CASE STUDY

Game-Based Learning: A Design-Based Theory of Teaching-Learning-Assessment Systems

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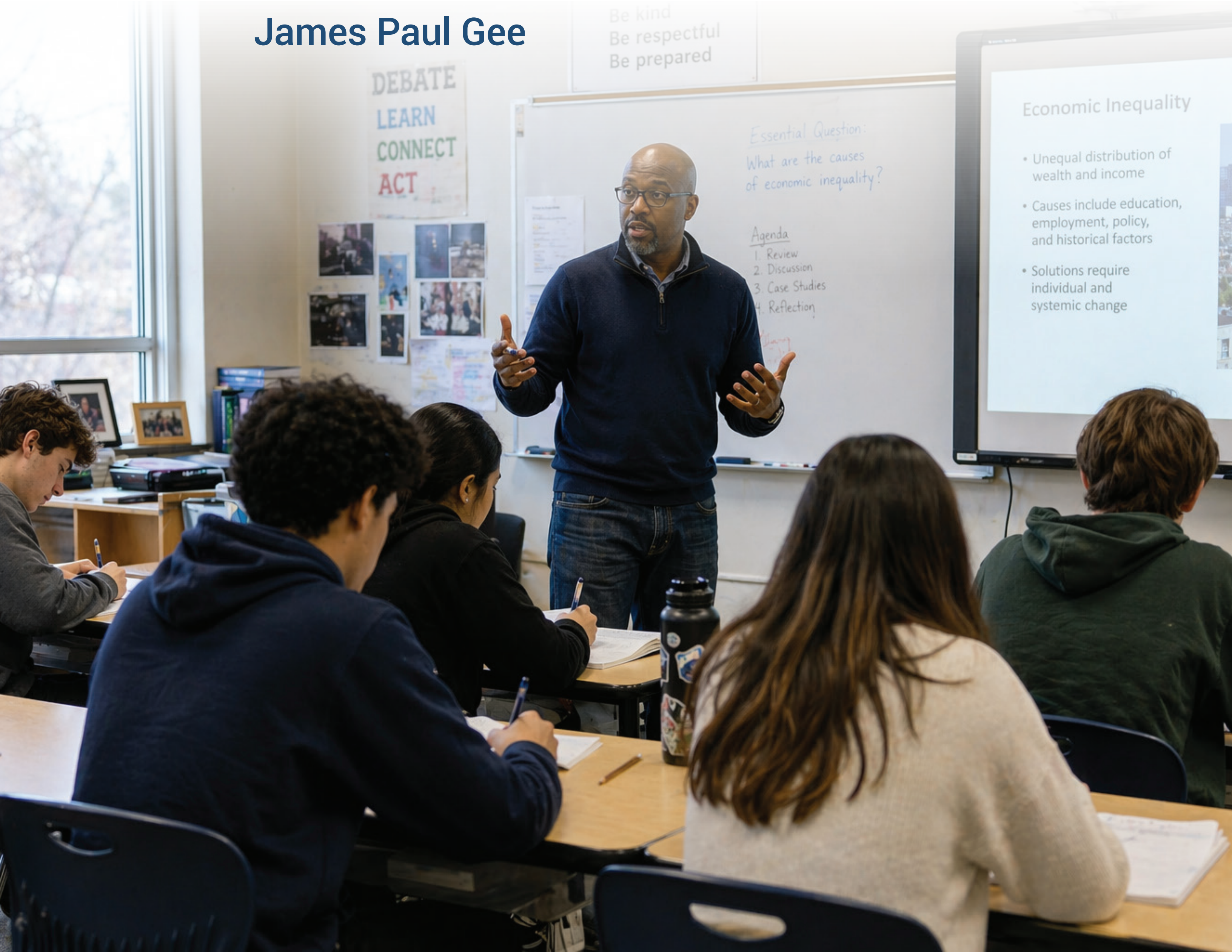

