We shall be Hobbits: Learning to Succeed through Collaboration in a Game Context

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Abstract

In this article, we concern ourselves with the learning potential of collaborative games. First, we introduce the problem of the competitive mindset and examine its origins. Next, we use game theory to create a framework for modeling interaction, from competition to cooperation and collaboration. Then, we use that framework to analyze a collaborative game in detail and show how some key design features lead to participants being able to overcome the competitive mindset in the context of a collaborative game. We support our analysis through close observation of two groups playing the game. Finally, we reflect on the potentials that games can have for learning. Specifically, we are interested in what educational technology designers can learn from these microworlds from both a learning and enjoyment perspective.

Introduction: Concerning Hobbits

In J.R.R. Tolkien's epic series of books, *The Lord of the Rings*, a magic ring of tremendous power and contagious evil is found in the possession of the unlikeliest of persons—a hobbit. The ring belongs to the dark lord Sauron who only needs to regain it to once more throw Middle Earth into darkness. Along with several companions, four hobbits set out on a journey to carry the One Ring to fiery Mount Doom, in the land of Mordor, the only place where the ring can be unmade. Though hobbits are the main heroes of Tolkien's adventure, they are unlike classic heroes. They are not naturally courageous. They are not great fighters. They are not fast runners. They are not even particularly intelligent. However, from the viewpoint of collaboration, it is only natural that the hobbits are the heroes, as they are the quintessential collaborators. They are unselfish; they put others before themselves. On his birthday, a hobbit gives presents to his friends as that brings him the most joy. They deeply value friendship and comradeship. They enjoy stories and talking over a good meal. They stick together. Because of these qualities, they have a natural resistance to the One Ring's temptation of great payoff / power to the individual who uses it.

In the field of education, we realize that collaboration can be useful for learning

(Cohen, 1994; Webb and Palincsar, 1996). For collaborative learning to be effective, learners need to be willing to collaborate and do so effectively. At times, they need to place the payoff to others above their own payoff. At times, they need to do for others even if the others can't do for them. In other words, they need to be hobbits. Even a small proportion of participants behaving altruistically can increase cooperation substantially (Cooper et al., 1996). Unfortunately, humans are not as naturally collaborative as hobbits. Instead, humans tend to get stuck in a competitive mindset, mistaking collaborative and cooperative situations for competitive ones (Barron, 2003). As such, a pressing concern for learning research needs to be creating learning environments that enable learners to get beyond the competitive mindset—to become hobbits.

In this article, we begin by detailing a problem with making collaboration work—the competitive mindset. We show how some of our best social institutions contribute to the problem. Unlike Barron (2003), we do not describe the problem space—why and how learners fail to collaborate. Instead, we explore the solution space—why and how do some environments encourage collaboration. As such, our research methods are quite different than observational studies. We hope that these two different perspectives and different methods can be mutually beneficial. To investigate this area, we look at games as a potentially powerful context for exploring the solution space. We survey a variety of games, studying the interaction during the game and how design features affected that interaction. Both of us, the authors, regularly play board games and have a wide experience with current board game designs. We use game theory to analyze the design decisions and challenges for creating such a learning environment. We concentrate on the archetypal collaborative game, detailing how it allows the players to go beyond the competitive mindset. We complement this analysis with examples taken from a wide range of collaborative, cooperative, and team games. We speculate what designers of learning environments can learn from the design of such games. In particular, we extrapolate seven rules-of-thumb that designers of collaborative learning environments will be able to use. We study groups playing a collaborative game, detailing how the rules of thumb manifest themselves. Finally, we discuss learning in microworlds in the light of our findings.

Problem: The Competitive Mindset

In the field of collaborative learning, we try to realize the potential that successful collaboration has for learning. Yet, we often find that learners' models and skills for collaboration are insufficiently developed to permit successful collaboration (Barron, 2003). For instance, in a recent study at Georgia Tech, two classes (a freshman calculus class and a senior chemical engineering class) were asked to collaborate on an assignment (Guzdial et al., 2002). The engineering seniors would produce a data set that the math students would analyze and return. The intent was that the seniors, through this collaboration, would gain a natural context to recall the calculus they had taken (and often forgotten) a few years ago. On the other side, the math students were expected to develop an appreciation that the calculus they were learning will be useful to them later in their schooling. Unfortunately, the collaboration failed; 40 percent of the math

students accepted a zero on the assignment rather than collaborate with the engineers.

After seeing an abysmal lack of successful collaboration (both between students in different classes and students in the same class) in engineering, mathematics and some computer science classes, a follow-up study was conducted to learn why students chose not to collaborate (Guzdial et al., 2002). Three common reasons were found:

1. Students felt that the subject was competitive and the questions posed had single answers. Thus, collaboration would only give them a competitive disadvantage; in a class where grades are assigned on a normal curve, helping a fellow student improve their score would only make your score look worse in comparison. However, this rational justification for not collaborating did not match the reality of the situation. The faculty for these classes had emphasized that the class was not curved and that the problems had more than one solution. The misperceptions of the students turned a situation where collaboration would be useful into a competitive one which precludes collaboration.

2. Students exhibited a condition known as learned helplessness. Students felt that they did not understand the material and therefore chose not to post any information, as it would likely be wrong and they would suffer public ridicule. Instead of using the collaborative environment as a supportive place to get the help they (badly) needed, they chose to remain silent. Again, their model of how collaboration can work was inaccurate.

3. Students failed to realize how to collaborate because they lacked the models or previous experience for collaborating in these subjects.

These findings suggest that these students lack models of useful collaboration and mistake collaborative and cooperative situations for competitive situations. Why? And, how can we fix this problem?

Models of Collaboration

One answer is that students encounter very few models of useful collaboration during their education and extracurricular activities. In many important areas, the individual and competition is emphasized. In other words, they don't know how to collaborate because they have not seen or experienced enough useful collaboration.

One place where models of collaboration are noticeably missing is children's literature. Almost no popular children's fictional stories encourage thinking about solidarity, cooperation, group struggle, or belonging to a caring group (Kohl, 1995a). In addition, children's history books often reduce a story of group struggle and cooperation to the tale of a single heroic person, as is the case with the story of Rosa Parks and the Montgomery bus boycott (Kohl, 1995b). The story is a clear instance of a group of people (African Americans for the most part) collaborating to overcome a challenge (racist discrimination in the form of segregation). Yet, most narratives simplify the details to tell the story of one person whose brave actions almost single-handedly solved a problem. Rosa Parks did indeed serve as a symbolic leader for the social movement but she was not responsible for initiating the movement itself. Rather, plans to boycott the

segregated Montgomery bus system had been in the works long before Mrs. Parks was arrested for refusing to give up her seat to a European American. Parks was not even the first African American arrested for refusing to give up a seat; however, because of her respected position in the community and her willingness to fight the racist police force, she was asked (and she agreed) to be the figurehead of the movement. Soon after her arrest, the boycott began. For over one year, African Americans worked together to live without the use of the bus system. In the end, they succeeded and the buses became integrated—one large step in the civil rights movement. Unfortunately, when the story is recapped in children's history books, it is often reduced to the tale of a tired woman who would not give up her seat and a spontaneous movement that erupted because of this (Kohl, 1995b).

> Our national myths often exaggerate the role of the individual heroes and understate the importance of collective effort. Historian David Hackett Fisher's gripping account of opening night in the American Revolution, for example, reminds us that Paul Revere's alarum was successful only because of networks of civic engagement in the Middlesex villages. (Putnam, 2000, p. 24)

Not only do children reading history books on the Montgomery Bus Boycott or the American Revolution miss out on the essential truth of the stories, they also miss out on seeing important examples of people collaborating to solve a problem.

The neglect of collaborative (group) models in favor of competitive (individual) ones extends to our standard model of schooling. First, most schooling, influenced strongly by Thorndike's psychology, is based on individual assessment (Koschmann, 2000). Grades as the common metric of individual assessment fundamentally reinforce competition, because students are ultimately measured by how they *compare to* (rather than *work with*) their classmates. Second, most schooling is built on asymmetric models of interaction—the students are subordinate to the teacher and the institution. From these asymmetric relationships, children learn rules of constraint and obedience (Damon, 1997); in contrast, from peer relations, children learn rules of cooperation, based on mutual respect for one's equals (Piaget, 1997). Studies on collaborative learning show that teacher involvement can often impede group collaboration (Cohen, 1994). As such, standard schooling may be an unnatural setting to learn about collaboration and cooperation. So, let us look to more peer-oriented settings, such as after-school activities like games.

Unfortunately, the situation does not prove to be much better here. Children's board games have an overwhelming tendency to favor competition (where only one person can win) over collaboration (where everyone wins or loses) (Deacove, 2000). Some archetypal games that people name when thinking of board games are chess and *Monopoly*.[1] Chess is a strictly competitive game of two opponents strategically trying to capture the other's king; it models war—a clearly competitive situation. *Monopoly* is a multi-player game where each player aims to achieve a monopoly over the other players; it models competitive business—again, a clearly competitive situation. In both

[1] Darrow, C. (1936) *Monopoly*. Parker Brothers.

of these games, the goal is for players to compete with each other for the definitive winner position. In contrast, there are no definitive collaborative games in our culture. In an informal survey of a popular board-game website[2] selling such games, only one of the twenty all-time best selling games was collaborative.

Forming the Competitive Mindset

We have noted that children's literature, schooling, and games—some of our finest social institutions—are built on the premises of competition. It is not that these institutions are inherently competitive. There are books that model useful collaboration for children (Kohl, 1995a). There are models of schooling, such as Montessori's (Standing, 1957), that focus on peer models of learning. There are collaborative games available (Deacove, 2000). Even at Georgia Tech, where students were found to actively resist collaboration in some settings, collaboration proved useful and educationally effective in other learning settings (Craig et al., 2000; Rick et al., 2002). Our observations were not to suggest that these institutions are only competitive, but rather that they tend to neglect collaborative and cooperative models in favor of competitive models. As such, they encourage the competitive mindset.

Yet, these institutions may not be the causal factors in promoting the competitive mindset. It may be that people spend more of their time acting in a competitive (selfish) way. This *nature* argument says that we behave competitively because our basic instincts tell us to do so (Dawkins, 1989). Children are born selfish and outgrow it only through socialization (Erikson, 1963; Vygotsky, 1978). Conversely, one can argue that we fail to teach collaboration properly and compound this deficiency by frequently advocating competitive explanations over collaborative ones. This *nurture* argument says we behave competitively because we are overly exposed to competitive situations. So, it is our upbringing and the culture we live in that nurtures the competitive mindset. There is some evidence to support this argument. Kagan and Madsen (1971) found that both American and Mexican children became more competitive with increased age. If socialization encourage collaboration, one would expect the opposite. Additionally, American children were found to become more competitive (Kagan and Madsen, 1972a) and rivalrous (Kagan and Madsen, 1972b) than Mexican children over time. The culture we grow up in affects our mindset (Shore, 1996). In terms of individualism versus collectivism, there is good reason to believe that the American culture is particularly problematic. In a survey of 53 countries, the U.S.A. scored highest on an individualism index (Hofstede, 2001, p. 215).

Probably, both the nature and nurture factors combine into a system that builds up the competitive mindset (see Figure 1). Having a natural inclination towards competition over collaboration contributes to a competitive mindset. That competitive mindset then encourages us to teach competition over collaboration, reinforcing the competitive mindset. To break out of such a self-reinforced system, we have to interrupt the cycle (Senge, 1990). In other words, educational designers need to become aware of the problems with the competitive mindset and design learning environments that encouraging collaborative thinking. In this article, we hope to extract rules of thumb that

[2] *http://www.funagain.com*

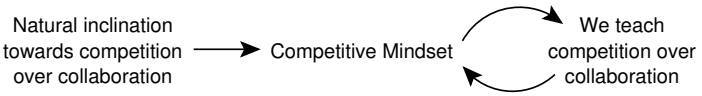

Figure 1: System Enforcing a Competitive Mindset

will help designers create these kind of environments.

Games and Learning

To do this, we have chosen to focus on games. There are several compelling reasons for this approach. First, there are many games to look at. Being able to compare across a variety of different environments allows us to more easily extract rules of thumb, which designers will be able to use for other environments. Second, games have an established framework that allows us to situate our analysis of collaboration. We can analyze games using game theory. Also, there is a sizable literature and history of using games for learning. Third, games seem to be a natural contexts for learning about collaboration because they ignore any existing structures of authority or hierarchy during play. All players have equal social importance in the context of a game; thus, collaboration is not automatically preempted by the intervention of an authority figure. Last, games operate in a setting removed from the real world, allowing the players to explore and implement different strategies and behaviors without fear of later repercussions—an ideal environment for learning to take place (Schank et al., 1994).

This section gives an introduction to games and using games for learning. First, we address how we define a game in our work. Next, we discuss why games are worth studying. Finally, we concentrate on why games may be particularly useful for learning. We will return to this subject in our discussion section, reflecting on our findings.

What is a game?

Games are a classically hard concept to define (Garris et al., 2002). Though most people can identify something as a game, it is hard to reduce it to a set of necessary and sufficient conditions. In general, games are *separate from the real world*, *uncertain*, *unproductive*, and *governed by rules* (Garris et al., 2002). But, not all games meet these conditions. Playing poker with actual money can affect the real world, yet most people would consider poker a game. Yet, we will try to stick to these essential characteristics, though we realize that at times they will need to be broken.

