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Playing a Social Dilemma Game as an Exploratory Learning Activity Before Instruction Improves Conceptual Understanding

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Society's most pressing problems involve social dilemmas, yet few individuals recognize and understand their core components. We examined how a serious social dilemma game used in an educational setting impacted understanding of a classic social dilemma, the tragedy of the commons. Participants ($N = 186$) were randomly assigned to one of two gameplay conditions or a Lesson-Only condition without the game (traditional lesson with a reading). In the Explore-First condition, participants played the game as an exploratory learning activity before the lesson. In the Lesson-First condition, participants played the game after the lesson. Both gameplay conditions were rated as more interesting than the Lesson-Only condition. However, participants in the Explore-First condition exhibited higher conceptual understanding and spontaneous transfer to real-world dilemmas than the other conditions, which did not differ. These benefits were selective to social concepts (e.g., self-interest, interdependency) explored via gameplay. These benefits did not occur for ecological concepts (e.g., scarcity, tragedy), which were taught to everyone during the beginning instructions. Policy preferences were equal across conditions. Serious social dilemma games offer a promising educational tool for conceptual development when students can explore the complexities of social dilemmas for themselves.

Public Significance Statement

Most problems in society stem from complex social dilemmas. This study suggests that individuals (college students) may learn important concepts about these dilemmas better if they first explore those concepts by playing a game which simulates the real-world dilemma, before being taught about those concepts. Using social dilemma games as an educational and scientific tool may facilitate student-learning and provide insight into the learning process.

Keywords: exploratory learning, social dilemma, common pool resource dilemma, serious game, productive failure

The ecological systems humanity requires for survival have been severely degraded by human activity (Steffen et al., 2015). Each day, we all make seemingly benign decisions that have social, ecological, and societal consequences (Cornforth, 2009; Gifford, 2011). Our individual decisions about how to travel (e.g., to/from school, work), what foods and products to purchase and where to purchase them (e.g., locally, online), where to live (e.g., city, rural town), and what kinds of dwellings to live within (e.g., single-family homes, high-rise apartment complexes) contribute collectively to local, regional, and global resource scarcity (e.g., water depletion, deforestation), climate change, and myriad other forms of ecological degradation (e.g., Attari et al., 2010; cf. Grimm et al., 2008). These problems arise because humans inhabit social–ecological systems: people, societies, and ecosystems are inextricably linked. These linkages are complex (Liu et al., 2007), making them difficult to understand (e.g., Attari et al., 2017; cf. Moser & Ekstrom, 2010; Weber & Stern, 2011).

Ecological problems fundamentally involve *social dilemmas*, situations that tempt individuals to behave selfishly, without regard for societal impacts (Parks et al., 2013). In Hardin's (1968) classic

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example of the tragedy of the commons, cattle farmers in the 17th century were said to have destroyed the scarce forest, pasture, and water resources they needed to graze their cattle, due to insatiable rivalry for larger, economically valuable personal herds. This dilemma continues worldwide, driven by accelerated consumer demand for beef cattle (Goldman et al., 2020). For example, in the Midwestern United States, the Ogallala aquifer supplies 30% of groundwater used for U.S. agricultural production. Large regions of this aquifer are being rapidly depleted due to water-intensive cattle farming, poor coordination, and competition among farmers (e.g., Royte, 2016; cf. Spiegal et al., 2020).

Although social dilemmas underly the major social–ecological problems societies confront (Ostrom, 1998, 2010), few individuals are aware of this contingency (DeCaro et al., 2017). This basic information is necessary for more effective societal cooperation and public policy, to ensure humanity's welfare and global sustainability (Folke et al., 2002; Ostrom, 1998). It may, therefore, be beneficial for the public to learn core characteristics of social–ecological systems and their associated dilemmas (Baird et al., 2014; Blackmore, 2007). Such knowledge may also be useful for addressing other kinds of social dilemmas, such as *public good dilemmas*, in which a collective contribution or effort is required to provide something beneficial for society (e.g., charity, public infrastructure, climate-change mitigation, systems of government; Eisenack, 2013; Ostrom, 1996).

The current experiment examined one way to educate individuals about key concepts of social dilemmas—using serious social dilemma games in an educational setting. Specifically, we examined (a) the effects of gameplay compared to more traditional passive instruction without a game (i.e., lesson and reading) and (b) the timing of gameplay (i.e., before or after traditional instruction). To better understand potential learning principles underlying individuals' conceptual knowledge development, we informed this research with educational theory and prior empirical work on exploratory learning. *Exploratory learning* is a constructivist-inspired, guided discovery learning technique in which individuals attempt a novel problem or activity themselves prior to formal instruction. This method is often used in science, technology, engineering, and math (STEM) education (DeCaro & Rittle-Johnson, 2012; Loibl et al., 2017; Schwartz et al., 2011; Weaver et al., 2018). STEM education has important similarities to learning in social dilemmas, as both involve developing key concepts within complex systems (cf. Blackmore, 2007; Wouters et al., 2013). The present study, therefore, experimentally examined whether and how games can be used to improve understanding of critical social dilemma concepts.

Serious Social Dilemma Games

Despite their central importance to society, core concepts of social–ecological systems and social dilemmas are rarely taught in public education. However, these concepts are increasingly being taught to individuals directly involved in specific real-world dilemmas, via *serious social dilemma games* (Barreteau et al., 2007). Serious games educate individuals about complex topics through *gamification*: Core concepts are translated into interactive, playable simulations. These simulations allow individuals to experience critical concepts (Wouters et al., 2013), such as the social and ecological dynamics of social dilemmas, in constrained, easier-to-understand formats (den Haan & van der Voort, 2018; Falk et al., 2021; Flood et al., 2018). Many social dilemma games exist, teaching core concepts in various domains, such as management of forests (Cardenas et al., 2013), groundwater (Meinzen-Dick et al., 2018), bay-areas (Learmonth et al., 2011), climate change (Eisenack, 2013), and cattle farming (García-Barrios et al., 2011).

There is an active research area examining principles of learning via gamification (Sailer & Homner, 2020; Wouters et al., 2013). Serious games have generally been shown to increase conceptual understanding of core topics compared to more traditional instruction alone (e.g., lecture). These learning benefits may be enhanced when games are combined with traditional educational methods (Wouters et al., 2013). Social dilemma researchers typically examine which factors of game design contribute to conceptual understanding (e.g., realism, individual vs. group play; den Haan & van der Voort, 2018; Flood et al., 2018).

