social experience. The management of implicit rules, the explicit discussion of what kinds of behaviour the game is designed to encourage and what kinds it is not, is one of the teacher's most important responsibilities in a game-based learning environment, and it is one that purely mechanical accounts of game design consistently underestimate.

2.5 Uncertainty, Conflict, and the Conditions of Real Decision

A game without uncertainty is not a game. It is a procedure. If every outcome is known in advance, there is nothing to decide and therefore nothing to play. The tension of play, the engagement that games produce and that makes them effective as learning environments, depends entirely on the presence of real uncertainty: the condition in which the player does not know what will happen next and must act on the basis of incomplete information, probability estimates, and judgment rather than certainty.

Game designers produce uncertainty through several distinct mechanisms, each of which has a specific relationship to the learning process. The first is hidden information: the withholding from one or more players of information that is present in the game's world but not available to them. Card games are the canonical example, but the principle applies across a wide range of educational game designs, from intelligence simulations in which each player knows only their own organisation's information, to market games in which each firm knows only its own costs and must estimate those of its competitors. Hidden information teaches a specific cognitive skill: the ability to reason under incomplete information, to make probabilistic inferences from partial evidence, and to act decisively on the basis of estimates rather than certainties. This is precisely the cognitive demand that most real-world professional situations make, and it is one that formal instruction, which typically presents complete and accurate information, rarely develops.

The second mechanism is randomness: the introduction, through dice, cards, or algorithmic processes, of outcomes that are not determined by player decisions alone. Randomness is educationally significant not because it makes games unpredictable, although it does, but because it forces the player to think in terms of probability and expected value rather than in terms of certain outcomes. The student who learns, through repeated play in a game that incorporates randomness, to evaluate decisions not by their actual outcomes but by the quality of the reasoning that produced them, to distinguish between a good decision that produced a bad outcome and a bad decision that produced a good outcome, is developing a form of probabilistic thinking that is fundamental to competence in any domain characterised by uncertainty, from medicine to finance to public policy.

The third mechanism is opponent behaviour: the uncertainty produced by the presence of other players whose decisions are not known in advance and whose goals may conflict with one's own. This is the uncertainty that game theory, in its classical formulations, was designed to analyse. The student who plays against another person in a competitive game is not merely navigating a complex

system; they are navigating a system that is actively responding to their behaviour, adapting to their strategies, and attempting to defeat them. This adversarial dynamic produces a kind of learning that no single-player game or static problem set can replicate: the development of strategic thinking, the capacity to reason about what others will do, to anticipate responses to one's own actions, and to construct strategies that are robust to the counter-strategies an intelligent opponent is likely to deploy.

The fourth mechanism is the complex decision space: the creation, through the interaction of the game's elements, of situations in which many options are available, none of them obviously superior, and each of them carrying consequences that extend far beyond the immediate moment. Complex decision spaces teach not through the provision of correct answers but through the experience of real choice, the cognitive demand of evaluating multiple options under conditions of uncertainty, with incomplete information and real consequences within the game's world. This demand is, again, precisely the demand that complex real-world situations make, and it is what distinguishes the thinking required by a well-designed game from the thinking required by a well-designed examination. An examination typically asks the student to identify the correct answer to a pre-specified problem. A game asks the student to identify the best available option in a situation that was not pre-specified, under conditions that make certainty impossible. The difference between these two cognitive demands is not merely a matter of difficulty. It is a difference in kind, and it is a difference that matters deeply for the development of the judgment that competence in any serious domain requires.

Conflict, finally, is not a regrettable byproduct of competitive game design. It is a structural necessity. Without conflict, against another player, against the system, against the constraints of one's own limited resources and capabilities, there is no tension, and without tension there is no engagement, and without engagement there is no learning. The conflict built into a well-designed game is not the arbitrary conflict of a contrived obstacle but the structural conflict of a system whose elements are in real tension with one another. Managing that tension, finding ways through it, around it, or within it, is the cognitive work the game demands, and it is, at its best, the same cognitive work the domain the game represents demands of those who practice it in the real world. A game that produces this alignment between its internal demands and the demands of its target domain is not merely entertaining. It is, in the fullest sense of the term, educational.