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Abstract

This chapter presents Game-Based Learning (GBL) as an integrated teaching-learning-assessment system rather than merely a tool for content delivery. It argues that good games inherently combine teaching, learning, and assessment through their design principles, which align with research in learning sciences. The paper outlines 20 principles that constitute effective GBL, including empowered learners through meaningful choices, problem-solving opportunities, contextual understanding, and embedded assessment. Rather than focusing on memorizing isolated facts, GBL prioritizes problem-solving skills within meaningful contexts. The chapter reconceptualizes teachers as designers who create or implement systems using these principles, whether through games or other learning activities. It further argues that classrooms represent complex systems with emergent properties that cannot be adequately studied through traditional randomized controlled trials. Instead, the paper suggests approaches from complexity science—such as agent-based modeling, network analysis, and systems thinking—can better capture classroom dynamics. While empirical research shows positive effects of GBL on learning outcomes, the author emphasizes that context remains paramount in determining effectiveness. The chapter concludes that an integrated approach to teaching, learning, and assessment is necessary to create learning experiences that engage students in the same way good games engage players.

Introduction

In this chapter, I develop an approach to Game-Based Learning (GBL) in which teaching, learning, and assessment are convergent, entangled, and inseparable. GBL on this view is a teaching-learning-assessment system that can be introduced into classrooms. In the end, I argue that classrooms are complex systems in the technical sense in which physicists use the term and, thus, not readily researched or assessed by controlled studies.

In earlier work (Gee, 2003), I claimed "Good video games are good for learning." What I should have said is, "Good games are good for teaching, learning, and assessment." This claim cannot be tested unless we know what "good" in "good games" and "good for teaching, learning, and assessment" means. Explicating the meaning of "good" here involved offering a theory about games and learning. And, then, when we are testing the claim, we are testing the theory, not some simple "fact."

Learning

Let's start with "learning." The theory of teaching, learning, and assessment in many schools today is based on what I have called the "content fetish" (Gee, 2004). The content fetish is the view that any academic area (whether physics, sociology, or history) is composed of a set of facts or a body of information and, thus, that the way learning should work is through teaching and testing such facts and information. Such learning can lead to students passing tests, but the information is poorly retained past the test and into life (Murre & Dros, 2015). Students can know lots of facts about physics, for example, but still be unable to solve problems in physics (Chi, Feltovich, & Glaser, 1981).

However, any actual domain of knowledge, academic or not, is first and foremost a set of activities (special ways of acting and interacting so as to produce and use knowledge) and experiences (special ways of seeing, valuing, and being in the world). Physicists *do* physics. They *talk* physics. And when they are being physicists, they *see* and *value* the world in a different way than do non-physicists (Glenberg & Gallese, 2012; Latour, 1999; Pickering, 1995). The same goes for gardeners, gamers, musicians, and mathematicians (Gee, 2011).

Problem solving is a much better goal for education than learning/memorizing facts. When people learn to solve problems, they use facts and information, along with other skills, to solve the problems. In the act, they both learn facts and can solve problems, and they retain the facts much longer (Shaffer, 2007). We live in a world replete with serious problems. Learning to solve problems—which involves learning to make good choices (Swartz & Arena, 2013)—is crucial for individuals and society. Good games—and I will move next to saying what that term means here—are based on problem solving, not facts and information, though you need to learn and use facts and information to solve the problems in the game.

Good Games

For my purposes (Gee, 2003, 2004, 2008, 2013; Gee & Hayes, 2011; Gee & Shaffer, 2010), "good games" are games which are focused on problem solving and which use a specific set of design principles to teach people how to solve problems. These design principles are supported by research in the learning sciences, but they have often also been discovered by game designers who will go broke if people cannot learn (and enjoy learning) to play their often long and complex games.

Good games, first and foremost, honor the principle that a game's "game mechanics" must be well married/matched to the sorts of problems the game involves solving. A game's game mechanics are the actions and tools gamers use to solve the game's problems. The game mechanics must work well and powerfully—and be motivating to use—to facilitate solving the problems the game is about. If the marriage of game mechanics and problem solving, in this sense, is not good, then all bets are off about the game being a "good game."

Following this principle, there are other design principles that constitute a form of "baked in" good teaching, learning, and assessment. These principles can be stated in various ways and others would modify them in various ways. This is not a definitive list, but an example of what a design system for teaching, learning, and assessment as convergent might look like. Below are some of these principles. There are 18 principles grouped by "empowered leaners," "problem solving," "understanding," and "assessment." There are others not discussed here.