In addition, to separate them from toys, we define games to have a *clear goal*. Games are environments where "participants are actively involved in experiments" (Rosenørn and Kofoed, 1998). Their decisions affect the outcome of the game. Though, throwing a ball around can be separate from the real world, uncertain, unproductive, and governed by rules, it is not a game until a goal is added. The ball is a toy. Another famous example of something that is often mistaken to be a game is *SimCity*

(Costikyan, 1994). *SimCity* offers a simulation of a city that the player can affect in different ways; however, there is no goal in SimCity. Instead, the player can formulate their own goals. In that way, *SimCity* is similar to a ball. A ball can be used to create a game, like soccer, but the ball is not a game—it is a toy.

Why are games important?

> Games evoke a sense of personal control when users are allowed to select strategies, manage the direction of activity, and make decisions that directly affect outcomes, even if actions are not instructionally relevant. (Garris et al., 2002)

The nature of play and games has been important to the development of civilization. Games serve as a culture-creating force (Huizinga, 1955). Playing is a social activity, a way to relax, a way to compete in a friendly way, and a way to learn new things (Lundgren, 2002). In some countries, such as Germany, playing games with family is synonymous with "family values" (Glenn, 2002). Games are worth studying because people spend a significant amount of time playing them.

In addition, games have been important to several fields of science, from anthropology and philosophy to psychology and education. The philosopher George Herbert Mead believed the child learns through play how to relate to the outside world (Carlson, 1969). The psychologist Lev Vygotsky (1978) extends this further, regarding play as essential to learning as there are two steps in acquiring a new ability—first it emerges as distributed between people and, second, it is mastered by the individual. The psychologist Jean Piaget (1997) found that simple games appear to be crucial means for learning about and experimenting with life, in particular with the building of morality. Educators, like Jerome Bruner (1966), stress the importance of the open-ended "play element" that games encourage in child development. Because games are challenging and provide clear goals and feedback, they can lead to conditions of *flow*, a kind of optimal experiences that happen when a person is completely engaged in an activity (Garris et al., 2002). These experiences can be useful for both increasing the happiness of the individual and allowing the individual to learn (Csikszentmihalyi, 1990).

Why are games important to learning?

> Games provide a superb means of getting children to participate actively in the process of learning—as players rather than spectators. (Bruner, 1966, p. 95)

The game is like a mathematical model in that it is artificial, separate from the real world, but often a powerful representation of reality (Bruner, 1966). Because the consequences of actions in a game are largely separate from reality, "play serves the function of reducing the pressures of impulse and incentive and making it possible thereby for intrinsic learning to begin" (Bruner, 1966, p. 135). In other words, games provide a safe way to experiment with concepts.

In addition, games have advantages over traditional education methods, such as lecture. First, unlike most classroom-based learning, the factual knowledge necessary

for a game is needed immediately (Tansey and Unwin, 1969). Learners are able to use the information to accomplish a goal, rather than having to wait until a test (or a hypothetical later period in life) to use it. The knowledge is used in an authentic manner. Second, games have independence in rate of progress, variability in kind of sequences, and the capability to provide appropriate feedback (Carlson, 1969). As such, they are able to adapt to the needs of the learners. Games have shown their ability particularly in social sciences and mathematics (Tansey and Unwin, 1969). For example, in two sections of a social science class, the game / simulation-based class outperformed the lecture-based class (Petranek, 1994). Even if games cannot supplant lecture, they present an alternative way of presenting information (Tansey and Unwin, 1969). Providing learners an alternate way to approach a topic can reinforce and enhance what is learned originally.

Modeling Interaction with Game Theory

To better study the learning potential of games, we need a framework to understand it. The theoretical basis for understanding and analyzing games (and interaction) is known as *game theory*. In this section, we first give a brief overview of game theory and some basic definitions. Then, we use the classic game theory construct of the *Prisoner's Dilemma*[3] to demonstrate the differences between competitive, cooperative, and collaborative games.

Introducing Game Theory

Game theory's modern formulations were developed by John Von Neumann and Oskar Morgenstern at Princeton and published in a comprehensive book *Theory of Games and Economic Behavior* in 1944. It provided the basic mathematical ideas for understanding decision making and strategy in the context of games. Economists had developed fairly clear models for understanding individual consumers and how they determined preferences. What was not understood was how two competing entities arrived at a rational decision in an economic interaction like a negotiation or sale. Von Neumann and Morganstern called these interactions, or specifically the set of rules, *games*. Their work describes how two or more rational players make decisions in a game and formulate their long term strategies based on expected payoffs and knowledge of the competing strategies.

The other major foundation of game theory is the work of John Nash Jr. His major contribution to game theory was to show that for any n-person game there would be a point (an equilibrium) that represented the maximum amount of benefit that each person could receive independent of the strategies that each selected (Nash Jr., 2002a). Recently, his theories were used in developing the very successful multiple "closed auctions" used by the FCC in 1994 to sell off frequencies for wireless devices (Nasar, 1998). Over several iterations of closed auctions, companies eventually learned what their competitors were willing to pay for certain frequencies and adjusted accordingly.

[3]The Prisoner's Dilemma was invented at the RAND corporation by Merrill Flood and Melvin Dresher in 1950 (Poundstone, 1992).

When the auctions were completed, the equilibrium point had been reached and all the participants had purchased what they wanted at the price they were willing to pay.

Today, game theory is taught to economists, political scientists, and business majors and is applied to business negotiations, investment strategies, and forecasting. It has also been used in anthropology and evolutionary biology to understand how both social and biological systems with competing elements develop and evolve over time.

Some Definitions

In game theory, a *game* can be defined as any situation where there are at least two players, each player has a number of possible *strategies* (courses of action to choose from), the strategies chosen by each player determine the *outcome* of the game, and there are measurable payoffs to each player at the resolution of the game (Straffin, 1993). When these payoffs can be expressed numerically, they are referred to as *utility*. Utility is a term used in economic theory and applied by Von Neumann and Morgenstern (1953) to characterize the abstract notion of *preferences*. Players will prefer certain outcomes to others. For example, all things being equal, capturing a queen in chess is preferable to capturing a pawn.

During a game, players will attempt to implement a strategy that will maximize their utility such that each move contributes towards winning the game. Strategies are usually formulated and optimized based on *information*. Information consists of possible outcomes for particular strategies, knowledge of the other players' goals, and awareness of the available resources for implementing a particular strategy. With *complete information*, a player can determine the strategy that will produce the optimal outcome. In the absence of complete information, the player has to develop a *search space* of the information they possess. They map their strategies and their likely outcomes onto this space and make decisions based on that analysis. The depth of the search space and the completeness of information contribute to the difficulty of a particular game.

Games fall into two basic categories under game theory: *competitive* or *cooperative*. Competitive games require players to form strategies that directly oppose the other players in the game. The goals of the players are diametrically opposed. Cooperative games allow players to form coalitions at the appropriate moments to maximize their utilities. However, players may still have opposing goals. These concepts can be illustrated using the *Prisoner's Dilemma*.

Prisoner's Dilemma

The police have apprehended two men (A and B), suspected of committing a crime. Unfortunately, there's not enough evidence to convict them for a long sentence. Both suspects are placed into separate holding cells and are each given the same deal: confess to the crime and if your testimony can be used against your partner, you will be let go without jail time (for helping to convict your partner) and your partner will serve a 3-year sentence (for committing the crime and denying it). The prisoners also know that if they cooperate with one another by not confessing, they will each only get a 1-year sentence (due to the lack of evidence). Furthermore, if both confess to the crime,

	B refuses deal	B confesses
A refuses deal	A: 1 year B: 1 year	A: 3 years B: 0 years
A confesses	A: 0 years B: 3 years	A: 2 years B: 2 years

Table 1: *Prisoner's Dilemma* Payoffs for A, B

the police no longer need the testimony against the other and both men will get 2-year sentences (for committing the crime and confessing to it). See Table 1 for the various payoffs.

What should the prisoners do? The least total amount of time they will spend in jail is 2 years (A: 1 year, B: 1 year) but requires that both of them cooperate with each other independently of knowing what strategy the other has chosen. The most amount of time they will both spend in jail is 4 years (A: 2 years, B: 2 years) if they both choose a competitive strategy by confessing to give up the other to save themselves. If the prisoners are looking out for each other, the logical choice is to choose the cooperative strategy and refuse the deal. Unfortunately, neither wants to end up in jail. From A's perspective, if B confesses, A will spend 2 years in jail if he also confesses and 3 years if he does not. The logical choice is to also confess. If, on the other hand, B does not confess, A will spend 0 years in jail if he confesses and 1 year in jail if he does not confess. Again, the logical choice is to confess. So, no matter what B does, it is logical for A to confess. But, B is in the same position as A, so B will also logically confess. In the end, both A and B will confess and will each spend 2 years in jail (the maximum total amount). It is the policemen who win this game. It is the competitive nature of people (trying to achieve maximum payoff for themselves) that earns both A and B another year in jail. In contrast, the collaborative hobbits would be out in 1 year, as neither would give up the other.

Competitive and Cooperative Games

In its purest form, a *competitive game* is a zero-sum game—the competing utilities of the players will sum to zero. If A's utility for adopting a particular strategy is 1, B's utility for A's strategy will be -1. An example of a zero-sum game is poker; for one player to win a sum of money, the other players have to lose the same amount of money across their respective pots of money. At the end of the poker game, the total amount of money across all the players will be the same.

In contrast, a *cooperative game* models a situation where two or more individuals have interests that are "neither completely opposed nor completely coincident" (Nash Jr., 2002b). Opportunities exist for players to be able to work together to increase their respective payoffs—in economic terms, to achieve a win-win condition. The classic example of a cooperative game is the iterated version of the *Prisoner's Dilemma*. In the iterative version of the game, A and B play a *Prisoner's Dilemma* style game several times with each other summing the total payoffs.

	B cooperates	B defects
A cooperates	A: 3 points B: 3 points	A: 0 points B: 5 points
A defects	A: 5 points B: 0 points	A: 1 point B: 1 point

Table 2: Payoffs for Iterated Version of *Prisoner's Dilemma*

Robert Axelrod set up a computer simulation for different programs, each designed to implement a different strategy, to play each other several iterations to try and maximize their overall payoffs (Dawkins, 1989). The maximum payoff a single program could achieve is $5N$ points, where N is the number of iterations (see Table 2 for the payoffs). This would only happen if A uses a completely collaborative strategy that always cooperates and B uses a completely competitive strategy that always defects. In this case, B will achieve maximum payoff ($5N$ points), while A achieves the lowest payoff (0 points). If A and B follow a purely collaborative strategy, both will achieve $3N$ points. In contrast, if A and B follow a purely competitive strategy, both will achieve N points.

Given that a competitive strategy (one that defects first) will always score at least as many points as its partner, it is surprising that the most successful strategy of Axelrod's competing strategies turned out to be the cooperative strategy Tit-for-Tat that simply mimics the opponent's last move and starts by cooperating. If the partner does not defect, both programs will earn $3N$ points by cooperating every time. If the opponent defects one round, then Tit-for-Tat will defect on the next round; because of this feature, Tit-for-Tat will not earn far fewer points when partnered up with a competitive strategy. Axelrod ran three different styles of simulations with groups of strategies, including one simulation where each point earned in a game spawns a copy of that strategy to simulate reproduction and population size as the measure of success. Tit-for-Tat was the highest scoring strategy across all the simulations. In a cooperative game, nice guys (collaborators) can finish first, as long as they make sure they are not being taken advantage of (Dawkins, 1989).

A cooperative game doesn't always guarantee that cooperating players will benefit equally. However, the underlying assumption in game theory is that all players wish to maximize their own utility by implementing the best strategy. Thus, cooperative games include enforceable rules for negotiating or bargaining that allow players to identify a desirable outcome for the parties involved.

Collaborative Games

Having defined competitive and cooperative games, we can now define *collaborative games*. In a collaborative game, all the participants work together as a team, sharing the payoffs and outcomes; if the team wins or loses, everyone wins or loses. A *team* is an organization in which the kind of information each person has can differ, but the interests and beliefs are the same (Marschak and Radner, 1972). *Collaboration* as a

team differs from *cooperation* among individuals in that cooperative players may have different goals and payoffs where collaborative players have only one goal and share the rewards or penalties of their decisions. "The team problem is to choose simultaneously the team information structure and the team decision rule that will yield the highest expected utility, taking account of information and decision costs" (Marschak and Radner, 1972, p. 124). In other words, the challenge for players in a collaborative game is working together to maximize the *team's utility*.

Because modeling the social processes of communication and team interaction mathematically proves difficult, collaborative games have been of little interest to game theorists.[4] The process of collaboration requires many interactions for the players—they must effectively communicate with each other and work with tools and inscriptions to achieve a result (Cobb, 2002). In addition, selecting a useful strategy in an interesting game is often quite difficult for humans. Luckily, collaborating with others (even fellow novices) to determine a good strategy to adopt can actually enhance the reasoning and inquiry process (Roschelle, 1996). As such, collaborative games can provide a natural environment for learners to solve problems with the support of others. So, though they are of little interest to game theorists, they are of interest to the collaborative learning community.