2.6 How Games Work on the Mind: Play, Knowledge, and the Learning Conditions

A game begins before the first move. It begins when the player looks at the screen or the board or the scenario and decides, in the space of a few seconds, whether they can enter the world being offered to them. This decision is not conscious. It does not feel like a decision. But it determines everything that follows, because a player who cannot enter a game's world does not learn from it. They endure it. The difference between those two experiences is the difference between education and its absence, and it is produced, in large part, by what the player already knows before the game begins.

This is the first thing to understand about how games work on the mind: they do not work on empty minds. They work on minds that already contain something, knowledge, experience, partial understanding, misconception, and the nature of what the game produces depends directly on the nature of what was already there. A game that ignores this fact can still be entertaining. It cannot reliably educate.

In a game designed for players who know nothing of the subject, the opening minutes do a specific and demanding job. They must make the unfamiliar navigable. Not simple, navigable. The player does not need to understand everything immediately. They need to understand enough to act, and to receive from the consequences of their action enough information to act again, better. This is how learning begins in such games: not through explanation but through iteration. The player acts, observes, revises, acts again. The concept the game is designed to teach is not stated. It is demonstrated, repeatedly, through the logic of the game's own mechanics, until the player has constructed it from the inside out.

This process is reliable because it does not ask the player to bring anything to it except attention and a willingness to try. It works with what is universal rather than what is particular Every human mind capable of noticing that one action produces a better outcome than another is capable of learning from a well-designed zero-entry game. The learning is inductive: experiences accumulate until a general pattern becomes visible. The player who has watched a simulated population collapse after an environmental shift, and watched it recover after a trait mutation spreads through successive generations, has not been told about natural selection. They have encountered it. The difference between being told something and encountering it is, in terms of what the mind retains and can use, very large.

But this process has a ceiling. Inductive learning from game experience produces understanding that is concrete, reliable, and grounded in the specific mechanics of the game. It does not automatically produce understanding that can travel, that can be

detached from the game's particular scenario and applied to cases that look different on the surface but share the same underlying structure. A student who has learned about natural selection through a population simulation may still struggle to recognise the same logic at work in the spread of antibiotic resistance, or in the evolution of market competition, because the surface features are different even though the deep structure is identical. The game has built a foundation. But a foundation is not a house. Something more must be built on top of it, and that building requires language, abstraction, and the teacher's deliberate intervention to make the connection between the game's logic and the wider conceptual world it belongs to.

2.7 When the Game Requires Something Already Known

A different kind of game works differently from the start. It does not build knowledge from the ground up. It takes knowledge the player already has and puts it under pressure. The player arrives at the game not empty but loaded, carrying a body of prior learning that the game will test, complicate, extend, and sometimes overturn. The opening minutes of such a game do not feel navigable in the way that a zero-entry game feels navigable. They feel demanding. They present a situation whose logic is only partly visible, whose decisions carry consequences the player cannot fully anticipate, whose feedback speaks in a language that requires prior study to read. For the player who has done that study, this is not confusion. It is recognition. The game is speaking a language they know, deploying concepts they have encountered in another register, the register of lecture, or textbook, or seminar, and asking them to use those concepts in conditions where using them is hard.

This hardness is not incidental. It is the point. A medical student who has memorised the pharmacology of a drug class has acquired information. A medical student who must apply that knowledge to a deteriorating virtual patient, under time pressure, with incomplete information, and with the constant possibility of error, is doing something qualitatively different. They are learning to think with what they know rather than merely knowing it. The distinction sounds simple. In practice it is the difference between a student who can reproduce correct answers on an examination and a student who can function in a situation where the correct answer is not given in advance and must be constructed from what is known and what is observed.