Among field researchers and practitioners, games are typically used as an experiential, exploratory learning device. Individuals explore the topic by playing the game, then engage in either a formal lesson or interactive, conceptual debriefing session with fellow players and/or community members (den Haan & van der Voort, 2018; Flood et al., 2018). Early descriptive evidence suggests that such approaches have a greater likelihood of triggering beneficial change in the social dilemmas under study, compared to situations where formal instruction and debriefing are absent. For example, Meinzen-Dick et al. (2018) found that a groundwater management game followed by community education and debriefing resulted in measurable improvements to community-level cooperation, rule-making, and groundwater sustainability in Andhra Pradesh, India. García-Barrios et al. (2011, 2017) reported comparable effects for cattle and coffee farming in Chiapas, Mexico.

However, the specific timing/order of gameplay versus traditional instruction has not received systematic, experimental attention. Additionally, there is variability in the way games are used both in practice and education, which has potentially important implications for learning. *Exploratory learning*, where individuals discover core concepts themselves prior to formal instruction, is thought to engage trial-and-error learning and problem-solving processes (Ostrom, 1990; Ostrom, 2005) associated with deeper conceptual learning (Darabi et al., 2018; DeCaro & Rittle-Johnson, 2012; Kapur, 2015; Loibl et al., 2017; Sinha & Kapur, 2021). Hence, there may be substantial benefits specifically to exploration via gameplay versus the typical, lesson-then-practice approach that is more widely used in educational settings. A formal test comparing these methodologies (i.e., Explore-First vs. Lesson-First) would inform educators and practitioners as to which approach is best suited for promoting conceptual understanding of core concepts in social dilemmas.

Core Concepts of Complex Social Dilemmas

The first step in addressing complex social dilemmas is recognizing their core features (Ostrom, 1990; Ostrom, 2005). Most social dilemmas have two core features: self-interest and interdependency (Hardin, 1968). *Self-interest* refers to the tendency for individual selfish behavior. This feature also refers to the way social dilemmas, by virtue of their inherent reward structures (i.e., payoff schemes), tempt individuals to behave more selfishly via some form of competition (i.e., rivalry) or personal advantage (e.g., free-riding on others' efforts). *Interdependency* refers to the linkages between individuals: individual decisions affect every dilemma stakeholder, directly or indirectly. These components are thus social in nature (i.e., social dimensions).

Resource dilemmas, social dilemmas with a central ecological component, introduce two additional, ecological features: scarcity and tragedy (Hardin, 1968). In a typical resource dilemma, individuals compete for access and usage of a finite (i.e., *scarce*), ecological resource, such as water, oil, timber, or land. *Tragedy* occurs when the resource is extracted faster than the resource pool can replenish, thereby collapsing the resource and its associated ecosystems. Dilemma stakeholders must recognize and understand both the social and ecological dimensions of the dilemma in order to properly manage the situation (Ostrom, 1990; cf. Blackmore, 2007).

In social dilemmas, stakeholders typically realize they are embedded within a dilemma and may gradually learn its key features via careful observation and iterated learning, in which they try various solutions, observe the social and ecological outcomes, revise their conceptual understanding, and then try new solutions. When successful, this learning process is costly and may continue for years, or generations (Ostrom, 1990; Ostrom, 2005). When unsuccessful, the ecosystem and its linked societies may eventually collapse (e.g., Selby et al., 2017; van der Heijden et al., 2015; cf. Butzer, 2012; Hardin, 1968).

Serious social dilemma games can facilitate this learning process via simulation. Players can experience key features, dynamics, and consequences of their decisions in the simulated dilemma faster and with greater (i.e., more obvious) feedback, helping them learn contingencies more quickly (Baird et al., 2014; Flood et al., 2018).

Exploratory Learning

In order for individuals to understand social dilemmas, they must accurately perceive their own knowledge gaps and the deep structure of the focal problem (Blackmore, 2007; Ostrom, 1990; Ostrom, 2005). Exploratory learning is an instructional method that has been previously shown to elicit these kinds of learning processes, primarily in other STEM education settings, such as math and physics (e.g., Loibl et al., 2017; Weaver et al., 2018).

More traditional, tell-then-practice educational methods may elicit more passive attention and superficial learning (e.g., memorization of facts, rather than conceptual elaboration and comprehension; Bjork, 1994; Bonawitz et al., 2011). Specifically, prior research indicates that students are more likely to experience fluency with traditional instruction—well-organized information reduces the need for learners to organize and elaborate on concepts themselves. This fluency leads to an illusion of understanding, whereby students think they understand the material better than they actually do. Thus, during a traditional lecture, students may devote superficial attention and effort that does not translate into deeper understanding (Bjork, 1994; DeCaro & Rittle-Johnson, 2012; Gerjets et al., 2004). By organizing the most relevant knowledge for students, the instructor may also decrease students' opportunity to encounter and make sense of key concepts and problem features. Students may, therefore, be more likely to harbor misconceptions, without having those misconceptions challenged via personal experience or mistakes made while working with the concepts themselves (e.g., Hartnett & Gelman, 1998; McNeil & Alibali, 2005). Information may be learned more quickly (e.g., Kirschner et al., 2006), but students do not necessarily learn why particular concepts or problem features are, or are not, important. By narrowing the topic for students, instructors may inadvertently discourage learners from questioning key concepts, considering new ideas, or considering how newly received information may connect with prior knowledge and future lessons (Bonawitz et al., 2011; Schwartz & Bransford, 1998). Thus, by foreshadowing key concepts, more traditional lecture-then-practice approaches may overshadow proactive forms of self-directed, discover-based learning that facilitate conceptual development. These mechanisms have been identified as some of the primary reasons traditional instruction sometimes yields poorer conceptual knowledge development than anticipated.

By exploring a new topic without prior conceptual guidance, learners bring their prior knowledge to the situation, and begin to recognize where that knowledge falls short (Glogger-Frey et al., 2015). They may make predictive errors or experience violations of prior assumptions. This experience can lead to "productive failure" (i.e., learning from mistakes; Kapur, 2015), and increase curiosity and motivation to learn more (Lamnina & Chase, 2019; Wise & O'Neill, 2009). In social–ecological dilemmas (e.g., Ostrom, 1990), and field/lab experiments (e.g., Cardenas et al., 2013; Janssen et al., 2010; cf. Ostrom, 2006), stakeholders often experience an initial period of failure, mismanaging the dilemma and causing crisis or tragedy. This period of failure is thought to be beneficial for future performance (Ostrom, 1998; Ostrom, 2005), motivating individuals to learn from their mistakes and search for solutions (DeCaro et al., 2021).