Collaborative games should not be mistaken for *team games*. A team game has two (or more) teams competing against each other (Solan, 2000). Thus the overall structure of a team game falls in the category of competitive games even though people may collaborate within the teams. Also, while they do promote collaborative activities within the team, team games reinforce the competitive mindset, especially when individual high performers within the teams are additionally rewarded for their contribution to a team victory. Bridge is an example of a team game (2 teams with 2 players each). The success of the bridge team depends on how well they are able to collaborate within the team while, at the same time, competing with the other team. Team games / activities do have the potential to be useful collaborative learning environments. However, in practice, they tend to have practical problems:

1. They require a minimum of 4 participants—2 teams with 2 players each. While this may not seem too problematic, it often proves challenging to find this many players at any particular time. So, team games are less likely to get played.

2. It is often difficult for teams to collaborate within the team while the other team is also present without giving away a competitive advantage. *Axis & Allies*[5] is an example of a team game with this problem. In that game, two teams play major players in World War II; one team plays the Axis powers (Germany and Japan), while the other team plays the Allied powers (Russia, Great Britain, and U.S.A.). Like real military combat, surprise moves and coordinated strategies are important. Unfortunately, both teams sit at the same table and can easily overhear the other team's plans. The element of surprise is lost. The game tries to compensate for this by regularly having team meetings, where one team

[4] There has been some game theory research on team games, such as modeling information distribution among the team members (Marschak and Radner, 1972), stochastic models, etc. (Solan, 2000).

[5] Harris, L. (1987) *Axis & Allies*. Milton Bradley / Hasbro.

leaves the room; this proves awkward as only one team has access to the board and only allows for a limited amount of time for open communication. Since communication is essential to collaboration, placing undue restrictions on the communication can easily stifle the effectiveness of the collaboration.

3. Collaboration in these games is often highly constrained. For example, in professional bridge tournaments, partners are not allowed to talk to each other during play. Furthermore, the partnership is separated by a curtain so that no forbidden communication takes place. In effect, one of the great challenges to bridge is communicating to your partner given extremely limited means (bidding, card play). Professional partnership have quite sophisticated systems, often exceeding 100 pages of print, to communicate effectively given these limited means. While this type of communication might be interesting in its difficulty, it is unlikely that people will be able to transfer this skill to other situations.

Purely collaborative games do not face these practical problems. As such, they provide several key advantages, mainly unhindered communication, that give them a potential to be better environments for practicing the skills of collaboration. Many of these limitations of team games can be overcome by using new technologies in board game design (Lundgren, 2002), though realistically these type of games are prohibitively expensive. Computer games, where players collaborate over the Internet, may be able to overcome some of these difficulties, yet they introduce new challenges of communicating outside of face-to-face interaction. We will further address these new technologies in a later section.

Cooperative vs. Collaborative Games

Competitive and collaborative games are at opposite ends of a spectrum. Competitive games preclude collaboration. Collaborative necessitate collaboration. What about cooperative games? They lie between competitive and collaborative games? Can collaboration be learned by playing cooperative games? At first glance, the answer would seem to be yes. Both styles possess game models that offer the participants a better payoff as a reward for working together than either would be able to achieve separately.

An interesting example of a cooperative game that encourages collaboration is *Seal Hunting*.[6] Players are Eskimo seal hunters who have to eat a certain amount of meat in order to stay alive. They can get that meat by hunting seals or from fellow hunters sharing their meat. Because the chance of capturing a seal on any particular day are small and the meat can spoil after a few days, it makes strategic sense to share meat with others (Carlson, 1969). Since individual survival is the goal of the game, *Seal Hunting* is not a purely collaborative game. Yet, players need to cooperate to survive. As such, it is an example of a cooperative game that encourages collaboration by demonstrating the value of collaboration.

However, because the underlying game model is still designed to identify a sole winner, cooperative games can encourage anti-collaborative practices in the partici-

[6] Abt Associates. *Seal Hunting.* Educational Development Center Inc.

pants such as *free riding*, *coordination loss*, and *backstabbing*. People often put personal security and their sense of fairness before group production (Bornstein et al., 2002; Cooper and Stockman, 2002). *Free riding* (e.g., when they are being evaluated and rewarded as a group, individual group members do not pull as hard as they can) and *coordination loss* (e.g., groups members do not pull on the rope at exactly the same time or in exactly the same direction) are problems that cause group performance to suffer (Bornstein et al., 2002). Cooperative games only exacerbate that problem as defectors are often rewarded for their free riding behavior. In particular, *backstabbing* is often unavoidable in cooperative games. Backstabbing is the act of defecting when your partner cooperates. If it is done at a particularly good moment, backstabbing can be an advantageous competitive maneuver in an otherwise collaborative game. For instance, in an iterated version of *Prisoner's Dilemma*, it makes sense to defect if this is the last iteration (Dawkins, 1989). The key to *Diplomacy*[7] is knowing when to backstab your allies (Costikyan, 1994). Another cooperative game that specifically emphasizes the backstabbing nature of cooperative games is *So Long Sucker*.[8] Shubik recalls playing the game with Nash and McCarthy,[9] who had formed a coalition (Shubik, 2002). Nash double-crossed McCarthy at a particularly vulnerable point. It was no longer possible for McCarthy to win the game. McCarthy was furious. Nash argued that McCarthy could have done the calculations and realized that it was in Nash's interest to double-cross him at that point. As such, logically, McCarthy had no right to be upset. This did not placate McCarthy, who spent the rest of the game making sure that Nash also did not win. McCarthy's actions have been classified as a rule of thumb known as McCarthy's revenge rule: "when fatally double-crossed, try to damage the double-crosser as much as possible before your demise" (Shubik, 2002). Free riding and backstabbing is not something we want to encourage if we want players to get beyond the competitive mindset.

The Learning Potential of Collaborative Games

As a society and as educators, we try to value collaboration. We hope to instill in our children the value of helping others, working together as a team, sharing, etc. Yet, when we play many popular games with children, the message is exactly the opposite. In chess, you aim to make the other side surrender; in *Monopoly*, you seek to bankrupt your competitors; in checkers, you try to annihilate your opponent (genocide). These common games emphasize a predatory nature that has us destroying our foes (Jones, 2000). Not infrequently, this leads to younger and less skilled players leaving the table crying because they constantly lose or resorting to cheating in order to compete (Deacove, 2000). In a competitive game of skill, it is often very easy for the more experienced player to win constantly; the less experienced player does not have a chance. An adult who occasionally plays chess will consistently crush most 10-year-olds if the adult is seeking to win. Many adults realize this and actually play the competitive game

[7] Calhamer, A. (1976) *Diplomacy*. Avalon Hill.

[8] Hausner, Nash, Shapley, and Shubik (1964) *So Long Sucker*.

[9] McCarthy here refers to John McCarthy, who, after his Princeton graduate work, became a leading researcher in the field of artificial intelligence. McCarthy originated the LISP programming language.

to make the child win sometimes, using the occasion to help the child learn the game. So, even in a competitive game, learning can happen as long as the culture of the play supports it (Nasir, 2005). Yet, older siblings or more skilled playmates are often less adept at transforming the competitive game into such a mutually interesting meta-game (Deacove, 2000). So, the competitive game ends with a real loser—someone discouraged in their abilities and less interested in playing that or other games.

In contrast, collaborative games offer the potential for each participant to be valued for their abilities and contributions, while at the same time allowing participants to engage in and practice the skills of collaboration, which are increasingly important to education and work environments. Unfortunately, this potential remains largely untapped as there are few collaborative games and even fewer widely-distributed collaborative games. In addition, collaborative games have a bad reputation for simply being unexciting variants of "let's throw the ball around" (Costikyan, 1994) or just "no fun" (Zagal et al., 2000). To investigate this problem further, we examined the design of collaborative games and their mechanisms.

We focused on collaborative board games, rather than computer games. Computer games offer interesting learning possibilities, though the learning in most commercial games is usually incidental or intentional only for the purpose of one becoming a better gamer (Dempsey et al., 2002). Problematically for our purposes, the vast majority of electronic games are individual in nature, whereas the non-electronic ones are collective by nature (Zagal et al., 2000). Sophisticated communications technologies, like the Internet, have enabled more multiplayer games, such as massively multiplayer online games like *Everquest*. While many of these games have cooperative elements, we found no strictly collaborative ones. This is not to say that there are no collaborative computer games. In fact, *Prime Climb*[10] is one example of such a game. In it, two players have to work together to scale a mountain of numbers. Since the characters they play are attached to each other by rope, their success depends on working together. As success is the team's success, it is a strictly collaborative game. Yet, we feel that the gaming mechanisms of these collaborative computer games are less sophisticated than their board game counterparts.

In the last 25 years, the field of board games has matured tremendously. The industry and market has matured to the point where many interesting and enjoyable games are being published every year. The designs have matured to the point where designers' names are now prominently featured on the game box, as authors are on books; many eagerly await the newest Wolfgang Kramer creation. Most of the greatest board game designers are still releasing new games every year. While designing board games remains more of an art than a science, this new generation of board games often use quite sophisticated gaming mechanisms and provide engaging contexts for interaction. As we can actually learn a great deal from playing games (Vygotsky, 1978), they are worth studying for their learning potential.

We focus on traditional board games, rather than paper and pencil role-playing games (RPGs). In RPGs, like *Dungeons & Dragons*,[11] a game master guides a group of players on an adventure. As the players have the same goals for completing the

[10] EGEMS Group (1995) *Prime Climb*. University of British Columbia.
[11] Gygax, G. and Arneson, D. (1974) *Dungeons & Dragons*. TSR, Inc.

adventure, most RPGs fall squarely within the category of collaborative games. Yet, RPGs differ from other games: There is added emphasis on playing a role. In a traditional game, a player might be represented by a piece. So, for example, a player might consider himself to be the king in chess. However, the commitment to that role is low. There is no need or impetus to behave like a king to play chess. In RPGs, the commitment to a role is much higher. Players in RPGs frequently seek to create a satisfying storyline for their character, rather than successfully complete the adventure (Fine, 1983). Success in the game is subordinate to the narrative. To allow for better stories, the rules are flexible. Cheating is often acceptable. All this makes it difficult to analyze RPGs using game-theory. Instead, RPGs are often understood in terms of narrative theory (Fine, 1983). As this is beyond the scope of our research, we exclude RPGs from our analysis.

To study the potential of collaborative games, we informally studied a number of collaborative games, team-based games, and competitive games with interesting cooperative game mechanisms.[12] A *game mechanism* is a physical artifact, rule, or type of interaction that implements an action in the game. Trading between players is an example of a cooperative game mechanism. Capturing territory with a token is an example of a competitive game mechanism. Many of the recent, popular game designs feature balanced combinations of cooperative and competitive game mechanisms. For example, *The Settlers of Catan,*[13] which has sold over five million copies, has the object of determining which player has built the best contributions to the Catan island but allows players to freely trade resources among each other to further their progress.

We investigated board games that encouraged collaboration and collaborative thinking and the design features of those games that allowed them to be both effective at encouraging collaboration and enjoyable to play. Along the way, we came across a wide variety of games. Some were interesting and enjoyable, but failed to encourage interesting collaborative practices because the game mechanisms were simplistic, as they had been designed for young children (*Der Tiger ist los...* [14], *Im Märchenwald*[15]). Others had interesting collaborative mechanisms, but failed to be enjoyable. A few proved to be successful on both fronts. In the next section, we detail one particularly interesting collaborative game and examine the design decisions that allow it to succeed.

Detailing a Collaborative Game

> People say, you can't play with each other—you have to play against each other, otherwise there's nothing to do. Of course, that's not true. I actually believe that playing with each other and really facing a common opponent in the game makes a much richer playing experience. My challenge was to create an atmosphere in the game that pushed people together and made

[12] For the most part, our informal studies involved playing the games, observing others play the games, and discussing the game with the participants. No laboratory experiments under controlled conditions were conducted.

[13] Teuber, K. (1997) *The Settlers of Catan*. Mayfair Games.

[14] Schlichting, E. (1998) *Der Tiger ist los...* Amigo.

[15] Nikisch, M. (2000) *Im Märchenwald*. Adlung Spiele

> them naturally want to stay together... The players realize after the first few turns that they get hit so quickly with so many bad things that if they want to just go off by themselves they have no hope. —Reiner Knizia (Glenn, 2002)

In Reiner Knizia's *Lord of the Rings*[16] board game, you are a hobbit. Together with your fellow hobbits (2-5 players total), you journey to carry the One Ring to fiery Mount Doom and destroy it. Your journey is not an easy one. Along the way, you will face many obstacles and get corrupted by Sauron and the power of the One Ring. Though you will get help from others along the way, it is your decisions that will shape the fortunes of all.

Regardless of whether you succeed, the entire fellowship receives a score determined by how much progress they make through the game; scores are recorded on a "Hall of Fame" sheet that comes with the game. Because all the players receive the same score, *Lord of the Rings* is a collaborative game; however, it incorporates cooperative game mechanisms into what could otherwise become a solitaire experience.[17]

The game has two basic components, a main board that keeps track of the story and displays the corruption track that marks the progress of the individual hobbits towards Sauron (represented as an ominous black tower with a single red lidless eye), and a scenario board that tells a part of Tolkien's *The Lord of the Rings* story. In this case (see Figure 2), the scenario is the journey through the mines of Moria. If Sauron reaches a hobbit on the corruption track, that hobbit (and the player) is removed from the game. If that hobbit is also carrying the One Ring, Sauron regains his ring and Middle Earth is plunged into a second darkness—the game is lost.