I. Empowered Learners

1. Choices

Good games make players feel like producers and not just consumers. Players' choices and actions in the game make the game world unfold and change, thereby becoming an important part both of the story in the game and the player's own story of what it meant to play the game.

2. Different Ways to Solve a Problem

Players need to be able to try different ways to solve problems and to find new ways to solve them when their problem solving gets too routine. Good games allow players to solve problems in different ways and to try new approaches. This allows players to see problems as part of a larger problem space.

3. Identity

Deep learning requires an extended commitment and such a commitment is powerfully recruited when people take on a new identity they value and in which they become heavily invested—whether this be a child "being a scientist doing science" in a classroom or an adult taking on a new role at work. Good games often offer players avatars—and sometimes let players design their own avatars—that exemplify and reflect an identity (with concomitant values) that the player's choices will modify and concretize.

4. Action

Cognitive research (Barsalou 1991a, b; Glenberg 1997; Glenberg & Gallese 2012) has argued that humans think and learn best when they have an action to take whose consequences they care about and when they are helped to be able to assess the results of these actions and to use these results as feedback about how to proceed. Good games motivate such actions and give players feedback about results and consequences and about alternative ways to proceed toward their goal.

5. Affinity Spaces

Good games do not just recruit software to teach and create problem solving. They very often also incorporate what I have called "affinity spaces." These are internet sites or places in the real world where gamers engage in social learning around strategies and problem solving and sometimes "mod" (modify) the software of the games they play. And, of course, players often socialize within their games and engage in multi-player play where competition and collaboration intermingle. Thus, GBL often involves the combination of the game and affinity spaces, as well as socialization and collaboration within the game. This whole system is what I have called the "Big G Game," the Game as a teaching-learning-assessment system and not just the game as software. (https://home.edweb.net/big-g-game-based-learning/)

II. Problem Solving

6. Performance Before Competence

Good games use the principle of "performance before competence." They do not demand that players learn everything before engaging in action, since they want players to learn by doing and reflecting on what they are doing.

7. Time is Not the Measure of Learning

Unlike schools, "good games" do not usually use time as a measure of learning. It does not matter how long it takes a player to finish a level or a game or how many times they must play a level or the game to achieve mastery. Sometimes, those who take longer learn more. And mitigating the role of time means that the game does not discriminate against players who have come with less preparation than other players. In the real world, no one cares how long it took someone to learn physics when they win the Nobel Prize.

8. Information "On Demand" and "Just in Time"

Human beings are quite poor at using verbal information (i.e., words) when given lots of it out of context and before they can see how it applies in actual situations. They use verbal information best when a small amount is given "just in time" when they can soon put it to use and test their understanding of it. Larger blocks of information are given "on demand" when players feel they need it and are motivated to seek it out. This is how good games deal with information.

9. Well-Ordered Problems

Given human creativity, if learners face problems early on that are too free form or too complex, they often form creative hypotheses about how to solve these problems, but hypotheses that do not work well for later problems (even for simpler ones, let alone harder ones). They have been sent down a "garden path." The problems learners face early on are crucial and should be well-designed to lead them to hypotheses that work well, not just on these problems, but as aspects of the solutions of later, harder problems, as well. Problems in good games are well ordered. In particular, early problems are designed to lead players to form good guesses about how to proceed when they face harder problems later on in the game. In this sense, earlier parts of a good game are always looking forward to later parts.

10. Cycles of Expertise

Expertise is formed in any area by repeated cycles of learners practicing skills until they are automatic (no longer require conscious reflection), then having those skills fail in ways that cause learners to have to think again and learn anew (Bereiter & Scardamalia 1993). In many games, at each level of the game, players practice a new skill set until they have achieved an automatic level of mastery. Then, they are confronted with a "boss battle" that demands a display of this mastery, but in ways that require some innovation and renewed conscious reflection on what they have previously learned and automatized. This is why players do not expect to beat the boss on the first or even the first few tries. This process gets them ready ("preparation for future learning") to learn new skills or take old ones to new levels, which they will do on the next level of the game.