Exploratory learning can also heighten attention to diagnostic features. When learners explore the problem space, they learn from trial-and-error, updating their conceptualization of the space and its important features as they attempt various solutions (DeCaro & Rittle-Johnson, 2012). These processes are thought to prepare learners to learn more deeply from subsequent instruction (Loibl et al., 2017; Schwartz et al., 2011; Schwartz & Martin, 2004). In social–ecological dilemmas, self-directed trial-and-error learning is thought to be how dilemma stakeholders discover and develop an in-depth understanding of key features and drivers of the dilemma (Anderies & Janssen, 2013; Ostrom, 1990; Ostrom, 2005). Exploratory learning processes therefore seem to align with the naturally occurring Bayesian learning processes seen and described in social dilemmas.

In studies primarily done with more traditional STEM topics (e.g., math, physics), students who explore before instruction often demonstrate better understanding of core concepts and ability to transfer knowledge (e.g., key concepts) to new, but related materials (e.g., Arena & Schwartz, 2013; Chin et al., 2016; Darabi et al., 2018; Loibl et al., 2017; Schwartz & Bransford, 1998; Schwartz & Martin, 2004; Weaver et al., 2018). However, we have not found prior studies that used serious social dilemma games for the exploration activity. We anticipate that similar learning mechanisms are involved for social dilemmas and that exploratory learning combined with a serious game may be an especially effective learning technique in this domain.

The Present Study

The present study examined whether exploratory learning with a serious game improves conceptual understanding of social dilemmas compared to more traditional approaches, with and without games. Participants learned about social dilemmas, contextualized within the example of a real-world analog to Hardin's (1968) classic cattle farming resource dilemma, taking place in the United States' Ogallala aquifer region.

There were three learning conditions. Participants in the *Explore-First condition* played a cattle farming social dilemma game before receiving a lecture on the social dimensions of the dilemma (Game 1). Afterward, they played the game again as conceptual consolidation (Game 2), which has been shown to be important in prior exploratory learning research (Loehr et al., 2014). Participants in the *Lesson-First condition* received the lecture before playing Game 1. Thus, Games 1 and 2 served as conceptual consolidation of the lesson. This design experimentally controls for the activities given and time-on-task across the two gameplay conditions. Such experimental control has been lacking in some prior exploratory learning studies (cf. Hsu et al., 2015).

Participants in the *Lesson-Only condition* received the lecture along with core rules and features of the game, without playing the game. Afterward, these participants read a detailed article about the Ogallala cattle farming dilemma. Thus, the Lesson-Only condition served as a comparison condition (see Wouters et al., 2013) to test the overall impact of playing the game (i.e., Lesson-First, Explore-First) versus a more typical educational approach, involving lecture and a reading. If conceptual understanding can be developed equally or better with this more traditional format, then the added time and instructional complication associated with a serious game may not be warranted.

After the learning activities, participants completed a survey and learning quiz. The survey assessed interest and asked participants to indicate their willingness to support economic and environmental policies to address the dilemma. To assess a range of cognitive learning outcomes, the quiz assessed both recall (essay questions) and recognition (multiple-choice questions) for the core social and ecological dimensions of the focal dilemma. We also assessed knowledge transfer, examining participants' recognition of additional resource dilemmas and a new type of social dilemma not taught or encountered during the session (i.e., public good dilemma). We also noted differences in participants' unprompted connections to real-world social dilemmas in their written essays.

Communication

The two-game sequence (Game 1, Game 2) used in the gameplay conditions (Explore-First, Lesson-First) also provided participants with a chance to experience the social–ecological dilemma with and without communication. Initial failure within a social dilemma is thought to be a necessary learning experience, highlighting important problem features and motivating improvement. Initial failure frequently occurs in real-world dilemmas when key stakeholders do not communicate. Communication is a powerful tool to help dilemma stakeholders learn from experience and devise cooperative solutions (DeCaro et al., 2021; Ostrom, 1990). Therefore, researchers who use serious social dilemma games to study or facilitate group cooperation often have a period without communication followed by communication (e.g., Cardenas et al., 2013; García-Barrios et al., 2015; Meinzen-Dick et al., 2018; cf. den Haan & van der Voort, 2018).

We implemented the same approach to better emulate real-world dilemmas and these practices. During Game 1, players in both gameplay conditions were not allowed to communicate. During Game 2, players could communicate. This design element was intended to facilitate learning in both conditions, as individuals may share insights that inform other players. If receiving a lecture about the core concepts and features of a social dilemma facilitates learning from experience (Lesson-First condition), then such communication may be enhanced, enabling participants to communicate more effectively about key dilemma concepts and features—thereby facilitating deeper conceptual insight. Alternatively, if exploring the dilemma before receiving the lecture facilitates better learning from experience, then communication should be more beneficial in the Explore-First condition, promoting better conceptual understanding. These conceptual benefits should be revealed in assessed learning outcomes.

Learning Outcomes

Our learning outcomes focused on what serious game researchers typically define as cognitive (i.e., conceptual) knowledge (Baird et al., 2014). Exploratory learning typically benefits conceptual understanding and transfer, rather than procedural learning or recollection of simple facts (Loibl et al., 2017; Schwartz & Bransford, 1998; Schwartz et al., 2009). Thus, we predicted that any potential benefits of exploratory learning would be most evident on items assessing conceptual knowledge.

In the current experiment, we had two forms of assessment: essay and multiple choice. Both assessments gauged conceptual understanding. However, multiple-choice items provide additional cues (e.g., response options), which may aid memory and provide conceptual clues. In contrast, essay questions require learners to retrieve conceptual knowledge without such aid (Craik, 1983). Exploratory learning may help learners develop their own conceptual cues that facilitate recall (Schwartz et al., 2007, 2009). Thus, if conceptual understanding is stronger in the Explore-First condition, we may expect this effect to be especially evident in the essay responses.

All participants were taught the core ecological elements of the game as part of the basic rule-set and game instructions. Thus, individuals did not discover those ecological dimensions for themselves in any condition. However, the social dynamics of the dilemma—and links between social behavior and the ecological elements—were not discussed. This design feature meant that participants in the Lesson-First and Explore-First conditions experienced these dimensions firsthand via gameplay. However, only participants in the Explore-First condition experienced these dimensions via explorative gameplay, during Game 1.

An initial exploration phase may activate the aforementioned learning mechanisms associated with self-directed discovery (prompting conceptual elaboration, recognizing core problem features, increasing awareness of knowledge gaps), better preparing individuals to learn from their misconceptions and mistakes (Loibl et al., 2017; Schwartz & Martin, 2004). We therefore expected playing Game 1 as an exploratory activity in the Explore-First condition to benefit conceptual knowledge development more strongly than in the Lesson-First and Lesson-Only conditions. We expected these benefits to be selective to the social dimensions of the dilemma, because these dimensions were explored without any prior educational instruction.