Each player has a hand of cards that either perform an action or have a symbol matching one along an activity line. Each turn, a player must first draw tile(s). These tiles have either good outcomes (advances a marker on an activity line earning the hobbits some progress or resources) or bad outcomes (requires the hobbits to sacrifice resources, move closer to Sauron, or triggers one of the scenario events connected to that particular board). Tiles and events can cause the hobbits to either advance towards Sauron or, worse, they cause Sauron to advance towards the hobbits. The player must continue drawing tiles until a good one is drawn. After drawing tiles, the current player can play up to two cards matching the symbols next to an activity line. Progressing on an activity line enables the hobbits to move closer to their final objective and / or gain resources that will help them later. Alternatively, they may draw cards to replenish resources or move themselves one space away from Sauron to avoid danger. When the hobbits reach the end of the main activity line (which also tells them their current score) or if the last event is triggered, they advance to the next scenario board.

Why Does *Lord of the Rings* Work?

In this section, we analyze why this one game works as an environment that encourages players to overcome their competitive mindset. We reduce these to four design

[16] Knizia, R. (2000) *Lord of the Rings*. Stuttgart: Kosmos Verlag.

[17] Most of the collaborative games studied suffered from a solitaire feel. One person could easily make all the decisions for the entire team. Often, the roles that players assumed were artificial and felt forced.

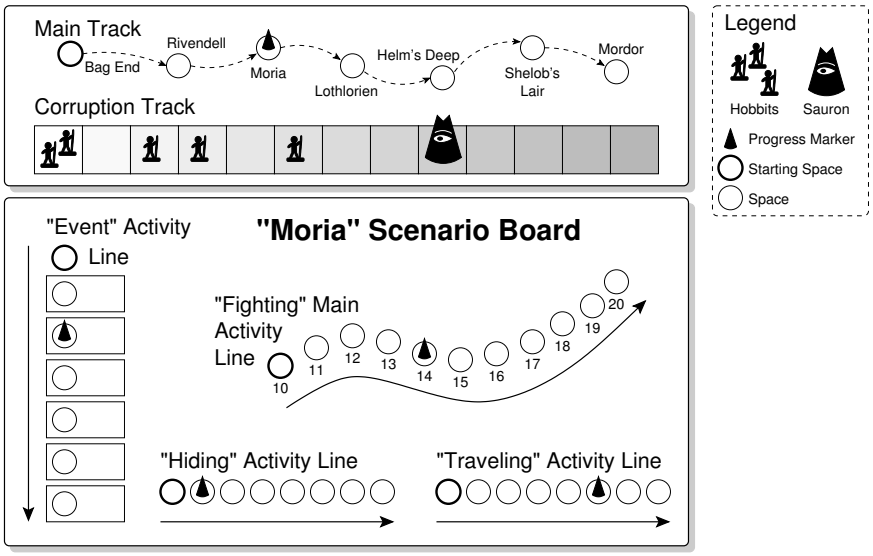

Figure 2: *Lord of the Rings* Game, Moria Scenario

principles: Rules of Thumb 1–4. First, we state the rule of thumb. Second, we describe how the game effectively puts this design principle to use. Third, we discuss the rule of thumb's general importance.

To simplify, *Lord of the Rings* is an effective environment for overcoming the competitive mindset as players are tempted to behave competitively, but winning the game requires them to behave collaboratively. Winning the game requires good resource management, some experience with upcoming events to know when resources should be expended, a willingness to sacrifice for the good of the team, and a little bit of luck. While the game is completely collaborative by definition, there are many opportunities for selfish behavior at the expense of the team. Usually, selfishness is expressed in a player making a decision that has high utility for their hobbit, but is not the best decision for the team. For example, a hobbit might choose to draw two cards to replenish resources or "heal" himself, moving further away from Sauron. A better decision might be to play the last card in the hand and take the consequences of an evil die roll. Competent play requires that players choose strategies that balance or forgo self-preservation to help the team.

Rule of Thumb 1: To highlight problems of the competitive mindset, a collaborative game should introduce a tension between perceived individual utility and team utility.

For example, Frodo draws an "active hobbit moves 2 or Sauron moves 1" tile that requires that either he is corrupted two steps or Sauron moves one step closer, corrupting all hobbits one step (see Table 3 for payoffs). Frodo gets to make the decision. If he chooses the former, he will achieve the least total corruption for the team (2 steps)

	Frodo moves 2	Sauron moves 1
Payoffs	Frodo: 2 steps Team: 2 steps	Frodo: 1 step Team: 5 steps

Table 3: Payoffs for "active hobbit moves 2 or Sauron moves 1" tile

but the most corruption for himself (2 steps). If he chooses the latter, he will achieve the most total corruption for the team (5 steps) but the least corruption for himself (1 step). A selfish hobbit will choose the latter, a collaborative hobbit the former. Notably, Sauron achieves his best result (5 steps) when a collaborative hobbit is corrupted to behave in a selfish, competitive manner.

The game is designed such that each decision a hobbit can make has many potential consequences and benefits. Because each hobbit is best able to judge his own utility and because the player may have a human tendency towards a competitive mindset, he will naturally favor a selfish choice that may or may not be optimal for the fellowship. Since the situation is purely collaborative, there is no real difference between individual and team utility. Yet, even a perceived difference can make people behave in ways that favor their own perspective over what is best for the team. To increase the impact of provoking an individual / competitive mindset, the individual makes the decision.

Rule of Thumb 2: To further highlight problems of the competitive mindset, individual players should be allowed to make decisions and take actions without the consent of the team.

In *Lord of the Rings*, a selfish hobbit has the ability to act selfishly without the consent of the fellowship. In the tile example above, Frodo makes the decision. As is shown in Table 3, there is a difference between Frodo's perceived utility and the team's utility. If the game were designed so that the team, not the individual, makes the decision, the other four hobbits would vote for the "Frodo moves 2" (collaborative) option. But, *Lord of the Rings* is not ruled by votes or consensus. If Frodo wants to chose the "Sauron moves 1" (competitive) option, he can. Since there are no ways for the team to stop or override an individual, competitive choices are more likely to be made.

Normally, designing a collaborative learning environment using Rules of Thumb 1 and 2 would be problematic, as the designers would want to avoid provoking competitive actions. However, in this case, the environment is designed to highlight the problem so that it can be addressed. The environment accentuates the problem that the participant mistakes a collaborative situation for a competitive one. Since success in a collaborative environment requires a concentration on team utility over perceived individual utility, the individualistic approach is problematic. In *Lord of the Rings*, players who behave individualistically are likely to run into difficulties, no matter how well they play according to their perceived individual utility. When a player discovers this, they discover that a collaborative situation requires a fundamentally different approach than a competitive one.

Rule of Thumb 3: For a game to be an effective learning environment, players must be able to trace payoffs back to their decisions.

This is true for just about any learning environment; learners need to be able to reflect on the consequences of their actions. In particular, they need to experience *expectation failure*—they expect their decision to be a good one, but later discover it to be problematic.

In *Lord of the Rings*, the action one player takes often directly affects the next player. For example, each hobbit needs to collect a certain amount of "life tokens" for every scenario board. Often, a hobbit will take an action, based on their individual perspective, that inadvertently makes it hard for the next hobbit to collect any life tokens. Without consulting with that next hobbit, that hobbit could not have realized this. However, their mistake quickly becomes obvious. The next hobbit does not have a good action to take. In the game, the next player is likely to complain that the last action has just put him into trouble. So, the first player discovers that his individual / competitive decision making is problematic.

Of course, discovering that a competitive approach is wrong in this collaborative situation is only the first step to overcoming the competitive mindset. The learning environment must allow learners to transition from a competitive to a collaborative mindset. For this, an important design feature is that the individual makes the decision but the team needs to work together for that decision to be properly informed. Because the other members of the fellowship can also evaluate the decision (from their perspectives), they have an incentive to persuade that hobbit to make the right decision for the entire fellowship. This encourages the kind of co-construction of meaning that Barron (2003) finds essential to good collaboration. That communication then turns into a way for the fellowship to convince the individual hobbits to behave in a collaborative manner. In this way, *Lord of the Rings* uses discussion as a learning mechanism to allow the player to move beyond a competitive mindset with the help of others. In addition, the game provides further incentives to encourage hobbits to make selfless decisions for the benefit of the team.

Rule of Thumb 4: To encourage team members to make selfless decisions, a collaborative game should bestow different abilities or responsibilities upon the players.

First, the hobbits have individual abilities. Frodo is particularly good at using his resources, Sam is less vulnerable to corruption, Merry does not require as many life tokens, and Pippin is particularly good at playing many cards. For good play, it is important to recognize these strengths and use them accordingly. For instance, a useful strategy is for Sam to take the move that requires the active hobbit to roll the evil dice, as it has less effect on him. Eventually, somebody would have to take the dice roll and it makes sense for Sam to be the one to sacrifice. Unless Sam is particularly stubborn or competitive, it is relatively easy to convince him to make the sacrifice. Though it is bad for his own utility, it is relatively easy to see that it is in his ultimate interest to sacrifice for the team.

Second, the ring of power can move from one hobbit to another hobbit after each scenario board. If the ring-bearing hobbit is captured by Sauron, the game is lost. As such, that hobbit is (often temporarily) more important than his comrades. So, occasionally (particularly late in the game), the correct decision regarding an "active hobbit moves 2 or Sauron moves 1" tile might be to have Sauron advance towards the

hobbits, instead of the ring-bearing hobbit moving two steps closer to Sauron. Rick played a game where in the second to last board, Shelob's Lair, it was certain that the ring would pass to Pippin for the last board, Mordor. Unfortunately, Pippin was only one step away from Sauron and would have a hard time staying uncorrupted in Mordor. The fellowship discussed various options of how to help Pippin survive Mordor. Could we afford to hang around in Shelob's Lair and allow Pippin to heal himself on his turn? Should we purchase the Gandalf card that allows one player to heal 2 steps, depleting our resources? After five minutes of intense discussion over various approaches, the solution was arrived at: Pippin made the ultimate sacrifice and voluntarily got corrupted by Sauron before Shelob's Lair concluded and, thus, the ring could not pass to him. Instead, it passed to Frodo, who was least corrupted. Frodo and Sam stormed through Mordor and plunked the ring into Mount Doom. The game was won; every player rejoiced. Pippin sacrificed his life to save Middle Earth. If such a moment of self sacrifice is interesting as a story, it is even more engaging when you are the one to make the decision (in the game).

To summarize, the entire game is about figuring out what the best choice for the team's utility is and taking that action. Because of the game's setup and, often, a competitive mindset, players will be tempted to choose by individual utility instead. To win the game, the players need to make choices that benefit the team's utility—effectively transitioning from a competitive to a collaborative mindset. This tension between individual and team utility makes this game well suited for encouraging players to overcome the competitive mindset.

Challenges in Designing Collaborative Games

In the previous section, we analyzed one collaborative game in detail. We extracted four design principles that are responsible for it being an environment where people can move from a competitive to a collaborative mindset. In this section, we shift our focus from *mechanisms that work* to *challenges that designers need to overcome*. We extract three pitfalls (Rules of Thumb 5, 6 and 7) that designers of such collaborative learning environments need to avoid. In the previous section, we exclusively focused on one game. In this section, we continue to draw on that game, but also complement that with analysis of other collaborative, cooperative, and team games. First, we state the rule-of-thumb / challenge. Then, we explain why it is important. Last, we show how some games, including *Lord of the Rings*, competently overcome these challenges; in some cases, we explain how other games fail to overcome these challenges.

Rule of Thumb 5: To avoid the game degenerating into one player making the decisions for the team, collaborative games have to provide a sufficient rationale for collaboration.

Without this rationale, the collaborative game can degenerate into a *solitaire game*. A solitaire game is one that can be abstracted to one player performing all the actions to achieve the win condition set out by the game. This was a major problem in many of the collaborative and team games surveyed. One person, the most competent player,

could direct the entire team. *Scotland Yard*[18] (a team game) can become boring as one person can tell everyone what to do (Aleknevicus, 2002). *Arkham Horror*[19] (an excellent collaborative game otherwise) can likewise be dominated by a single player. Avoiding this solitaire feel can be accomplished by several design techniques.

One technique is to give the players different roles and abilities so that optimal game-play depends on good coordination and decision-making on the part of the players. *Lord of the Rings* gives different abilities to each of the hobbits so that each hobbit has a useful role to play at various points in the game. Furthermore, resources are hidden so that each player only sees their own. From an optimal information awareness perspective, this design choice might be considered a problem. But, from a learning and game play perspective, it is a good choice as it forces communication. A better (or dominant) player is unable simply to command the other players, as it is difficult to make good informed decisions without the help of the others.

Another technique is to make the problem sufficiently difficult so the players need to work together to solve it. In collaborative games, players work together by sharing knowledge and resources, exploring the information space as completely as possible to identify the best strategy to use. If there are insufficient information or resource management requirements, the collaboration becomes forced and it usually falls on one player to make the majority of the decisions. In *Lord of the Rings*, there is enough variability of play and in the resources held by the players to require individual management. Communication among the players about the available resources for a particular task becomes more efficient than a single player trying to marshal all the resources at one time. Another collaborative game that manages this well is *Eagle Eye Agency*.[20] In that game, the players are detectives gathering clues to solve a caper. They have limited resources, so there are only so many places they can visit to pick up clues. The detectives have to work together to gather the right clues and then analyze them to solve the mystery. As there are many clues and several red herrings, it is useful to discuss theories with others. Passing theories by fellow players proves an excellent way to reflect on them. The collaboration feels natural and useful. In addition to mechanisms that require collaborative interaction, the design should incorporate good tension and rationale.