The feedback such a game provides works differently from feedback in a zero-entry game. It does not construct understanding. It addresses understanding already present and shows it where it is wrong, incomplete, or insufficiently precise. When the virtual patient's condition worsens after a clinical decision, the prepared

student does not merely observe a bad outcome. They recognise the mechanism by which the outcome was produced. They connect the consequence back to the decision, and from the decision back to the knowledge that should have governed it and did not, or governed it incorrectly. This is a more demanding cognitive event than contingency learning. It requires the player to move in two directions simultaneously: forward from consequence to cause, and backward from cause to the knowledge structure that produced it. What the player learns from this movement is not new information but revised understanding, existing knowledge made more accurate, more nuanced, and more connected to adjacent knowledge than it was before the game began.

This kind of learning is what the educational literature means when it speaks of elaboration: the process by which knowledge already held is deepened, integrated, and made more resistant to the distortions that application always introduces. It is, by any reasonable measure, a higher cognitive achievement than the acquisition of new information. And it is only available to the player who arrives at the game with enough prior knowledge to make the movement between consequence and cause intelligible.

There is a clean way to state the difference between what zero-entry games require of the mind and what knowledge-dependent games require. Zero-entry games ask the mind to move from experience to principle. Knowledge-dependent games ask the mind to move from principle to experience, and then back to a revised principle. The first movement is inductive. The second is something more complex, a loop rather than a line, in which the player's existing understanding is tested against the game's reality and returned to them altered.

The loop matters because it is the mechanism by which real understanding develops, as distinct from the accumulation of information. A student can accumulate information without ever completing this loop. They can hold a large number of correct propositions in memory without those propositions ever having been tested against anything resistant enough to reveal their limits. The game, when it is well designed and when the player brings sufficient prior knowledge to it, provides precisely this resistance. It presents situations that cannot be handled by the mechanical application of a remembered rule. It requires judgment. And judgment, the capacity to apply general knowledge to particular cases in ways that account for the specific features of those cases, is not taught by instruction. It is developed by practice in conditions that make it necessary.

This is why the placement of a game in a learner's trajectory matters as much as the design of the game itself. Orvis, Horn, and Belanich (2008) provide empirical support from instructional videogames, showing that prior gaming experience interacts significantly with task difficulty in shaping both performance and motivation: novice players

benefit most from lower initial challenge levels before progressing to more demanding scenarios. The instructional design literature converges on a complementary principle. Weinstein, Sumeracki, and Caviglioli (2018) identify retrieval practice, elaborative interrogation, spaced practice, and interleaving as strategies that consistently produce durable learning, and argue that instructional design must be informed by evidence about how memory and understanding actually work. Dirksen (2012) similarly argues that effective learning design must begin from an analysis of what learners already know, what they need to do, and where the gap between the two lies, an approach that maps directly onto the distinction between zero-entry and knowledge-dependent games developed in this chapter. The implication is practical as well as conceptual: designing for how people actually learn, rather than for how we assume they should learn, is what distinguishes effective game-based learning from weaker counterparts. A complementary warning comes from Brusso (2013), who demonstrated that unrealistic initial goal-setting impedes performance in videogame-based training, identifying overconfidence in prior ability as a source of early failure. Sakkal and Martin (2019) replicate this concern in a music-learning context, showing that prior experience with a game moderates both skill transfer and the role of explicit instruction. A knowledge-dependent game placed too early produces not elaboration but confusion; it does not accelerate learning but short-circuits it. A zero-entry game placed too late produces not discovery but boredom, because it reconstructs a conceptual structure the student already possesses.

The right game at the right moment in the learner's development is not a luxury of good curriculum design. It is the condition under which game-based learning works at all. Meta-analytic evidence consistently supports this view: Vogel et al. (2006) found that interactive simulations and computer games produce better cognitive outcomes than traditional instructional methods, particularly when challenge is aligned with learner competence, while Hays (2005) notes that the effectiveness of instructional games depends heavily on their integration into a broader instructional context.

2.8 The Surface of the Game and What Lies Under It

Every game has a surface: the scenario, the characters, the visual environment, the immediate drama of decision and consequence. And every instructional game has something beneath that surface: the concept, the principle, the disciplinary logic that the game was built to teach. The relationship between surface and depth varies across the spectrum from zero-entry to knowledge-dependent design, and this variation matters for learning because the degree to which the

concept is visible at the surface of the game determines how much work the learner must do to connect the experience of play to the content of the subject.