We also hypothesized that participants in the Explore-First condition would demonstrate greater knowledge transfer. Greater insight into key features of the resource dilemma should facilitate transfer of the underlying elements to real-world dilemmas, evident in participants' essays (cf. Schwartz et al., 2011). Finally, though we are not aware of research that has examined presentation order, prior research indicates that learning outcomes from serious games paired with educational instruction are typically higher than those from traditional instruction alone (e.g., Wouters et al., 2013). Therefore, we expected conceptual learning in the Lesson-First and Explore-First conditions to be greater than the Lesson-Only condition.

Interest

Interest is an important short- and long-term motivational driver of learning and conceptual development. Individuals who are interested in an educational topic typically exhibit greater engagement and persistence, contributing to improved learning (Hidi & Renninger, 2006; Ryan & Deci, 2020). Effects of serious games, and of exploratory learning, on aspects of motivation (e.g., interest) are mixed (e.g., Glogger-Frey et al., 2015; Newman & DeCaro, 2019; Weaver et al., 2018; cf. Wouters et al., 2013). We expected interest to be higher in the gameplay conditions compared to the Lesson-Only condition in the present experiment, because the game contained many elements associated with interest and engagement (e.g., multiple players, complex game mechanics, monetary stakes). Interest may also be comparatively higher in the Explore-First condition, versus the Lesson-First condition, if the novelty and surprise associated with exploration is able to surpass the already high interest associated with playing the game. We therefore included a standard measure of interest, as a potential correlate of motivational engagement. Perceived importance of the social dilemma topic was also measured for this reason.

Policy Preferences

In behavioral economic and field-study applications of serious social dilemmas games in actual dilemma settings, researchers often examine potential community-level and policy outcomes of the game, as an indicator of success (e.g., Meinzen-Dick et al., 2016, 2018). Our participants, university students, were not focal actors (e.g., farmers) in the current dilemma; they were indirect actors linked by their consumer behavior and potential public policy preferences. Therefore, we assessed willingness to support costly public policies designed to ameliorate the cattle farming social dilemma, as a potential indicator. If better conceptual understanding of a social dilemma facilitates a perception of responsibility and efficacy to act, then participants in the Explore-First condition might also show an increased willingness to support these policies. However, many other factors contribute to policy choice and action (e.g., conceptual debriefing, expert and community discussion; Flood et al., 2018; Meinzen-Dick et al., 2018), so increased knowledge may not be sufficient (cf. Cornforth, 2009; McKenzie-Mohr, 2000).

Method

Transparency and Openness

In keeping with APA requirements for transparency and openness in research, we report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study. Sample size was determined using conventions based on the sample sizes reported in prior education (e.g., Newman & DeCaro, 2019; Weaver et al., 2018) and resource dilemma experiments (e.g., Cardenas et al., 2013; Janssen et al., 2010) that inspired the present study, with the assumption of small/moderate effect sizes. From this information it was determined that approximately 60 participants per condition would be sufficient to test the hypothesized effects. For conditions involving gameplay (e.g., Explore-First), this value translates into approximately 15 four-person groups. Sample size was also constrained by the challenge of securing four individuals available to play a game for 2 hr the same day and time. When arrivals to run a game session were insufficient, individuals were invited to complete the *Lesson-Only* condition.

Because we did not conduct an a priori power analysis, we used *G*Power* (Version *3.1.9.7*) to conduct a post hoc sensitivity analysis (Faul et al., 2007). With an obtained 186 participants and desired power of at least 80%, our primary analyses involving mixed-factorial analysis of variance (ANOVA; three conditions, two-instance repeated measures) exhibited sufficient sensitivity to detect small main effects (between: $\eta_p^2 = 0.05$, within: $\eta_p^2 = 0.03$) and interactions ($\eta_p^2 = 0.02$). Planned comparisons probing hypothesized differences between the Explore-First and Lesson-First conditions could detect small/medium effects ($d = 0.37$). Thus, the current sample size provided sufficient sensitivity to test our key hypotheses.

This study's hypotheses, research design, and analytic plan were not preregistered. The hypotheses, research design, procedures, materials, and analytical plan were reviewed and approved by the University's human subjects institutional review board to ensure ethical treatment of participants (institutional review board No. 18.1057). We describe the analytic procedures in this article. We also describe the coding criteria used to code participants' answers to the open response questions. Data, experimental materials, and information about the analytical procedures are available by contacting (e.g., emailing) the corresponding author.

Participants

Undergraduate students ($N = 186$, $M_{\text{age}} = 19.56$, $SD = 1.76$, 56.5% female) completed the study for partial fulfillment of psychology course requirements. Three additional participants were excluded from the dataset due to experimenter error (giving the incorrect survey, $n = 2$) or for giving illegible responses on the learning quiz essay items ($n = 1$). In addition to course credits, participants were paid based on an in-game economy, to create a compelling economic resource dilemma that allows for competition and rivalry. Participants could earn up to $16.75 based on their decisions in the game ($13) and learning quiz performance ($3.75). This payment system is standard practice in the interdisciplinary domains that inspired the present study (i.e., behavioral and experimental economics; e.g., Cardenas et al., 2013; Meinzen-Dick et al., 2016, 2018). In these disciplines, payoffs (economic consequences) are thought to be essential to engage participants cognitively and behaviorally, as self-interested economic agents (Hertwig & Ortmann, 2001; Ostrom, 2006). We included these elements to facilitate interdisciplinarity and acceptance by diverse scientific communities.

Design Overview

Participants were randomly assigned to one of three conditions: *Explore-First* ($n = 59$), *Lesson-First* ($n = 68$), or *Lesson-Only* ($n = 59$). The elements and timing of each condition are illustrated in Figure 1. The measures used in this study are listed in Table 1.

Figure 1
Procedure for Each Experimental Condition

Explore-First	Lesson-First	Lesson-Only
Core Rule Set	Real-World Example Lesson Core Rule Set Social-Dilemma Lesson	Real-World Example Lesson Core Rule Set Social-Dilemma Lesson
Game 1 (No Communication)	Game 1 (No Communication)	Read National Geographic Article *To The Last Drop*
Real-World Example Lesson Social Dilemma Lesson	Game 2 (Communication)	Survey
Game 2 (Communication)	Survey	Learning Quiz: *Essay* *Multiple Choice*
Survey	Learning Quiz: *Essay* *Multiple Choice*	
Learning Quiz: *Essay* *Multiple Choice*		

Materials

Resource Dilemma Game

We used a modified version of the cattle farming board game *Sierra Springs* (García-Barrios et al., 2011, 2015). In the standard game, four players ("farmers") manage individual cattle farms, with important local and regional social and ecological consequences. The game was developed as an instructional research tool to help quasinomadic farmers in the La Sepultra MAB (United Nations Educational, Scientific, and Cultural Organization "Man-in-the-Biosphere") nature reserve region of Chiapas, Mexico, recognize that their land-use decisions were resulting in cyclic collapse of forest, water, and cattle systems, severely degrading local ecological systems and farmers' livelihoods. Aggressive deforestation to make room for dense cattle populations triggered land erosion and water siltation that threatened drinking water for the cattle and villagers. This tragedy forced the farmers to move to new pastures where the vicious cycle repeated.