Rule of Thumb 6: For a game to be effective in engaging players, players need to care about the outcome and that outcome should have a satisfying result.

This rule applies to any game design. If players do not care about the outcome, then they are not motivated enough to improve on their performance. If players find the outcome to be unsatisfying (either boring or random), they are unlikely to learn anything or want to play it again. Games require a good narrative and flow to be entertaining to the players. A good game can be like a good story. A good collaborative game can be even more entertaining because it involves the collective contributions of all the players. It also helps if the outcomes have some variability to them to promote surprise and tension. Yet, the outcome should still be largely accountable to the decisions made by

[18] Schlegel, Garrels, Ifland, Burggraf, Scheerer, and Hormann (1996) *Scotland Yard*. Ravensburger USA.
[19] Nicely, S. and Schomburg, B. (2005) *Arkham Horror*. Fantasy Flight Games
[20] Deacove, J. (1982) *Eagle Eye Agency*. Family Pastimes.

the players; a random outcome is neither desirable from an enjoyment nor a learning perspective. *Lord of the Rings* has very good tension; especially at the very end where the draw of a tile can mean victory or ruin for the hobbits.

> Watch a *Lord of the Rings* player as he flips over a tile during the last part of the game. Some inhale sharply or wince or close their eyes... [This game seems] to involve people in a way more than the quiet mental gyrations of chess or go. (Branham, 2001)

The story of the hobbits as they journey through Middle Earth and face a myriad of dangers combined with the limited randomness provided by the cards, tile, and die creates a very engaging experience for the players. Because the outcome is often uncertain until the very end, the game manages to maintain (and often build) interest and tension. A well-played adventure that fails at the edge of Mount Doom is often as satisfying as one that succeeds.

Rule of Thumb 7: For a game to be enjoyable multiple times, the experience needs to be different each time and the presented challenge needs to evolve.

While this rule is true for all games, it can prove to be an even greater pitfall for collaborative games. Collaborative games face unique problems in *replayability*. People learn skills through practice (time on task). To put in more practice time, they need to be able to repeatedly play the game. However, if a collaborative activity has an easily-learned deterministic solution, then the participants will find it pointless to repeatedly play the game. The repeatability of a game can be enhanced by random elements in setup and randomization of the resources and obstacles through the course of the game. Too much randomization and the players will have no reliable information to formulate and discuss strategies. *Lord of the Rings* is a game of controlled chance, as the main mechanism is drawing from a bag filled with evil and good tiles (Branham, 2001). Unlike completely deterministic games, like chess, *Lord of the Rings* cannot be played exactly the same way twice. It maintains good replayability by having constrained randomization of the tiles and cards, which leads to different decisions and situations each time the game is played.

Competitive games are most engaging when opponents are closely matched. Two novice chess players will have competitive games. Likewise, two expert players will have competitive games. However, an expert playing a novice is not a competitive situation. If we expressed playing ability numerically, a challenging situation in a competitive game occurs when the difference in the players' abilities is close to zero. In contrast, a challenging situation in a collaborative games is better modeled by the sum of the players' abilities being close to the difficulty of the game. If two intermediate players find a collaborative game challenging, a novice / expert pair might find it challenging, particularly when the expert's additional skill balances the novice's lacking skill. That same game will be too challenging for two novices and too easy for two experts.

A collaborative board game only has a set of static goals and rules to provide obstacles and counter-strategies. As a result, after multiple playing sessions, the players

can become more familiar and better at the game until it is below their combined abilities. The game becomes unchallenging as the team is able to easily beat the game. So, unlike competitive games, like chess, collaborative games need to adapt to the players' abilities to maintain replayability. *Lord of the Rings* does this in a number of ways. Players can adjust how many steps Sauron is away from the fellowship at the beginning of the game. This provides an easy, relatively flexible manner to increase the difficulty of the game. Once a fellowship has mastered beating the game at 15 corruption steps to Sauron, they can try it at 12 steps. In addition, there are two expansion sets (*Friends & Foes*[21] and *Sauron*[22]) that increase the difficulty of the game and fundamentally alter the strategies for the game (Glenn, 2002). A good decision in the base game may not be a good one when playing with one of the expansions.

Playing *Lord of the Rings*

> I was amazed that I bought into the whole group-effort thing. [Everyone laughs.] I seriously was. I was very skeptical about collaborative games being as fun as competing with other people and this actually was really fun. —Pippin, Group 1

Based on informal observations and game-theory analysis, we identified seven rules-of-thumb to help designers create collaborative games. To examine these design guidelines more closely *in situ*, we studied groups playing *Lord of the Rings*. Volunteers were recruited from a pool of graduate students who had not played the game. The volunteers were split into two groups: Group 1 consisted of four players, two women and two men; Group 2 consisted of two women players.

Both groups followed the same procedure. First, the rules of the game were explained, with the game participants frequently asking clarifying questions. Because the game is fairly complex, this took some time. Next, the group started playing the game. Throughout the first of four game boards, Moria, we helped the groups by clarifying rules, pointing out options, and suggesting viable strategies. After the first board, we stopped suggesting strategies and were principally active in clarifying rules. The rules are nuanced. At times, even we, who are quite familiar with the game, had to consult the 25-page rule book. Once the game concluded, the groups discussed their experience, responding to our questions. Each group was video taped; that video was later analyzed and selectively transcribed. What follows is that analysis. When appropriate, references to the corresponding rules of thumb (RoT) are included.

Unlike traditional psychology studies (Kagan and Madsen, 1971, for example), we are not examining a simplistic "model" game (e.g., *Prisoner's Dilemma*), with simple rules and limited choice. *Lord of the Rings* is a real board-game, with complex rules and complicated choices. As such, statistical analysis, common in these psychology studies, is ill-suited for analyzing the game play. Instead, we provide a qualitative description of game play with specific examples when appropriate and accessible to an audience largely unfamiliar with the game. While the simplicity of model games makes them easier to analyze, there is an advantage to studying a real game—the collaboration

[21] Knizia, R. (2001) *Lord of the Rings: Friends & Foes*. Fantasy Flight Games.
[22] Knizia, R. (2002) *Lord of the Rings: Sauron*. Fantasy Flight Games.

should be better. Research on group collaboration indicates that groups function better when approaching an ill-structured solution (Cohen, 1994). Hence, the complexity of *Lord of the Rings* should better engender authentic group collaboration.

Nobody in either group was an avid board-game player, though the Frodos[23] in both groups had significantly more experience with modern board games than the others. In practice, this difference in experience was hardly noticeable. Irrespective of their experience, the players learned the game well enough in the first part of the session that they were able to play the game competently (making sensible decisions based on a reasonable understanding of the game) in the second phase.

Group 1: a Challenging Game

Group 1 starts Moria with some bad luck, drawing mostly evil tiles. Some of the fellowship wonder if they will make it through Moria. As the tiles they have drawn are mostly evil, the odds of them drawing good tiles increases. Consequently, things turn around. Still, the group finishes Moria through the event line, rather than the main activity line (Figure 2). Since the event line is full of bad events, it is preferable to finish through the main activity line. In Helm's Deep, the first two players replenish their resources, rather than progress on an activity line. Hence, the third event causes problems. That event is conditioned on the progress of the group. If the group has achieved a certain amount of progress, the group will receive additional resources—a good outcome. If not, the group will be corrupted—a bad outcome. In this case, the group has made little progress and is corrupted. The players realized their mistake and, from then on, spend more time looking ahead (an important game strategy). By tracing the payoff back to their decision, the group is able to learn to play the game better (RoT3). Additional problems arise as Pippin, the current ring-bearer, is close to being corrupted by Sauron. While Pippin will likely make it through Helm's Deep, the chances of her staying alive in Shelob's Lair are not good. This should not have been a problem as the ring would normally pass to someone else—the ring passes at the end of each board to whoever left of the current ring-bearer has the most ring tokens. Unfortunately, on her turn, Pippin inadvertently gains another ring token. At this point, she has the most ring tokens and the One Ring will remain with her. She realizes the predicament, but she can't see any way out of it. Because of the special responsibility of being the ring-bearer, Pippin's choices become the focus of attention (RoT4). Eventually, Sam suggests that she move forward on the "friendship" activity line. That way, Sam will be able to get a ring token on his turn and the One Ring will pass to him. Pippin completes that move. As Pippin does not know about Sam's resources, they have to collaborate in order to succeed (RoT5). Again, the group finishes the board through the event line, but the ring passes to Sam who is one of the least corrupted. Shelob's Lair proves more perilous. About a third of the way through, Pippin dies. Merry dies shortly thereafter. Towards the end of the board, Frodo is close to death; "I know I'm dead." With her remaining resources she buys healing for the lone Sam, allowing him to make it to Mordor. For the third and final time, the group finishes the

[23] For protect the confidentiality of the volunteers, we refer to the players by the characters they played. In Group 1, the players are (in turn order) Frodo, Pippin, Sam, and Merry. In Group 2, only Frodo and Sam are played.

board through the event line. In Mordor, it looks dire. Sam starts one step away from getting corrupted by Sauron and has virtually no resources. Within a minute, he gets corrupted by Sauron. Sauron regains his ring and the game is lost.

In this game, the play of Merry and Pippin is particularly enlightening. Pippin admitted early that she liked to talk: "This is probably wonderful for research, but maybe annoying to other people, but I tend to talk." Throughout the game, she was actively leading the discussion and became quite engaged in the game. Because she communicated so well, she often made self-sacrificial decisions that were good for the team, but not for her character. As a consequence, her character was the first to die. Rather than letting that slow her down, she continued. If anything, she was more vocal: "I was the first one who died. And, normally… [after being eliminated in a competitive game] I would be watching TV in the other room. I didn't mind dying and I actually started thinking 'now, I can be a totally objective adviser, and I won't have to worry about how much life I have.' So, that was a very different experience." *Lord of the Rings* was engaging enough for Pippin to stick around in the game (RoT6), even after her character's death. Because she was a good communicator, Pippin helped the group. Though the group failed to win, her contributions directly helped the group get to Mordor.

Merry is the opposite case. Where Pippin is garrulous, Merry is reserved, communicating noticeably less than the other players. Through Moria, Merry occasionally asks questions and makes decisions that are as altruistic as any of the other player. In Helm's Deep, things change. Sauron is moving dangerously close and Merry becomes aware of the danger to his character's survival. He chooses a self-preservation strategy. On his turns, he does little to advance the team, preferring to heal himself or replenish his resources. In one particularly glaring example, the team is trying desperately to get out of Helm's Deep through the main activity line, rather than the event line. It is Merry's turn. He has the resources to finish the board. Instead of using them, he chooses to receive further resources. This was a terrible decision that cost the team dearly. Because of his inexperience, Merry concluded (incorrectly) that a self-preservation strategy was a good strategy. Falling back on a selfish strategy is the problem of the competitive mindset: Merry mistook a collaborative situation for a competitive one. Because he perceived a threat to his individual utility, Merry behaved selfishly, thereby highlighting the problem of the competitive mindset (RoT1). As he was able to decide what to do on his turn, that affected the outcome of the game (RoT2). Thus, the team had an incentive to help Merry get beyond his competitive mindset. Merry admitted, in the post-game discussion, that it was hard for him to determine a good strategy; however, if he had been more communicative, the other team members could have helped him form a better strategy, allowing him to move beyond a competitive mindset. Yet, playing with strangers made this less likely as Pippin pointed out: "I think that it doesn't help that we all don't really know each other very well, because there were times when I wanted to say 'you shouldn't do that' and I didn't feel like I knew you well enough to say 'no, you need to take the hit.' If I was with good friends, I'd say that." It is likely that had the group played a second time, they would not only be more experienced, but also more comfortable communicating with each others. Other players would question selfish decisions and the lines of communications would open up, allowing Merry to chose a better (i.e., more collaborative) strategy.

Group 2: a Collaborative Game

Group 2 starts Moria with some good luck. Thing are running smoothly. As in the other group, things turn around as the ratio of good to evil tiles changes. This time, things turn for the worse. In an attempt to stop their losses and clear the board, Frodo puts on the ring. Her luck fails her, but the bad luck ceases. Frodo and Sam are able to clear the board through the main activity line. Helm's Deep starts. Unlike Group 1, this group realizes early on that the third event requires them to have made some progress. They quickly complete that progress and are thus rewarded when the third event happens. Towards the end of the board, things are starting to go sour. It is Frodo's turn. Frodo would like to finish the board, but does not have the necessary resources. So, she is about to use her turn to replenish resources. Sam interrupts, "Wait! You have no cards to get us out?" Frodo confirms that she does not. Sam then plays her "pass 1 card to another player" card to pass the card necessary for Frodo to complete Helm's Deep. Frodo plays the card and they escape Helm's Deep in good shape. Since Frodo did not see Sam's resources, she was not aware of this move; collaboration was necessary to achieve success (RoT5). Shelob's Lair proves treacherous. The fellowship has to use most of its resources in order to avoid negative consequences. Though they finish the board through the event line, they are in reasonable shape for Mordor. In Mordor, things start swimmingly. Almost every tile drawn is good. It looks like victory is assured. Then, things turn ugly. Luck fails the fellowship both in terms of drawing tiles and in rolling the die. Sam puts on the ring to clear the board. The chance of succeeding is 83.3%. She fails. She plays a card that allow her to try again. Again, she fails. The party feels pretty low, doubting their success. Then, Frodo dies. Sam is left alone. By depleting the rest of her resources, Sam makes it to the edge of Mount Doom. She has two die rolls left. The chance of success is 57.6%. The first roll goes sour and the chance of winning is reduced to 33.3%. She rolls. Success! At the edge of Mount Doom with no resources left, Sam lobs the One Ring into the volcano to destroy it and save Middle Earth.