11. Regime of Competence

People learn best when they are given problems within their "regime of competence" (diSessa, 2000), but at its outer edge. This way the problems feel doable but challenging, a highly motivating state for humans (and often the source of the state of flow). This is why games are rarely easy. Players often enjoy hard games but they demand that they are "fair." "Fair" here means that players realize when they fail that it is their fault (and a source of learning) and the game is not rigged against them and that with more effort and reflection they can and will succeed.

12. Fish Tanks (Models)

In the real world, a fish tank can be a simplified eco-system that clearly displays some critical variables and their interactions that are otherwise obscured in the highly complex eco-system in the real world. Using the term metaphorically, fish tanks are good for learning: if we create simplified systems, stressing a few key variables and their interactions, learners who would otherwise be overwhelmed by a complex system get to see some basic relationships at work and take the first steps towards their eventual mastery of the real system (e.g., they begin to know what to pay attention to). Good games offer players fish tanks, either as tutorials or as early levels. Otherwise, it can be difficult for newcomers to understand the game as a whole system, since they often cannot see the forest because of the trees.

13. Lower the Consequences of Failure

Games often have levels or parts where the price of failure is lowered so that players are encouraged to take risks, try new things, and explore widely. Games alternate between spaces where players are encouraged to take their time to explore the lay of the land (the set of possibilities) and spaces where they are encouraged to use their growing knowledge of the system to make more rapid progress towards higher levels of skill. These two ways of learning have been called horizontal learning and vertical learning. Schools focus too much on vertical learning and too little on horizontal learning, yet it is horizontal learning that prepares learners to learn well in later vertical learning.

14. Skills as Strategies

There is a paradox involving skills: People do not like practicing skills out of context over and over again, since they find such skill practice meaningless, but, yet, without lots of skill practice they cannot really get any good at what they are trying to learn. People learn and practice skills best when they see a set of related skills as a strategy to accomplish goals they want to accomplish. In good games, players learn and practice (and, indeed, practice many times) skill packages as part and parcel of accomplishing things they need and want to accomplish. They see the skills first and foremost as a strategy for accomplishing a goal and only secondarily as a set of discrete skills.

III. Understanding

15. System Thinking

People learn skills, strategies, and ideas best when they see how they fit into an overall larger system to which they give meaning. In fact, any experience is enhanced when we understand how it fits into a larger meaningful whole. Players cannot just view games as “eye candy,” but must learn to see each game (actually each genre of game) as a distinctive semiotic system affording and discouraging certain sorts of actions, interactions, and values. Good games help players see and understand how each of the elements in the game fit into the overall system of the game and its genre (type). Players get a feel for the “rules of the game”—that is, what works and what does not work, how things go or do not go, in this type of world.

16. Meaning as Action Image (Situated Meanings)

Learners need to learn to use both abstract and contextual meanings to think, reason, interpret, and solve problems. A word or concept like “democracy” has an abstract, categorial, definitional meaning, but takes on different shades and vectors of meaning in different specific contexts. For humans, words and concepts are most useful when they are clearly tied to perception and action in the world. Knowing what “abrasion” means in geology only in a definitional way is not as useful of knowing how it actually applies when you are doing geology in specific contexts. This is, of course, the heart and soul of video games. Even barely adequate games make the meanings of words and concepts clear through experiences the player has and activities the player carries out, not through lectures, talking heads, or generalities. Good games can achieve marvelous effects here, making even philosophical points concretely realized in image and action.

IV. Assessment

17. Assessment and Learning are Not Separate

We can readily claim that games are nothing but assessment, that in games, assessment and learning are the same thing. In games, players constantly choose, act, and get actional feedback from the game world (an assessment). Furthermore, after each action and across the game they must assess their own performance in order to get better and be able to finish the game. Games often give players tools to help them with these self-assessments. Finally, gamers often receive feedback socially through multi-player play and in interactions on affinity spaces. In good games, learning and assessment converge.

18. Stealth Assessment

Games often engage in “stealth assessment.” The game collects (with players being aware of it) multifaceted information on the player's progress and can compare this progress both to the player's previous play and to a great number other players. This can allow the game to give players feedback about how they are progressing and how they compare to other players. The game can even adjust difficulty levels for different players or customize problems for them. The game can suggest what players should do next, given how they are progressing, and even encourage players to seek different or more innovative approaches to their problem solving.