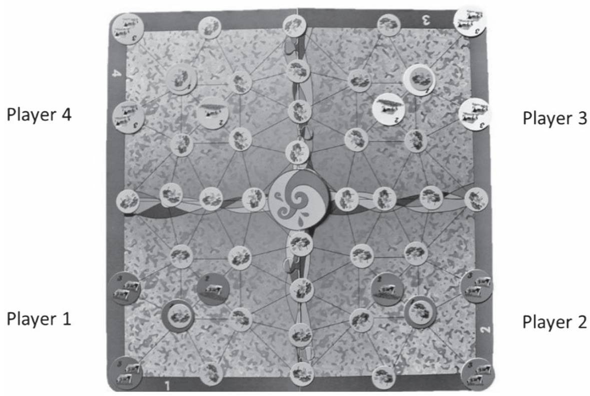
The core elements of this dilemma are simulated through several design features. Each player controls an individual farm, flanked by two other players (Figure 2). These private farm areas are separated by small creeks openly accessible by the two adjacent players. At the beginning of the standard game, the board is populated by trees (*forest tokens*). Each round, the active player decides whether to retain a forest token (leaving the forests unchanged), sustainably harvest timber from a particular forest location (by placing a *timber token* there), or raise cattle by replacing a forest token with a *cattle token* (this action symbolizes cutting down one area of forest to create a pasture). Timber and cattle tokens earn points equivalent to real monetary exchange after the game. Timber tokens are worth 1 point. There are two types of cattle tokens, a low-intensity token (2 points) and a high-intensity token (3 points). Thus, in this game, as in the actual dilemma, cattle are more valuable in the economy.

Ecological Dimensions. *Scarcity* is introduced by the limited number of available spots to play tokens. There are a total of 48

Table 1
Measures

Category	Format	Content
Learning		
Conceptual knowledge	Essay	Two items: Social (self-interest, interdependency) and ecological (scarcity, tragedy) dimensions of dilemma
		One item: Complex ecological dynamics
	Multiple choice	Five items: Social dimensions of dilemma (self-interest, interdependency)
		Three items: Ecological dimensions (scarcity, tragedy)
Transfer	Essay	Three items (Essays 1 − 3): Unprompted mention of real-world dilemmas (cattle farming, other specific or general)
	Multiple choice	Two items: Identify other resource dilemmas
		Three items: Identify public good dilemmas
Motivation		
Interest importance	Survey	Four items: Interest during lesson/game (learning activity)
		One item: Perceived importance of the topic/issue
Policy preferences	Survey	Six items: Willingness to support costly environmental policies to address the Ogalla cattle farming dilemma
Cooperation	Gini coefficient	Econometric index indicating the extent that group members shared the resource (earnings) equally

Figure 2
Sierra Springs Board Game



Note. Pictured is the modified initial setup we used.

available spots, but any single player only has access to 16. Eight spots are within the farm (private property) that an individual controls. Eight additional spots lie within the two creeks that separate each farm (four spots each). These latter spots are accessible to the two players whose farms border the creek (common property). The first person to use one of those spots becomes its current controller. Thus, there is scarcity over who controls commonly accessible spots within the creeks. There is also scarcity in terms of where, and how many, cattle tokens can be played. Low-intensity cattle tokens can be placed adjacently. However, high-intensity cattle tokens cannot be placed adjacently. Therefore, the presence of a high-intensity token in a particular location limits additional high-intensity cattle tokens from being played nearby. This limitation arises because high-intensity cattle farming exceeds localized ecological carrying capacity, resulting in devegetation, soil compaction, mudslides, and siltation, ultimately killing-off or starving the cattle. Two additional forms of scarcity exist. When an additional cattle token is played, a forest token must be removed. If 33 (69%) of the total 48 forest tokens are removed, then a critical deforestation threshold is reached, triggering soil degradation, mudslides, and siltation, threatening the entire region (i.e., all players lose if left unresolved). Additionally, each creek can only carry two cattle tokens: if a third cattle token is played there, siltation spoils the cattle's drinking water, causing potential die-offs. Thus, players confront a scarce supply of locations to play cattle tokens, which detrimentally affect finite forest and water resources.

Ecological tragedy is simulated via regional deforestation, localized creek collapse, and drinking water collapse. When deforestation reaches the critical threshold, all players lose the game (and their earnings), unless someone immediately removes a cattle token, replacing it with a forest token, thereby restoring ecological equilibrium. Similarly, when a creek is overladen with cattle, the creek collapses, resulting in die-offs unless a player immediately rectifies the situation. There is also a central spring with drinking water for the village: If the spring collapses due to overladen cattle, then all players lose, unless immediately remedied.

Social Dimensions. *Self-interest* is introduced via players' inherent desire for personal economic gain (Hardin, 1968). As in real-life, many individuals find themselves compelled to place increasingly more cattle tokens to maximize personal profits, driven by competition for scarce available resources and market opportunity. *Interdependency* exists because players' decisions affect other players. For example, playing a cattle token on the creek separating two players prevents the other player from using that spot. Choosing to place a high-intensity cattle token there additionally prevents the other player from playing high-intensity cattle tokens in the nearby areas within their own farm, because creek spots directly border private property locations on both players' sides (Figure 2). Furthermore, every additional cattle token played contributes to regional deforestation, affecting every player.

Modifications. We modified the standard setup to match the time constraints and objectives of this study. Pilot testing indicated that participants would encounter important social and ecological features (e.g., potential tragedy) faster if the game began with some cattle tokens already in play, effectively speeding up the game by a few rounds. Thus, in our configuration, the game started with one timber token, two high-intensity ("high") cattle tokens, and one low-intensity ("low") cattle token in play within each player's private pasture (Figure 2). These tokens were placed strategically to not interfere directly with other players' farms or available spots.

Players received \$0.25 for each point in play at the end of the game. Each forest token (1 point) was worth \$0.25; low cattle tokens (2 points), \$0.50, and high cattle tokens (3 points), \$0.75. If players coordinate and strive for equitable earnings, then it is possible for everyone to earn 26 points (\$6.50 per game). However, as in the actual dilemma, reaching such an optimal outcome is unlikely unless players communicate. More commonly, gameplay results in diverse strategies among the players, yielding suboptimal coordination and inequitable earnings.