Comparing the Groups

Both groups enjoyed the game, laughing frequently. Everyone was familiar with the Tolkien theme and found it engaging in a lighthearted way. Though Group 1 lost, it was still a satisfying experience. Though various characters died, the players never lost interest in the game. When questioned about her character's death, Frodo in Group 2 replied, "if he hadn't died, we wouldn't have won... My name's on the high score table too." The outcome of the game was satisfying enough to engage players that had been eliminated from the game (RoT6). Both groups also felt that further games would be interesting (RoT7). For instance, Pippin suggested that they had not yet fully utilized the different abilities that their characters had (RoT4). While both groups had taken advantage of Sam's ability, the others' abilities were less utilized.

Group 2 succeeded where Group 1 failed. Why? Luck was not the determining factor. Though much of the game is controlled by chance, that chance tends to balance out over time. While there might have been lucky or unlucky streaks, by the end of each board, the balance was restored. Group 2 was not luckier than Group 1. Experience

	Group 1			Group 2		
Board	Time	Turns	Time/Turns	Time	Turns	Time/Turns
Moria	18:17	8	2:17	31:57	8	4:00
Helm's Deep	25:45	12	2:09	22:50	8	2:51
Shelob's Lair	24:00	8	3:00	26:11	10	2:37
Mordor	0:40	1	0:40	37:55	9	4:13
Total	1:08:42	29	2:22	1:58:53	35	3:24

Table 4: Time to Play *Lord of the Rings*

was not the determining factor either. Both groups had about the same amount of prior gaming experience and both groups started playing the game without a good understanding of the game and useful strategies in the game. As Sam in Group 2 explained, "I felt like there was a lot of strategy that could be going on. I just wasn't aware of what it was or should be." If not for luck or experience, why did Group 2 fare better? The answer is that they were more collaborative. While Group 1 played competently, communication was sometimes missing and unwise selfish choices were occasionally made. In contrast, Group 2 collaborated well from the beginning, looking for approval before completing moves and, consequently, making few selfish choices. In Moria, fueled by their collaboration, Sam and Frodo spent more time figuring out the game (Table 4). By the time they reached Helm's Deep, they had adopted a "look ahead" strategy and, thus, avoided the negative effects of event three. Overall, Group 2 averaged a minute longer per turn than Group 1 (Table 4). As shown in Table 4, both groups spent more time per turn as the elimination of a character drew near.

Frodo and Sam made a great team, occasionally speaking in tandem or completing each others' sentences. Why? As indicated previously, Group 1 felt that being strangers was a barrier to their success. So, we suspected that the opposite was true for Group 2: Their success was a function of their familiarity. We asked them about it. To our surprise, we had misread the situation. Frodo and Sam did not know each other well. Frodo suggested an alternate explanation: "I think maybe it's because neither one of us have a problem speaking our minds." Sam added, "to me, it was obvious, in terms of the goal of the game, that it would be more successful that way…" Frodo completed the thought, "…if you share what you have or moves that you see that are available that the other person might not see." Both Frodo and Sam were natural communicators and collaborators; they had no problem identifying *Lord of the Rings* as a collaborative situation.

While Sam and Frodo collaborated well, they did not master the game. Even with help, they barely beat the game on its easiest level. Improved play would be necessary to win at a harder level. Yet, their collaboration skills were good enough that they would be able to acquire those skills through continued play. The same is true for Group 2. While they may also need to improve on their communications skills, there were clear signs that this would happen with continued play. Both groups were able to play the game to become better at the game. Since being better at the game requires players to act unselfishly (like a hobbit), *Lord of the Rings* was a good setting to foster

collaboration.

Beyond the One Game

In the previous sections, we detailed one collaborative game and demonstrated how it allows players to get beyond the competitive mindset; we also demonstrated how that one game overcomes some of the unique challenges of designing collaborative games. We believe that detailing what makes *Lord of the Rings* work, particularly in regards to the unique way in which it encourages participants to go beyond their competitive mindset, can inform designers of collaborative learning environments. In this section, we seek to go beyond the one game. To do that, we first examine the limits of our approach. Second, we look at the *transfer problem*—how do we get learning that happens in the game context to transfer to other contexts. If an educational activity is to have lasting effect, the learners will have to be able to transfer their understanding to new situations. Third, we examine the *scope problem*—how can the lessons learned from our analysis be applied to the design of other systems. We show the limits of *Lord of the Rings* and suggest what would need to be done to overcome these limits. Finally, we address how computers provide interesting opportunities for overcoming these limitations.

The Limits of Our Approach

In this article, we have described one game in detail and supplemented this description with a few other examples rather than drawing conclusions across a cross-section of collaborative board games. One reason for this is that this depth approach allows us to give a better description and feel for how a collaborative game works. Another reason is that *Lord of the Rings* is an extraordinary game. It is the most popular collaborative board game ever; it is the only collaborative game on the popular game site's twenty all-time best selling games.[24] It received the prestigious game award Spiel des Jahres[25] in 2001 for "Literature in Games." Furthermore, because of its Tolkien's *The Lord of the Rings* theme, it was one of the most anticipated games of all time, designed by one of the greatest and most prolific game designers of all time (Levy, 2001). Many critics feared that an interesting collaborative game could not be made and they had reason to. As accomplished game designer Bruno Faidutti noted in his review, "it [*Lord of the Rings*] is the first collaborative game that really works.[26]"

Though we have detailed some of the major challenges in the design of collaborative games and detailed how one game overcomes these challenges while at the same time allowing players to overcome the competitive mindset (in its context), we do not have a design process for creating such a game. One cannot derive a design process by

[24] http://www.funagain.com

[25] "Spiel des Jahres" is the German "Game of the Year" award. It is the board-game world's equivalent of the film world's Academy Award (Oscar).

[26] Faidutti actually writes "it is the first cooperation [not collaborative] game that really works." This is because the terminology used by the board game community and game theorists vary. So, board games that are collaborative are labeled as cooperative by the community. See http://faidutti.free.fr/jeux/articles/lotr/lotr.html for the full review.

analyzing the design product (Goel and Pirolli, 1992). Thus, specifying a design process for collaborative games is beyond this article and beyond the current capabilities of its authors. Designing a board game that is fun to play is already extremely difficult. Designing a fun and interesting collaborative board game is even more difficult. Designing *Lord of the Rings* required considerable imagination, skill, and play-testing (Knizia, 2004). Knizia has designed well over 100 games and, as of this writing, *Lord of the Rings* (and its two expansions) remains his only collaborative one. This article is not a design process. Instead, it is reporting on a unique, interesting learning environment that has great potential in providing an engaging, active environment for people to get beyond the competitive mindset. Along the way, we hope to have extrapolated rules of thumb that designers of collaborative learning environments might be able to use.

We have demonstrated, both analytically and observationally, that *Lord of the Rings* encourages collaboration. People learn to play the game better and, since playing the game better means playing more collaboratively, players learn to collaborate. Yet, our case study is limited; we have not detailed to what extent learning happens. More extensive studies could be conducted to quantify learning; however, we doubt that they would be fruitful, as all of them would be limited to the scope of this one game. It is not clear how results from such studies could be applied elsewhere. Our aims in this research were to inform designers of learning environments, rather than to encourage educators to adopt *Lord of the Rings*. Effectively using the game as part of a learning environment or curriculum would require work that is only tangentially related to the design of the game.

The Transfer Problem

> If the learners cannot be guided to use the experience of participating in the simulation to understand that the decisions they have made therein are applicable to other life activities and their behavioral choices therein, if it is thought of as just a game, then there is no significant instructional value. (Lederman, 1994, p. 217)

One of the problems about using collaborative games (or games in general) as learning environments is it has often proved difficult for students to apply the concepts demonstrated or skills practiced during a game to other situations. This is the transfer problem. Even if a person is able to overcome their competitive mindset while playing a collaborative game, they may not be easily able to transfer that knowledge to another task. If the calculus class mentioned earlier had played *Lord of the Rings* and even overcame their competitive mindset during the game, they might still be unable to apply those collaborative models of interaction to their homework assignments.

To assure that transfer is more likely to happen, what goes on outside of the actual playing of the game can be important (Goodman, 1995). *Debriefings* have been shown to be particularly effective (Petranek, 1994; Lederman, 1994). A debriefing is a small, often expert-led, discussion after the completion of a simulation. The debriefing offers an opportunity for the participant in the simulation to reflect on what occurred during the simulation, after the experience rather than during it. So, an educator who wanted

to use *Lord of the Rings* should think about what kind of debriefing would be useful for students to best reflect on their experiences.

In addition, *Lord of the Rings* is only one environment. Difficult concepts, like collaborative thinking, are more likely to transfer to new situations if they have been addressed from multiple paths (Kolodner, 1993; Kolodner, 1997). As such, the one game should not be the only learning environment that supports collaborative thinking. As *Lord of the Rings* is fairly unique, it is up to educational designers to create other such environments. Only having one environment limits effectiveness. It also limits the scope.

The Scope Problem

Lord of the Rings, though a great game, does not serve all audiences. Some will find the Tolkien theme unengaging or objectionable (for example, all playable hobbits are male). Some will find its mechanics to be tedious or its rule set too complicated. Many will find it to be beyond their zone of proximal development—they will be unable to play the game well, even with the help of others. The game is intended for ages 12+ and, even at its easiest setting, is still challenging for first-time-playing experienced gamers. Some novices may not be able to defeat the game at all, no matter how collaborative their intentions. In that case, it is unlikely that learning will happen as feedback about success from the system is critically important (Tansey and Unwin, 1969).

In addition to the problems of accessibility, the game was not designed to fit into standard educational settings, such as schools. This limits its usefulness to those contexts. In order for them to succeed, educational games have to fit into existing set of constraints (Tansey and Unwin, 1969). For example, a typical session of *Lord of the Rings* takes longer than a typical class period. As such, even a willing teacher would find it difficult to use the game during class.

This game and collaborative games in general are not a panacea for the problem of the competitive mindset. But, they are active and engaging contexts that allow (some) players to learn lessons of collaboration without the help of a teacher. As such, they should be of interest to the collaborative learning community. In particular, there is a need to create other environments that support collaborative thinking. Designing a good collaborative game may be extremely difficult, but there is good reason to believe the flexibility of a computational medium can make this task more achievable.

Beyond Board Games: Designing with Computers

The computer offers great potential for designing learning environments (Papert, 1993). Computers open the design space of designing games as fairly sophisticated computation can be done quickly and accurately (Lundgren, 2002). First, computers can easily do computational operations, like calculating and keeping a running total of scores; these operations, when left to a human participant in a board game, often become tedious and error prone. Second, computers can display information in different (and often more meaningful) ways. Third, computers can also analyze how players are doing and provide just-in-time help or other flexible scaffolding to support the learners in their activities.

On top of their computational flexibility, computers offer communication flexibility. Board games are limited to one style of communication—open face-to-face communication between the participants, as they are sitting at the same table. In contrast, computers can be more flexible. While using a standard computer usually impedes communication as players look at the screen instead of each other, there are computer systems with horizontal screens that could mimic the board game experience. Communication is of particular importance to a collaborative game, as players have to coordinate their strategy. Changing the medium for communication can vastly change how participants work together (Clark and Brennan, 1991). Restricting some types of communication while supporting others can be quite powerful in changing the nature of collaboration (Dillenbourg and Traum, 1999; Scott et al., 2002). For example, the computer program can support conflict resolution and group decision making skills in ways that may be superior to face-to-face discussions (Núñez et al., 1998).

The computer significantly opens the design space in designing collaborative games (Manninen, 2002). Interestingly, adding collaboration also improves computer games. Studies have shown that playing together in a collaborative computer game increases motivation, particularly for girls (Inkpen et al., 1995; Inkpen et al., 1994). So, computers seem to be a natural environment for creating the type of learning environments needed to overcome the competitive mindset.

Discussion: Learning from Microworlds

At this point, we have shown how collaborative games provide interesting mechanisms for addressing the problem of the competitive mindset. We have done this mainly by detailing one game (its mechanisms and how it overcomes some of the challenges in creating such environments). For the discussion section, we use this work to reflect on learning in microworlds. For this, *Lord of the Rings* provides a rich, concrete example of such a learning environment. We do this partly because this more systematic analysis of learning possibilities is worthwhile, but also because we feel that the epistemological change facilitated by *Lord of the Rings* is a particularly valuable kind of learning.

Games are microworlds—small worlds that model a part of the "real world." Microworlds provide interesting affordances for learning (Papert, 1987). First, real world complexity can make it difficult to isolate events and identify their causes. Microworlds can be designed to make these causal relationships apparent, which can clarify the learning objectives. Secondly, real world elements are often difficult to access and manipulate with accuracy. Microworlds can be designed so learners can control as many or as few elements as desired. Thirdly, the milieu of the real world can feel threatening to the learner by engendering a sense that the learner's performance has external consequences (Tansey and Unwin, 1969). Microworlds allow the participant to be more objective by removing this element of personal threat.