19. Multifaceted Assessment

Good games do not just give players' grades—which offer little operational feedback—but multiple types of information, sometimes across time tracking progress, as well as sometimes comparison on each several different variables to how other types of players have progressed. This allows players to reflect on the data and form new strategies for getting better. And they can go to affinity spaces and learn about and share different strategies.

20. Assessment for Teachers/Designers

Much of the information about performance that game designers collect, in alpha and beta testing of their games and in collecting information about play styles over time, is used both to give feedback and encourage reflection on the part of players and of themselves as designers. Players also regularly give designers feedback via affinity spaces and other forums. Feedback is a two-way street. Designers use much of the information they collect on player performance—including the information players use to assess their own progress—to learn better how to do their job as designers (teachers, assessors).

Let me end this list by making it clear that the above principles are neither conservative or liberal, traditional or progressive. The progressives are right in that situated embodied experience is crucial. The traditionalists are right that learners cannot be left to their own devices, they need smart tools and, most importantly, they need good designers who guide and scaffold their learning (Kelly 2003). For games, these designers are good game designers. For schools, these designers are good teachers.

Game-Based Learning (GBL) as Design

For me, GBL does not mean using a game—though it can most certainly involve doing so—but using the design principles built into good games in or out of school. What we want to bring to in-school and out-of-school learning are teaching-learning-assessment systems that incorporate the sorts of design principles that good games use. These design principles can be used in many different activities and modes, not just games. This perspective casts teachers as designers.

Teachers in school should think and act like good game designers whether they are using games or other activities for learning. They should build good teaching, learning, and assessment principles into the games and other activities they use or ensure they have been already been built into the games and activities they use. They should create good social systems around the learning in their classrooms.

While using good games is something we should do, we should never use one tool (like a textbook) for everything and everyone. No one tool fits everyone. We want to network the best tools, activities, social systems, texts, technologies, and games together into a teaching-learning-assessment system. For example, here are just some of the tools ("game mechanics") students could use to learn about how pendulums work:

1. **Simulation Software** (Programs like PhET Interactive Simulations);
2. **Online Tutorials;**
3. **Lab Equipment** (Physical pendulums, stopwatches, protractors, and rulers for practical experiments to measure periods, lengths, and angles);
4. **Smartphone Apps** (There are apps that use the phone's sensors to measure periods and angles, turning the phone into a pendulum);
5. **Spreadsheet Software** (Tools like Microsoft Excel or Google Sheets to record data, create graphs, and analyze the relationship between variables like length, mass, and period);
6. **Data Logging Tools** (Devices that can record time intervals and angles with high precision for detailed analysis);
7. **Physics Forums and Online Communities; DIY Pendulum Kits: 3D Models and Animations** (Visual aids that help in understanding the motion of a pendulum in three dimensions);
8. **Augmented Reality** (AR) and Virtual Reality (VR): (Technologies that can simulate pendulum experiments in a virtual environment, providing an immersive learning experience);
9. **Mathematical Modeling Software** (Tools like MATLAB or Mathematica for more complex simulations and analyses of pendulum motion).
10. **Games** (Like Brain Pop's Pendulum Lab game).

These tools and others can constitute the "game mechanics" for different "levels" of understanding about pendulums. A system might well involve students choosing those tools which work best for them. Then our other design principles can be used to create a "teaching-learning-assessment system." The teacher is, then, designing in much the way good game designers do.

Empirical Research: Classrooms Are Complex Systems

There is a little commented on, but obvious, paradox in studying classrooms. Classrooms are complex systems in the sense in which physicists use the term. A complex system is a system composed of many components which may interact with each other. These systems are often characterized by the following features (Bar-Yam 2002; Ladyman & Wiesner 2020):