We used the standard rules for deforestation and creek collapse. Regional deforestation was triggered if 33 (69%) of the forest tokens were cleared for cattle, and localized creek collapse was triggered if three cattle tokens were placed on a creek. The player that triggered an event could not resolve the event: instead, any other affected player could remedy the situation by immediately removing one of their own cattle tokens and replacing it with a forest token, restoring equilibrium. If regional deforestation was not remedied, then all players lost the game and their points/earnings. If a creek collapse was not remedied, all the cattle died on that creek. For simplicity, we did not use the drinking water game feature.

Lesson

The lesson consisted of three components, which were given at different times, depending on condition (see Figure 1). The *Core Rule Set* included basic gameplay instructions (rules, tokens, economy) and ecological dynamics in the game (e.g., regional deforestation, creek collapse). The *Real-World Example* discussed how the board game is an example of a real-world social dilemma (described as a decision-making situation) currently taking place among cattle farmers in the United States. This example was used to illustrate the concept of a social dilemma, and was based on the Ogallala Aquifer dilemma, described in the *National Geographic* magazine article *To The Last Drop* (Royte, 2016). The *Social Dilemma Lesson* described the four key components of a resource-based social dilemma, including social aspects (i.e., self-interest, interdependency) and ecological aspects (i.e., scarcity, tragedy). The lesson also discussed competition as an aspect of self-interest, and ecological complexities (e.g., deforestation thresholds, creek collapse) as broader elements of scarcity and tragedy. The lessons were prerecorded for consistency across conditions and lasted approximately 18-min total.

Learning Quiz

The learning quiz (Appendix A; see Table 1 for list of study measures) consisted of three essay questions and 15 multiple-choice questions. Participants were paid \$0.15 for each correct multiple-choice answer. Participants received \$0.50 for each essay question fully attempted, because it was not possible to score each essay question while conducting the experiment.

Essay

Two essay questions assessed conceptual understanding of the core social and ecological dimensions of the dilemma. Essay 1 asked participants to identify and explain the core features of a social dilemma (i.e., What are the key features or characteristics of a situation that make it a social dilemma? Briefly explain each feature). Essay 2 asked participants to explain how the cattle farming board game is a social dilemma, with examples drawn from the game (i.e., Briefly explain how the Cattle Farming Board Game is a social dilemma. What aspects of the game make it a social dilemma? Give examples from the game to explain your answer).

Responses to both questions were coded for core concepts, using the coding scheme in Appendix A. For each question, participants earned 1 point for each social dimension (self-interest/competition, interdependency) and ecological dimension (scarcity, tragedy) correctly identified and explained, requiring correct usage of concepts. Scores for each subscale (i.e., social, ecological) were summed between the two questions (4 points possible for each subscale). A second rater coded 50% of the responses (*interrater reliability*: social dimensions, *r*s = .72–.90; ecological dimensions, *r*s = .70–.95). Coders were blind to condition.

An additional essay question (Essay 3) was included to determine how many complex ecological concepts and dynamics participants understood (i.e., Briefly explain how the Cattle Farming Board Game is a complex environmental situation). Responses were scored for inclusion of six potential dynamics simulated in the game, such as ecological thresholds (e.g., deforestation thresholds) and interdependencies (e.g., adverse interactions for the type and location of cattle tokens); 6 points possible; (*interrater reliability: r*s = .59–.85).

Transfer. All three essay questions were also scored for evidence of spontaneous transfer. Participants received one point for each essay question in which they applied concepts to actual cattle farming (e.g., Ogallala) or other resource dilemmas. This scale was used to assess the extent that participants made conceptual links to real-world dilemmas, applying principles learned in the game or lesson to these dilemmas (*interrater reliability: r*s = .71–.91). Three types were identified: connections to cattle farming (e.g., Ogalla dilemma), connections to other dilemmas (e.g., household electricity bills, gun control), and general connections (e.g., worldwide environmental collapse). We documented these types of transfer, because prior research has identified failure to recognize real-world dilemmas as a barrier to their solution (Blackmore, 2007; Flood et al., 2018; cf. Ostrom, 1990, 1998). Transfer to cattle farming may be a form of near-transfer, recognizing the focal dilemma concept and underlying features. Transfer to another (isomorphic) dilemma, with similar underlying features but a different context/domain may be a form of far transfer (Barnett & Ceci, 2002; cf. Schwartz et al., 2011).

Multiple Choice

The multiple-choice items (Appendix A) asked participants to recognize important social and ecological concepts, and transfer knowledge to other dilemmas.

Social Dimensions. Five multiple-choice items, including true-false questions, assessed (a) participants' recognition of the core social dimensions of the social dilemma (e.g., Question: "What is a social dilemma?" Answer: "A situation where individual goals conflict with what is best for the group.") and (b) participants' ability to identify the effects of these dimensions within the game and real-world dilemma (e.g., "True or False: In social dilemma situations like the cattle farming situation in the United States' Ogallala Aquifer and the Cattle Farming Board Game …": "People's decisions do not affect other people"). The items were designed to assess different aspects of social dimensions, such that higher scores across the range of items indicated greater understanding of more dimensions. An additional item was later removed from the analyses because review indicated there was technically no correct answer.

Ecological Dimensions. The ecological multiple-choice questions primarily targeted basic concepts taught in the core rule-set (e.g., what happens when more than two cattle are placed on the same creek), rather than higher order concepts such as identifying or defining scarcity and tragedy. There were three items, assessing different aspects of the focal dilemma/game: localized creek collapse, localized impacts of intensive cattle farming, and regional deforestation.

Transfer. Transfer consisted of two items to assess participants' ability to recognize other kinds of resource dilemmas not encountered in the experiment (e.g., scarce fossil fuels). Three additional items assessed ability to recognize public good dilemmas, situations where individuals must contribute time or personal resources (e.g., money) to produce something beneficial for society (e.g., taxes, charitable blood drive). We also included one foil item.

Survey Items

All survey items used in this study are presented in Appendix B. Additional items assessing need satisfaction (e.g., self-determination, security) and cooperative motivation (e.g., acceptance of cooperative agreements) were also assessed as part of a separate study on psychosocial determinants of group cooperation, and are not reported here.

Interest

Four items (α = .93) assessed participants' reported interest during the experiment (e.g., "Today's experiment has been interesting"; adapted from Ryan, 1982). Responses were recorded using a 7-point Likert scale (1 = *strongly disagree*, 7 = *strongly agree*).

Importance

One item assessed perceived importance of the focal topic (i.e., "This experiment has been about cattle farming and potential social and environmental problems associated with it. How important is this topic to you?"). Responses were recorded on a 4-point scale (0 = *not important at all,* 1 = *a little*, 2 = *moderately*, 3 = *very important*).