Generally, microworlds fall into two types: *modeling environments* and *simulations*. A modeling environment allows the learner to model the situation, thereby creating simulations. A simulation is an analogue of reality that may or may not have an underlying mathematical model (Tansey and Unwin, 1969). Learners engage or investigate the simulation to acquire knowledge or skills. For the purposes of learn-

ing, participant simulation where learners play different roles and their actions affect the outcomes of the simulation are particularly effective in encouraging active learning (Colella, 2000). Strategic games are inherently participant simulations, where learning is active.

One example of a modeling microworld is StarLogo (Resnick, 1994; Resnick, 1996). With StarLogo, users can program a massive number of moving turtles and stationary patches. Then, when the program is running with all active elements executing at the same time, users can observe and study how the simulation they created behaves. Often, simple individual behavior can lead to emergent system behavior that is not obvious from the simple behavior of the individual elements. StarLogo is a programming environment that is particularly well suited for exploring emergent behavior based on decentralized control. Many common phenomena, such as traffic systems and slime mold behavior, function without a centralized determining factor. The queen ant does not command the other ants where to go, yet an ant colony functions well in providing food to the ant hill. However, most learners have a hard time understanding decentralized processes or even realizing that such processes exist. So, when they try to model an ant colony in StarLogo, they try to program it in a centralized manner. Because of the way the programming language is designed, it is actually quite hard to create a centralized model with StarLogo. By struggling through the problem, it becomes apparent that a simple decentralized approach to modeling the situation can be much simpler, while being quite effective. As such, StarLogo provides an active environment that affords modeling "real world" phenomena to explore emergent behavior and the behavior of decentralized systems.

An example of a participant simulation microworld is the *Beer Game*.[27] Participants play positions of a production / distribution system for a single brand of beer. The players are free to make any decision they see as advantageous; their goal is to manage their position so as to maximize their profits. At one time in the game, the demand for the beer doubles. Because of the communication and delivery delays in the system, this becomes a large problem as the individual positions try to maximize their profits. Eventually, everyone ends up in pretty bad shape; the distributors have much more inventory of the beer than they can possibly get rid of in a reasonable time while the producers have no new orders coming in. Interestingly, no individual is to blame—they all acted rationally; instead, the system is at fault. The simulation demonstrates that the system can be problematic even if all participants are behaving rationally (Senge, 1990).

Learning in Microworlds: From Theme to Epistemology

Microworlds provide several opportunities for learning. First, participants can learn from or about the theme. Second, they can learn about the modeled situation. Third, they can use the microworld to practice and refine the skills that the environment supports. Finally, they can gain connections to the underlying epistemology of the microworld.

[27] The *Beer Game* was first developed in the 1960s at Massachusetts Institute of Technology's Sloan School of Management (Senge, 1990).

Theme

The *theme* of a microworld consists of an infrastructure of real-life aspects that provides a context for the microworld. For example, the original version of *Monopoly* takes its theme from famous streets in Atlantic City. A microworld does not necessarily need a strong theme; for instance, there is an entire category of board games, commonly known as abstract games, that have little to no theme. However, appropriate themes can often aid in the accessibility of the microworld; they provide fictional frameworks that provide a concrete context. This makes it easier to understand the rules of the microworld as learners can build upon their knowledge of the context (Hardin, 2001). Also, good themes allow for immersion that can enhance the enjoyment of (and thereby, commitment to) the experience (Hardin, 2001).

For StarLogo, modeling ants, termites, traffic jams, etc. is more motivating and accessible than simply programming abstract turtles on top of abstract patches for many purposes. Users are better able to relate the concepts to the concrete "real world" examples, rather than purely abstract concepts. For the *Beer Game*, the beer distribution theme provides an easily understandable and reasonably realistic framework to demonstrate systemic problems. For *Lord of the Rings*, the Tolkien theme provides a motivating and engaging concept for fans of the books (or the movies). Players often come into the game already familiar with the characters and find it easy to immerse themselves in the story of the game; as such, defeating Sauron and saving Middle Earth becomes important. For the *Prisoner's Dilemma*, the prisoner theme makes the game easier to understand. At times, themes can be educationally interesting. For instance, in *TransAmerica*,[28] players create railroad systems that connect major American cities. The game board is a fairly accurate map of the continental United States. By playing the game, participants will learn something about the location of major cities. The game also affords a natural context where an adult mentor might introduce geography concepts and knowledge. *Lord of the Rings* can be used to learn about the characters and events in the book. StarLogo can provide an interesting context to start thinking about ants. The *Beer Game* can be valuable for understanding systems of beer distribution.

Modeled Situation

The *modeled situation* of a microworld often provides important learning opportunities. For instance, the goal-based scenarios approach to creating educational technology is based on the premise that accomplishing a goal in the context of an interesting scenario can allow participants to learn about the modeled situation and practice the necessary skills that situation requires (Schank et al., 1994).

"A *model* is an abstraction of things held to be important in the real life situation" (Tansey and Unwin, 1969, p. 36). In order for the learning opportunities from the modeled situation to be interesting, the modeled situation must be an important concept and / or match well with the "real world" situation it represents. For instance, the iterated version of *Prisoner's Dilemma* is a useful modeled situation as it accurately models several "real world" phenomena (Dawkins, 1989): healthy vampire bats share

[28] Delonge, F. (2002) *TransAmerica.* Winning Moves.

blood with sick ones; some trench warfare, in World War I, became a game of neither side attacking the other in order to assure mutual survival; the final minutes of the 1977 Bristol / Coventry soccer match became exceedingly dull as both teams tacitly agreed to play for a draw. If the modeled situation fails to have fidelity to the "real world" action it models, it can even be educationally harmful. For instance, this is sometimes the case in the popular *Sim* line of games, such as *SimCity* (Schank et al., 1994; Starr, 1994). As the models of the world these games use are not particularly accurate, participants can come away with erroneous conclusions, such as raising taxes will always cause riots. In contrast, the *Beer Game*'s modeled situation of supply chain management is an accurate, though simplified, example of a system that can have influential systemic effects. StarLogo's simulations of ant colony behavior and traffic systems are accurate enough to get at the decentralized nature of these phenomena. *Lord of the Rings*'s model of a collaborative mission is accurate enough for demonstrating the strategies for good collaboration.

Skills

The *skills* that a microworld enables participants to practice and learn can be extremely important. For some learning microworlds, such as goal-based scenarios, fostering skills is the primary learning objective. How well those skills are learned and how closely those skills align with the learning objectives determines how effective a goal-based scenario is (Schank et al., 1994). Learning to better use the microworld requires increasing competence in the requisite skills. So, as people seek to understand and master the microworld, they become more competent in the underlying skills. As such, microworld use inherently encourages learning certain skills. At times, learning these skills, necessary for properly engaging the environment, can be orthogonal to or even get in the way of the learning objectives. For instance, playing *Lord of the Rings* well requires skills in resource management. Learning resource management is largely orthogonal to the learning goal of overcoming the competitive mindset. If players do not possess or are unable to gain enough competence in resource management, they will not be able to succeed at the game no matter how open they are to a collaboration. Similarly, lack of programming competence can be prohibitive to the effectiveness of StarLogo. If the users are unable to program simulations in StarLogo, they will be unable to use it as a modeling microworld. Programming is largely orthogonal to the learning objective of overcoming the centralized mindset, but is a requisite skill to properly engage StarLogo. Though some requisite skills may be orthogonal to the learning goals, others frequently align well with the learning objective. In the *Beer Game*, the requisite skills of communication, negotiation, and bargaining are fundamental to solving systemic problems. In *Lord of the Rings*, payoff satisficing (being able to evaluate the potential payoffs involved with particular decisions) and collaborative inquiry (working together to understand a problem and negotiate a solution) are important processes of collaboration.

Epistemology

Some microworlds go beyond teaching facts, processes, and skills; they "encourage new ways of thinking (and even new ways of thinking about thinking)" (Resnick et al., 1996). These *epistemologies* are the underlying structures that people use to form their understanding of the world.

Some epistemologies are clearly more constructive than their complement. For learning purposes, an incremental theory of intelligence is preferable to an entity theory (Dweck, 2000). In the entity theory, intelligence is seen as a fixed, internal entity. In the incremental theory, intelligence is a dynamic quality that can be increased. When entity-theory learners run into difficulties, they often view their lack of success as an indictment against their intelligence; as they view intelligence as fixed, they give up working on the problem. In contrast, incremental-theory learners view the difficulties as a learning challenge; they continue to work longer on the problem and often succeed where their entity-theory counterparts fail (Dweck, 2000).

In other cases, two epistemologies can be quite different, yet equally valid for approaching a problem. Turkle and Papert (1991) note how learners approach programming tasks with two distinct styles: a "hard" and a "soft" one. The hard style is a structural and top-down approach. The large problem is divided into smaller more-manageable problems; solving the smaller problems solves the larger problem. In contrast, the soft style is bottom-up and negotional. It involves a closeness to objects. While hierarchy and abstraction are valued by the structured programmers, these bricoleur programmers prefer negotiation and rearrangement of their materials (Turkle and Papert, 1991). Traditionally, the hard style has been given a higher status, while the soft style has been maligned. Turkle and Papert point out that the soft style too has its advantages; even in Western science, where a distance from the object of study has been strongly encouraged, there are examples of breakthrough success using a soft approach.

Often, what epistemology is appropriate to a given problem, depends on the problem. One can attempt to understand the workings of an ant colony based on a centralized epistemology. In this case, the coordinated actions of the individual ants will be attributed to a centralized source, such as (inferentially) the commands of the (one) queen ant (Resnick, 1994). Unfortunately, this is not a particularly accurate model of how ant colonies actually function. A more accurate model might be based on a decentralized epistemology. In that case, the coordinated actions of the individual ants can be explained as an emergent property of the decisions made and actions taken by the individual ants. These two different ways of understanding ant colonies are fundamentally incompatible, as they are based on different epistemologies. To understand the more accurate model of ant colonies, a person needs to have decentralized knowledge structures to base their understanding on. Different epistemologies, such as decentralized thinking, often provide important ways of understanding the world. Our three examples of microworlds (*Beer Game*, StarLogo, and *Lord of the Rings*) are environments that encourage such different epistemologies.

Exposure to whole new ways of thinking and understanding can be quite powerful. Microworlds can provide an excellent way to dramatically convey these major messages (Petranek, 1994). Senge (1990) recalls an executive rushing to a phone af-

ter playing the *Beer Game*. He just realized that problems in his company could be systemic in origin and was calling to stop the firing process of an employee whom he had previously thought was accountable. Resnick (1994) recalls the moment when a respected expert in emergent systems realized that a certain StarLogo simulation he had insisted was based on centralized control turned out to be decentralized. We, the authors, have seen the shock of surprise when experienced competitive gamers fail to win *Lord of the Rings* the first time, though they were confident in their resource management skills. They had failed to realize that sacrificing individual resources for the success of the team can be a useful strategy. In all of these instances, experiences in these microworlds fundamentally changed the way these participants understood something. They had been confident in their way of understanding the world, but found out that their approach could be fundamentally flawed in certain situations, as it was based on the wrong epistemology.

Designing Microworlds

> I wanted to stay true to the spirit of the book... Therefore I had no other choice than to look at cooperative mechanisms to reflect the spirit of Tolkien. —Reiner Knizia (Glenn, 2002)

When designing microworlds with epistemological aims, it is important that the theme and the modeled situation are in harmony with the underlying epistemology, and that the skills required to succeed in the microworld are fundamentally linked to that epistemology. This is the case in our three examples. For the *Beer Game*, the theme and modeled situation provide a simple, concrete way of illustrating systemic problems. The skills necessary to succeed at the *Beer Game* are some of the skills necessary to solve systemic problems. For StarLogo, the themes and modeled situations provide concrete connections to start thinking about decentralized systems. The modeling skills necessary to succeed in creating a working simulation are closely tied to the skills necessary to understand (in this case, emergent) systems. For *Lord of the Rings*, playing hobbits in a game where the object is to collaborate selflessly is charmingly appropriate; in other words, the Tolkien theme supports and reflects the underlying epistemology of collaborative thinking. Most of the skills necessary to win the game are important skills of collaboration.

Whether from theme, modeled situation, requisite skills, or underlying epistemology, microworlds provide interesting opportunities for learning; see Table 5 for a summary of these possibilities in the three microworlds we have detailed. Due to the maturity of board game design and mechanics, board games (at least in the case of collaborative games such as *Lord of the Rings*) prove to be a useful subset of microworlds that can inform the design of learning environments.

Conclusion: Beyond the Individual

Our current society emphasizes the individual. This can have measurable negative consequences (Putnam, 2000). Often, people become trapped in an individual accountability mindset; they do not realize that their failures or successes are sometimes produced

	Beer Game	StarLogo	Lord of the Rings
Theme	Beer Distribution	Ants, Termites, Traffic Jams, etc.	J.R.R. Tolkien's The Lord of the Rings
Modeled Situation	Supply Chain Management	Ant Colony Behavior, etc.	Collaborative Mission / Quest
Skills	Communication, Negotiation, Bargaining	Modeling through Programming	Resource Management, Collaborative Inquiry
Epistemology	Systemic Thinking	Decentralized Thinking	Collaborative Thinking

Table 5: Summary of Learning Possibilities

by system-level behaviors (Senge, 1990). The *Beer Game* is one instance of a microworld that allows participants to actively encounter such a system and expose them to systemic thinking. People get stuck in a centralized mindset; they mistakenly attribute emergent behavior to a centralized entity (Resnick, 1994). StarLogo is one instance of a microworld that allows its users to actively model these emergent systems and thereby discover the existence and principles of decentralized control—it exposes them to decentralized thinking. People get stuck in a competitive mindset; they mistake collaborative and cooperative situations for competitive ones. *Lord of the Rings* is one instance of a microworld that enables its players to actively engage in collaboration and learn to overcome their competitive mindset, making decisions based on team utility rather than individual utility. It exposes them to collaborative thinking.