1. **Emergent behavior:** Complex systems exhibit properties that are not evident from the properties of the individual parts. The behavior of the system emerges from the interactions between its components and cannot be predicted by simply analyzing the components in isolation.
2. **Nonlinearity:** The interactions within a complex system are often nonlinear, meaning that small changes in input can lead to disproportionately large changes in output, and vice versa. This nonlinearity can lead to phenomena such as chaos and tipping points.
3. **Feedback loops:** Complex systems often have feedback mechanisms where the output of the system feeds back into the input, potentially amplifying or dampening effects within the system.
4. **Adaptation:** Many complex systems can adapt and evolve over time in response to changes in their environment. This is particularly true for biological and social systems.
5. **Self-organization:** Complex systems can exhibit self-organization, where order and structure arise from local interactions between parts of an initially disordered system, without external direction.
6. **Interconnectedness** and interdependence: The components of a complex system are interconnected and interdependent, meaning that the state or behavior of one component can significantly affect the state or behavior of others.

Examples of complex systems include ecosystems, the human brain, the climate system, social and economic systems, and many others. Classrooms, too, indeed, appear to fit these features well. A multitude of complex variables influence outcomes. These include student backgrounds, teacher practices, school culture, socio-economic factors, and many other variables. Since classrooms are composed of multiple people acting together—multiple physical and social brains using various tools and technologies all embedded within multiple complex institutions inside a highly diverse society—it is hard to see how they could fail to be a complex system.

Paradoxically, the gold standard of educational research—with government backing—has been randomized controlled trials (RCTs), where participants are randomly assigned to either a treatment or a control group (https://ies.ed.gov/ncee/pubs/evidence_based/randomized.asp). This is just the method that will not work for complex systems.

Physicists study complex systems using a variety of methods and approaches. Some of these methods are mathematical modeling, computer simulations, network theory; nonlinear dynamics and chaos theory, big data and AI, and others. Because complex systems often involve phenomena that span different scientific domains, physicists frequently collaborate with biologists, ecologists, social scientists, computer scientists, and others to study these systems.

The problem with the complexity of classrooms gets bigger when we realize that what we should be studying are teaching, learning, assessment, curricular, and social systems (all interacting), not isolated bits of them. Educators have sought alternative methods, such as mixed-methods research, quasi-experimental designs, implementation studies, design-based research, and even forms of A/B testing that engage in rapid cycles of testing and refining interventions in real-world settings, to learn what works and under what conditions. The problem is that in the mainstream of education and in the public view, controlled studies remain predominant despite large problems of ecological validity. Educators have not, for the most part, sought to study classrooms as outright complex systems in a truly interdisciplinary way.

There are, of course, educational researchers and cognitive scientists who have applied principles of complexity science to understand classroom dynamics (Gómez, Ruipérez-Valiente, & García Clemente 2022; Jacobson, Levin, & Kapur 2019; Keshavarz, Nutbeam, Rowling, & Khavarpour 2010; Knight 2022; Larson-Freeman 2016; Osberg & Biesta 2010). Agent-based modeling, network analysis, and systems thinking have been utilized to understand and explore classroom dynamics.

Agent-based modeling (ABM) is a powerful simulation tool that allows researchers to create computational models for studying complex systems. ABM is a computational approach used to simulate the actions and interactions of autonomous agents (individuals or collective entities such as organizations) with a view to assessing their effects on the system as a whole. It combines elements of game theory, complex systems, emergence, computational sociology, multi-agent systems, and evolutionary programming. In the context of classrooms, for example, ABM can be used to simulate the interactions between individual students (agents) and their environment, providing insights into how collective behaviors emerge from individual actions interactions (Jaiswal & Karabiyik 2022).

Network analysis examines the relationships and interactions among students and teachers to reveal patterns of communication, the flow of information, and the influence of social dynamics on learning outcomes. This approach aligns with the principles of "systems thinking," which emphasizes the importance of understanding complex dynamic systems, including educational settings, as networks of interdependent components (Penuel, Sussex, Korbak, & Hoadley, 2006).

Systems thinking itself is a holistic approach that focuses on how different parts of a system interrelate and how systems work over time within the context of larger systems. In the classroom, systems thinking can help educators and researchers understand the complexities of educational processes, including how various elements such as student behavior, instructional methods, and curricular design interact to produce the overall educational experience (Abbott & Hadzikadic, 2017).