Policy Preferences

Six items assessed potential differences in policy preferences associated with each condition. Four of these items assessed participants' support of specific costly economic and environmental conservation policies related to the focal dilemma (e.g., "If you were a farmer, would you be willing to support policies that reduce the number of cattle raised in the Ogallala Aquifer region of the United States?"). These policies pertained to (a) reducing the number of cattle raised in the Ogallala Aquifer region, (b) monitoring water use and requiring water conservation, (c) paying higher beef product prices to improve farmers' livelihoods and environmental conservation, and (d) paying higher product prices to reduce the number of forests being cut down for farms. Two items assessed general preference for change in U.S. cattle farming: (a) continue without change, or (b) increase production. Responses were recorded on a 4-point Likert scale (1 = *no, not at all*; 4 = *yes, completely*). Lower scores on the latter two items indicates greater desire for positive change and were reverse scored.

Procedure

The *Lesson-Only* condition was run in sessions of 1–12 participants, whereas *Explore-First* and *Lesson-First* conditions were run with 1–2 groups of four participants each, because each game required four players. Participants completed informed consent in a waiting room, where they were instructed not to speak with other participants, to ensure against potential relationships or impressions forming prior to the experiment. Then participants were led to a classroom with two tables and a large screen. Each group was randomly seated at separate tables with walled dividers between the groups. In the Lesson-First and Explore-First conditions, each table had the *Sierra Springs* board game and player score cards.

In the Explore-First condition, participants first watched the video on basic gameplay instructions (Core Rule Set, 8-min) before playing the first session of the board game (20-min). Then they were shown the video on the real-world and social dilemma lessons (10-min) before playing the game again (20-min). In the *Lesson-First* condition, participants watched the real-world dilemma lesson, basic gameplay instructions, and the social dilemma lesson, before playing the game twice. In both conditions, communication was allowed only during the second game. In the *Lesson-Only* condition, participants watched the real-world dilemma lesson, basic gameplay instructions, and the social dilemma lesson. Then they individually read the *National Geographic* article *To the Last Drop* (Royte, 2016), which the lesson was based on (up to 20-min). The article described an example of a cattle grazing resource dilemma in the Ogallala Aquifer in the U.S. Midwest. These participants did not play the board game.

After these activities, participants were seated in private computer stations in a nearby room to complete the survey and learning quiz (approximately 21-min). The learning quiz began with the recall (essay) items, then the recognition (multiple choice) items. Essay items were presented in fixed order. Multiple-choice and survey items were randomized within their respective sections. After receiving payment, participants were debriefed. Lesson-Only condition sessions lasted approximately 90-min, including informed consent, debriefing, and payment. Explore-First and Lesson-First sessions lasted approximately 120-min.

Results

Learning Quiz

Essay and multiple-choice test scores were examined using separate 3 (*condition*: Explore-First, Lesson-First, Lesson-Only) × 2 (*dimension*: social, ecological) mixed-factorial ANOVAs, with dimension as a within-subjects factor. Follow-up analyses for significant effects were conducted using Least Significant Differences tests because, unless noted otherwise, these were targeted planned comparisons based on a priori hypotheses.

Essay

As previously described, we combined the first two essay questions for analysis, because these questions both directly assessed the four features of a social dilemma (i.e., social: self-interest, interdependency; ecological: scarcity, tragedy). The third essay assessed knowledge of complex ecological dynamics and was therefore examined separately.

Core Concepts. For the first two essay questions, a significant main effect of condition was found, $F(2,183) = 3.54$, $p = .031$, $\eta_p^2 = 0.04$ (Explore-First: $M = 2.47$ out of 4 points, $SE = 0.12$; Lesson-First: $M = 2.05$, $SE = 0.12$; Lesson-Only: $M = 2.17$, $SE = 0.12$). A main effect of dimension was also found, $F(1,183) = 105.31$, $p < .001$, $\eta_p^2 = 0.37$. Learning scores were higher for the social dimensions ($M = 2.76$, $SE = 0.08$) than the ecological dimensions ($M = 1.69$, $SE = 0.12$). These effects were qualified by a significant interaction, $F(2,183) = 7.15$, $p = .001$, $\eta_p^2 = 0.07$.

An ANOVA including only social dimensions revealed a significant difference among conditions, $F(2,183) = 9.45$, $p < .001$, $\eta_p^2 = 0.09$. As shown in Figure 3, participants in the Explore-First condition ($M = 3.27$, $SD = 0.91$) scored significantly higher than those in the Lesson-First condition ($M = 2.53$, $SD = 1.23$), $p < .001$, $d = 0.68$, and the Lesson-Only condition ($M = 2.49$, $SD = 1.15$), $p < .001$, $d = 0.75$. Scores did not differ between the Lesson-Only and Lesson-First conditions, $p = .848$, $d = 0.03$.

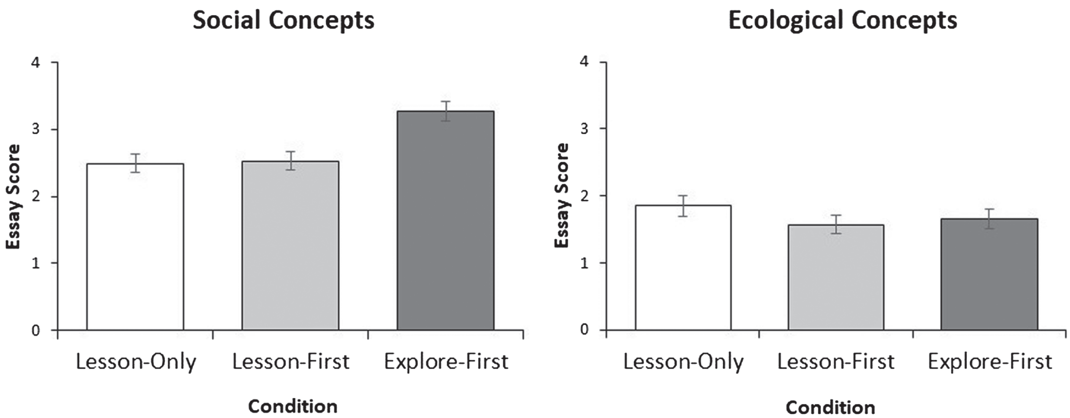
For the ecological dimensions, there was no effect of condition (Figure 3; Explore-First: $M = 1.66$, $SE = 0.15$; Lesson-First: $M = 1.57$, $SE = 0.14$; Lesson-Only: $M = 1.85$, $SE = 0.16$), $F < 1$.

Complex Ecological Dynamics. Essay 3 assessed participants' correct identification of six potential complex ecological features of resource dilemma within the game. This essay score was not significantly impacted by condition, with participants identifying approximately 1–2 features in each condition (Lesson-First: $M = 1.71$, $SE = 0.18$; Lesson-First: $M = 1.93$, $SE = 0.18$; Explore-First: $M = 1.72$, $SE = 0.17$), $F < 1$.