While we acknowledge that individual responsibility, centralized causes, and competition have an important role to play in our society, we believe that the importance of systemic, decentralized, and collaborative thinking has been undervalued. With today's increasingly interconnected and coupled world, we need to provide learning environments that support alternative epistemologies to those of the individual. Knizia's collaborative game, *Lord of the Rings*, is one such system—a learning environment that can transform us into collaborative hobbits. As designers of learning environments, we need to create others.

> If more of us valued food and cheer and song above hoarded gold, it would be a merrier world. —Thorin Oakenshield, from Tolkien's *The Hobbit*

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References

Aleknevicus, G. (2002). Player interaction in games. *Counter Magazine*, 16.

Barron, B. (2003). When smart groups fail. *The Journal of the Learning Sciences*, 12(3):307–359.

Bornstein, G., Gneezy, U., and Nagel, R. (2002). The effect of intergroup competition on group coordination: an experimental study. *Games and Economic Behavior*, 41:1–25.

Branham, F. (2001). What is the goal? *The Games Journal*, September, 2001.

Bruner, J. S. (1966). *Towards a Theory of Instruction*. The Belknap Press of Harvard University Press, Cambridge, MA.

Carlson, E. (1969). *Learning Through Games: A New Approach to Problem Solving*. Public Affairs Press, Washington, D. C.

Clark, H. H. and Brennan, S. E. (1991). Grounding in communication. In Resnick, L. B., Levine, J. M., and Teasley, S. D., editors, *Perspectives on Socially Shared Cognition*, pages 127–149. American Psychological Association, Washington, DC.

Cobb, P. (2002). Reasoning with tools and inscriptions. *The Journal of the Learning Sciences*, 11(2&3):187–215.

Cohen, E. G. (1994). Restructuring the classroom: Conditions for productive small groups. *Review of Educational Research*, 64(1):1–35.

Colella, V. (2000). Participatory simulations: Building collaborative understanding through immersive dynamic modeling. *The Journal of the Learning Sciences*, 9(4):471–500.

Cooper, D. J. and Stockman, C. K. (2002). Fairness and learning: an experimental examination. *Games and Economic Behavior*, 41:26–45.

Cooper, R., DeJong, D., Forsythe, R., and Ross, T. (1996). Cooperation without reputation: Experimental evidence from prisoner's dilemma games. *Games and Economic Behavior*, 12:187–218.

Costikyan, G. (1994). I have no words & I must design. *Interactive Fantasy*, 2.

Craig, D., ul Haq, S., Khan, S., Zimring, C., Kehoe, C., Rick, J., and Guzdial, M. (2000). Using an unstructured collaboration tool to support peer interaction in large college classes. In Fishman, B. J. and O'Conner-Divelbiss, S. F., editors, *Proceedings of ICLS 2000*, pages 178–184. Lawrence Erlbaum Associates.

Csikszentmihalyi, M. (1990). *Flow: The Psychology of Optimal Experience*. Harper & Row, New York, NY.

Damon, W. (1997). Foreword. In Piaget, J., editor, *The Moral Judgement of the Child*. Simon & Schuster, New York, NY.

Dawkins, R. (1989). *The Selfish Gene*. Oxford University Press, New York.

Deacove, J. (2000). Family pastimes. *The Games Journal*, November, 2000.

Dempsey, J. V., Haynes, L. L., Lucassen, B. A., and Casey, M. S. (2002). Forty simple computer games and what they could mean to educators. *Simulation & Gaming*, 33(2):157–168.

Dillenbourg, P. and Traum, D. (1999). Does a shared screen make a shared solution? In Hoadley, C. and Roschelle, J., editors, *Proceedings of CSCL 1999*, pages 127–135. Lawrence Erlbaum Associates.

Dweck, C. S. (2000). *Self-Theories: Their Role in Motivation, Personality, and Development*. Taylor & Francis.

Erikson, E. H. (1963). *Childhood and Society*. W. W. Norton & Company, New York, NY, second edition.

Fine, G. A. (1983). *Shared Fantasy: Role-Playing Games as Social Worlds*. The University of Chicago Press, Chicago and London.

Garris, R., Ahlers, R., and Driskell, J. E. (2002). Games, motivation, and learning: A research and practice model. *Simulation & Gaming*, 33(4):441–467.

Glenn, S. (2002). Interview with Reiner Knizia. *Funagain Games*.

Goel, V. and Pirolli, P. (1992). The structure of design problem spaces. *Cognitive Science*, 16(3):395–429.

Goodman, F. L. (1995). Practice in theory. *Simulation & Gaming*, June, 1995:178–190.

Guzdial, M., Ludovice, P., Realff, M., Morley, T., and Carroll, K. (2002). When collaboration doesn't work. In *Proceedings of ICLS 2002*, pages 125–130.

Hardin, A. (2001). Is it really about theme vs. mechanism. *The Games Journal*, February, 2001.

Hofstede, G. H. (2001). *Culture's consequences: Comparing values, behaviors, institutions, and organizations across nations*. Sage Publications, Inc., Thousand Oaks, CA.

Huizinga, J. (1955). *Homo ludens: a study of the play-element in culture*. Beacon Press, Boston, MA.

Inkpen, K., Booth, K., Klawe, M., and Upitis, R. (1994). Cooperative learning in the classroom: The importance of a collaborative environment for computer-based education. Technical Report TR-94-05, Department of Computer Science, University of British Columbia, Vancouver, BC, Canada.

Inkpen, K., Booth, K. S., Klawe, M., and Upitis, R. (1995). Playing together beats playing apart, especially for girls. In Schnase, J. L. and Cunnius, E. L., editors, *Proceedings of CSCL 1995*, pages 177–181. Lawrence Erlbaum Associates.

Jones, K. (2000). Non-predatory games. *The Games Journal*, August, 2000.

Kagan, S. and Madsen, M. C. (1971). Cooperation and competition of mexican, mexican-american, and anglo-american children of two ages under four instructional sets. *Developmental Psychology*, 5(1):32–39.

Kagan, S. and Madsen, M. C. (1972a). Experimental analyses of cooperation and competition of anglo-american and mexican children. *Developmental Psychology*, 6(1):49–59.

Kagan, S. and Madsen, M. C. (1972b). Rivalry in anglo-american and mexican children of two ages. *Journal of Personality and Social Psychology*, 24(2):214–220.

Knizia, R. (2004). The design and testing of the board game—lord of the rings. In Salen, K., editor, *Rules of Play: Game Design Fundamentals*, pages 22–27. The MIT Press.

Kohl, H. (1995a). A plea for radical children's literature. In *Should we burn Babar?: Essays on children's literature and the power of stories*, pages 57–93. The New Press.

Kohl, H. (1995b). The story of Rosa Parks and the Montgomery Bus Boycott revisited. In *Should we burn Babar?: Essays on children's literature and the power of stories*, pages 30–56. The New Press.

Kolodner, J. (1993). *Case-Based Reasoning*. Morgan Kaufmann Publishers, Inc.

Kolodner, J. (1997). Educational implications of analogy: A view from case-based reasoning. *American Psychologist*, 52(1):57–66.

Koschmann, T. (2000). The physiological and the social in the psychologies of dewey and thorndike: The matter of habit. In Fishman, B. J. and O'Conner-Divelbiss, S. F., editors, *Proceedings of ICLS 2000*, pages 314–319. Lawrence Erlbaum Associates.

Lederman, L. C. (1994). Give a small child a hammer and soon everything needs hammering. *Simulation & Gaming*, June, 1994:215–220.

Levy, L. (2001). Reiner Knizia: The special k's of german game design. *The Games Journal*, September, 2001.

Lundgren, S. (2002). Joining bits and pieces: How to make entirely new board games using embedded computer technology. Thesis (M.S.), IT University of Göteborg, Göteborg, Sweden.

Manninen, T. (2002). Towards communicative, collaborative and constructive multiplayer games. In Mäyrä, F., editor, *Proceedings of Computer Games and Digital Cultures Conference*, pages 155–169. Tampere University Press.

Marschak, J. and Radner, R. (1972). *Economic Theory of Teams*. Yale University Press, New Haven, CT.

Nasar, S. (1998). *A Beautiful Mind: The Life of Mathematical Genius and Nobel Laureate John Nash*. Simon and Schuster, New York.

Nash Jr., J. (2002a). Non-cooperative games. In Kuhn, H. W. and Nasar, S., editors, *The Essential John Nash*, pages 53–98. Princeton University Press, Princeton, NJ.

Nash Jr., J. (2002b). Two-person cooperative games. In Kuhn, H. W. and Nasar, S., editors, *The Essential John Nash*, pages 99–114. Princeton University Press, Princeton, NJ.

Nasir, N. S. (2005). Individual cognitive structuring and the sociocultural context: Strategy shifts in the game of dominoes. *Journal of the Learning Sciences*, 14(1):5–34.

Núñez, G., Agüero, U., and Olivares, C. (1998). Group decision-making for collaborative educational games. In *Proceedings of CRIWG 1998*, pages 143–155.

Papert, S. (1987). Microworlds: Transforming education. In Lawler, R. and Yazdani, M., editors, *Artificial Intelligence and Education, Volume One: Learning Environments & Tutoring Systems*, pages 79–94. Ablex Publishing Corporation.

Papert, S. (1993). *The Children's Machine: Rethinking School in the Age of the Computer*. Basic Books, New York, NY.

Petranek, C. (1994). A maturation in experiental learning: Principles of simulation and gaming. *Simulation & Gaming*, December, 1994:513–523.

Piaget, J. (1997). *The Moral Judgement of the Child*. Simon & Schuster, New York, NY.

Poundstone, W. (1992). *Prisoner's Dilemma: John Von Neumann, Game Theory, and the Puzzle of the Bomb*. Anchor Books, New York.

Putnam, R. D. (2000). *Bowling Alone: The Collapse and Revival of American Community*. Simon & Schuster, New York, NY.

Resnick, M. (1994). *Turtles, Termites, and Traffic Jams: Explorations in Massively Parallel Microworlds*. MIT Press, Cambridge, MA.

Resnick, M. (1996). Beyond the centralized mindset. *The Journal of the Learning Sciences*, 5(1):1–22.

Resnick, M., Bruckman, A., and Martin, F. (1996). Pianos not stereos: Creating computational construction kits. *Interactions*, 3(6):41–50.

Rick, J., Guzdial, M., Carroll, K., Hollaway-Attaway, L., and Walker, B. (2002). Collaborative learning at low cost: Coweb use in English composition. In Stahl, G., editor, *Proceedings of CSCL 2002*, pages 435–442.

Roschelle, J. (1996). Learning by collaborating: Convergent conceptual change. In Koschman, T., editor, *CSCL: Theory and Practice of an Emerging Paradigm*, pages 209–248. Lawrence Erlbaum Associates.

Rosenørn, T. and Kofoed, L. B. (1998). Reflection in learning processes through simulation/gaming. *Simulation & Gaming*, 29(4):432–440.

Schank, R., Fano, A., Bell, B., and Jona, M. (1994). The design of goal-based scenarios. *The Journal of the Learning Sciences*, 3(4):305–345.

Scott, S. D., Mandryk, R. L., and Inkpen, K. M. (2002). Understanding children's interactions in synchronous shared environments. In Stahl, G., editor, *Proceedings of CSCL 2002*, pages 333–341. Lawrence Erlbaum Associates.

Senge, P. M. (1990). *The Fifth Discipline: The Art and Practice of The Learning Organization*. Doubleday.

Shore, B. (1996). *Culture in Mind: Cognition, Culture, and the Problem of Meaning*. Oxford University Press, New York, NY.

Shubik, M. (2002). The uses of teaching games in game theory classes and some experimental games. *Simulation & Gaming*, 33(2):139–156.

Solan, E. (2000). Absorbing team games. *Games and Economic Behavior*, 31:245–261.

Standing, E. M. (1957). *Maria Montessori, her life and work*. A Plume Book.

Starr, P. (1994). Seductions of sim. *The American Prospect*, Spring 1994:19–29.

Straffin, P. (1993). *Game Theory and Strategy*. Mathematical Association of America, Washington DC.

Tansey, P. J. and Unwin, D. (1969). *Simulation and gaming in education*. Methuen Educational Ltd, London, UK.

Turkle, S. and Papert, S. (1991). Epistemological pluralism and the revaluation of the concrete. In Harel, I. and Papert, S., editors, *Constructionism*, pages 161–191. Ablex Publishing Corporation.

Von Neumann, J. and Morgenstern, O. (1953). *Theory of Games and Economic Behavior*. Princeton University Press, New Jersey.

Vygotsky, L. S. (1978). *Mind in Society: The Development of Higher Psychological Processes*. Harvard University Press.

Webb, N. M. and Palincsar, A. S. (1996). Group processes in the classroom. In Berliner, D. C. and Calfee, R. C., editors, *Handbook of Educational Psychology*, pages 841–873. Simon & Schuster Macmillan.

Zagal, J. P., Nussbaum, M., and Rosas, R. (2000). A model to support the design of multiplayer games. *Presence*, 9(5):448–462.