The application of complex systems theory to education can help in understanding how individual actions can lead to collective behaviors, how patterns of interaction affect learning, and how to design educational interventions that are sensitive to the complexities of real-world classrooms. Nonetheless, the studies in this area—and there are not a great many—remain outside the mainstream of research and policy in education and in education.

Studies

Since classrooms are complex systems, it is not surprising that controlled studies in education often reach rather mixed results. These studies rarely assess classrooms in terms of learning systems, but as discrete variables that can be controlled and isolated in the absence of any emergent properties. When we take them as a whole, we find out what every linguist already knows: Context is king. And context in the case of humans is itself a complex system.

There are, of course, important studies and meta-analyses that have contributed to our understanding of how games can be used for learning. For example, Clark, Tanner-Smith, and Killingsworth (2016) systematically reviewed research on digital games and learning for K–16 students and synthesized comparisons of game versus nongame conditions and comparisons of augmented games versus standard game designs. Arztmann, Hornstra, Jeuring and Kester (2023) examined the effects of games in STEM education. They found that game-based learning has positive effects on students' cognition, motivation, and behavior. This study also highlighted differences based on certain students' background characteristics. Wang, Chen, Hwang, Guan, & Wang (2022) focused on the impact of digital game-based STEM education on students' learning outcomes across different STEM subjects. Their findings suggest that digital games are a promising pedagogical method in STEM education that effectively improves learning gains. Sitzmann's (2011) meta-analysis found that trainees using simulation games had higher self-efficacy, declarative knowledge, procedural knowledge, and retention of the material than trainees in more traditional learning methods.

Valerie Shute and her colleagues' seminal work on "stealth assessment" within games (Rahimi & Shute 2023; Shute & Becker 2010; Shute & Rahimi 2021; Shute, Wang, Greiff, Zhao, & Moore 2016) has explored how games can be used to assess learners' skills and knowledge in a way that is integrated with the gameplay, making the assessment process less intrusive and more engaging.

Farber (2018); Klopfer, Hass, Osterweil, and Rosenheck (2018); Isbister (2017); Plass, Mayer, and Homer (2020); Shaffer (2007); Squire (2011, 2021); and Toppo (2015) are among the best books on games for learning and cover among them a wide range of topics and approaches. These books all mix teaching, learning, and assessment with design principles. Each sees game design and curriculum design as similar activities when done right.

Conclusion

In this chapter I argued that teaching, learning, and assessment are co-dependent, interacting, convergent, and reciprocal aspects of a system that must be dealt with as a whole. GBL as a design theory offers one systematic theory of teaching-learning-assessment. Embedded in classrooms this system interacts with the classroom as a true complex system which has different emergent properties in different contexts.

In a good game players are always learning from teaching-learning-assessment principles "baked into" the design of the game by good game designers. That learning is based on choice, action, and problem solving and inherently involves assessment in several ways (e.g., feedback on performance, self-assessment, using evaluative information for reflection in and on action, assessment of a trajectory of progress, and comparison to other players and other strategies).

If a player plays a game like *Halo* on the hard difficulty level and completes the game, would you be tempted to give him or her a *Halo* test to assess their mastery? Surely not. The game is its own assessment. Why, then, don't our teaching-learning-assessment systems for algebra in school work the same way? Why do gamers like hard games and students don't like hard subjects in schools?

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James Paul Gee is a Regents Professor Emeritus at Arizona State University. He was, in his career, a professor at six universities. He is an elected member of the National Academy of Education. He received his Ph.D. in linguistics in 1975 from Stanford University and initially worked on syntactic theory and the philosophy of language, later becoming interested in a variety of other areas, including psycholinguistics, discourse analysis, sociolinguistics, literacy studies, learning theory, and video games. His books include Sociolinguistics and Literacies; The Social Mind; An Introduction to Discourse Analysis; Situated Language and Literacies; What Video Games Have to Teach Us About Literacy and Learning; The Anti-Education Era; and What is a Human? His current work is about the paradox that while we say "humans learn from experience" and experience is composed of sensory interactions with the world, we hear precious little about sensation in educational research.

About the Study Group

The Study Group exists to advance the best of artificial intelligence, assessment, and data practice, technology, and policy; uncover future design needs and opportunities for educational systems; and generate recommendations to better meet the needs of students, families, and educators.

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