In a zero-entry game, the surface and the depth are designed to be close together. The drama of organisms competing for limited resources is, already, a representation of natural selection close enough to the surface that a player with no prior knowledge can begin to grasp it through play. The narrative does not decorate the concept from outside; it enacts it. The player who inhabits the narrative is, in the act of inhabiting it, constructing the concept. This proximity of surface and depth is one of the central design achievements of a good zero-entry game, and it is harder to produce than it looks. It requires that the game's mechanics be not merely analogous to the concept but structurally identical to it, that the game's internal logic be the concept's logic, expressed in the language of play rather than the language of the discipline.

In a knowledge-dependent game, the relationship between surface and depth is more complicated and, in well-designed cases, more intellectually honest. A simulation of international treaty negotiation has, at its surface, a story of states, diplomats, and competing interests. Beneath that surface lies the formal logic of cooperation under conditions where no authority can enforce agreements, where each party calculates its own advantage, and where the history of past interaction shapes the credibility of present commitments. None of this deeper structure is directly visible in the drama of the negotiation. It must be brought to the surface by a player whose prior knowledge provides the tools to see it. The student who lacks those tools plays a shallower game, interesting, perhaps, but not instructive in the way it was designed to be. The student who possesses those tools plays a richer one, in which each decision is shadowed by the theoretical framework that makes its implications legible.

This is not a failure of the game's design. It is a feature of a game designed for players at a particular stage of development, with a particular body of knowledge already in place. Research by Hamdaoui, Khalidi Idrissi, and Bennani (2018) adds nuance to this picture: their modelling work on learner profiles in educational games reveals that the relationship between playing style and learning style is neither fixed nor straightforwardly predictive, suggesting that individual differences in how learners engage with game structures are themselves variables that adaptive design must account for. The game makes a bet on its players. It bets that they know enough to see what the game is really about. When the bet pays off, the learning it produces is of a kind that no other instructional method produces as efficiently. This distinction between games that teach new knowledge and games that mobilise existing knowledge maps directly onto Chee's (2016) theoretical contrast between games-to-teach, instrumental

environments designed to transmit predetermined content, and games-to-learn, performative environments that invite learners to enact disciplinary understanding in the context of meaningful, goal-directed activity: the experience of a theory under load, tested against the resistance of a simulated reality that does not arrange itself to confirm what the student already believes.

2.9 What Prior Knowledge Actually Does

It is worth being precise about what prior knowledge does in a knowledge-dependent game, because the common account of it that it makes the game easier, more accessible, more productive, is true but incomplete. Prior knowledge does make the game more accessible. But in the best cases it does something more significant than that. It makes the game generative: it makes the game capable of producing, in the player's mind, understanding that did not exist before and that the prior knowledge alone, without the game's intervention, could not have produced.

This is the cognitive event that justifies the investment of prior study. The student who has learned contract law from textbooks and lectures holds a body of doctrine in memory. That doctrine is, in isolation, inert: it describes the world but does not engage with it. The moot court simulation changes this. It places the doctrine under adversarial pressure, requiring the student to use it against another person who is using it differently, in a situation where the outcome is uncertain and the stakes, within the game's logic, are real. What the student discovers in this experience is not new doctrine. They discover the limits of the doctrine they already hold, the places where it underdetermines the outcome, where judgment must supplement rule, where the opponent's argument reveals a possibility in the law that the student had not considered. This discovery is, in the strictest sense, the production of new understanding from existing knowledge. It is not the acquisition of information. It is the transformation of information into understanding, the process by which what is known becomes, through the pressure of application, really understood.

Prior knowledge, in this account, is not the road the game runs on. It is the material the game works with. The game is the process; the prior knowledge is what gets processed. And what comes out of the process, when the game is well designed and the player is well prepared, is something neither the game nor the prior knowledge could have produced alone. It is the specific product of their encounter: understanding that has been earned through the difficulty of application, tested against the resistance of a world that does not simplify itself to accommodate what the learner already believes, and

refined by the experience of being wrong in conditions where being wrong teaches something that being right never could.