Transfer

We identified a total of 116 instances in which individuals made linkages to real-world dilemmas in their essay responses: 94 (81.03%) referred to cattle farming (e.g., in the Ogallala), six (5.17%) referred to another specific dilemma (e.g., sharing the bill for electricity in

Figure 3
Essay Scores for Social and Ecological Concepts



Note. Error bars represent standard error.

an apartment), and 16 (13.79%) made general linkages to real-world dilemmas (e.g., global impacts of unspecified local environmentally irresponsible behaviors). To determine whether individuals in a particular condition were more likely to make connections to real-world dilemmas, we counted the number of essay questions in which an individual mentioned a connection. There were three essays. Therefore, scores ranged from 0 to 3. There was a significant effect of condition, $F(2,182) = 4.59$, $p = .011$, $\eta_p^2 = 0.05$. As shown in Figure 4, individuals in the Explore-First condition ($M = 0.86$, $SE = 0.80$) mentioned real-world conditions across more essays than individuals in the Lesson-First ($M = 0.52$, $SE = 0.70$), $p = .007$, $d = 0.45$, or Lesson-Only ($M = 0.53$, $SE = 0.63$), $p = .012$, $d = 0.46$, conditions. No significant difference was found between Lesson-First and Lesson-Only conditions, $p = .933$, $d = 0.02$.

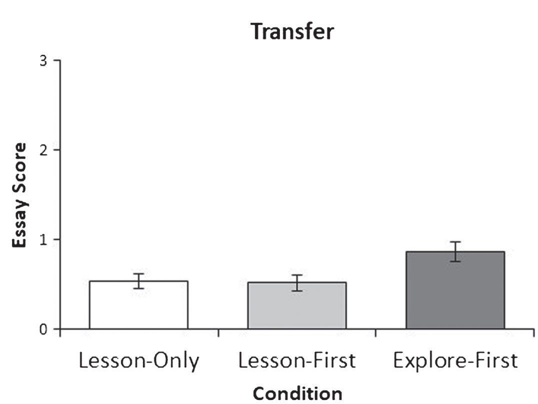
Surveys

Interest. Participants' reported interest differed by condition, $F(2,183) = 15.14$, $p < .001$, $\eta_p^2 = 0.14$ (Figure 5). Participants in the Lesson-Only condition ($M = 4.85$, $SE = 1.43$) reported significantly less interest than those in the Explore-First condition ($M = 5.71$, $SE = 0.96$), $p < .001$, $d = 0.71$, and Lesson-First condition ($M = 5.93$, $SE = 1.03$), $p < .001$, $d = 0.87$. Interest did not differ between Explore-First and Lesson-First conditions, $p = .296$, $d = 0.22$.

Importance. Participants rated the focal topic as highly important across all three conditions (Explore-First: $M = 2.47$ out of 3, $SE = 0.92$; Lesson-First: $M = 2.50$, $SE = 0.95$; Lesson-Only: $M = 2.73$, $SE = .81$), $F(2,183) = 1.46$, $p = .235$, $\eta_p^2 = 0.02$.

Policy Preferences. Participants reported similar support for various policies relevant to the cattle farming social dilemma across conditions (Explore-First: $M = 2.79$ out of 4, $SE = 0.47$; Lesson-First: $M = 2.69$, $SE = 0.46$; Lesson-Only: $M = 2.66$, $SE = 0.38$), $F(2,183) = 1.44$, $p = .240$, $\eta_p^2 = 0.02$.

Figure 4
Transfer to Real-World Dilemmas (Essay)



Note. Error bars represent standard error.

Multiple Choice

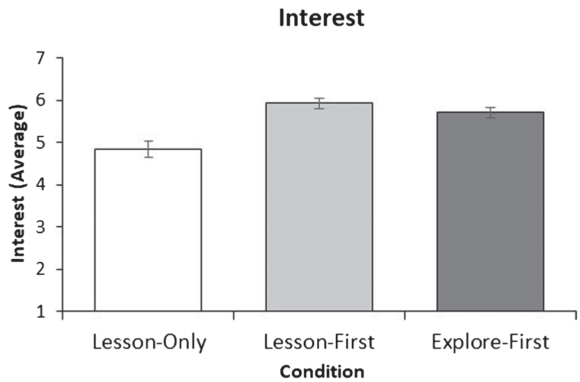
Core Concepts. For multiple choice, a significant effect of dimension was found, $F(1,183) = 104.77$, $p < .001$, $\eta_p^2 = 0.36$. Participants scored higher on items assessing ecological dimensions ($M = 91.84\%$, $SE = 1.26$) than social dimensions ($M = 78.90\%$, $SE = 0.91$). There was no effect of condition, $F(2,183) = 1.06$, $p =. 349$, $\eta_p^2 = .01$, or interaction, $F < 1$.

Transfer. Transfer to novel resource dilemmas did not differ by condition (Explore-First: $M = 65.25\%$, $SE = 3.87$; Lesson-First: $M = 70.59\%$, $SE = 3.95$; Lesson-Only: $M = 71.19\%$, $SE = 3.86$), $F < 1$. Transfer to public good dilemmas also did not differ by condition (Explore-First: $M = 71.75\%$, $SE = 3.68$; Lesson-First: $M = 64.71\%$, $SE = 3.41$; Lesson-Only: $M = 67.80\%$, $SE = 3.51$), $F(2,183) = 1.02$, $p = .364$.

In-Game Behavior and Outcomes

To help interpret the results for the learning outcomes, we conducted exploratory analyses examining in-game behavior and outcomes in the Explore-First and Lesson-First conditions. During each game, we recorded major events (e.g., creek collapse triggered, creek collapse occurred). If participants learn differently from experience in these conditions, then the number of events individuals encountered may be important. Participants' earnings during

Figure 5
Average Reported Interest



Note. Error bars represent standard error.

Games 1 and 2 were also recorded. This information can be used to determine the extent to which group members shared the available resources (earnings) equally—a common indicator of cooperation and success in the Sierra Springs board game, which may serve as an additional indicator of learning in the present study (García-Barrios et al., 2011, 2017).

Events

In this social dilemma game, participants experience the basic social and ecological dynamics with every action they take. Individual decisions affect the supply of available spots to play tokens, types of tokens that can be played, and ecological processes. However, triggered events and resource collapse are especially impactful, representing crises. A total of 47 events occurred during Game 1: Creeks were placed in jeopardy (i.e., potential collapse triggered) 21 times; creeks collapsed 6 times; potential deforestation was triggered 19 times; deforestation occurred 1 time. There were 38 events during Game 2: Creeks placed in jeopardy 35 times, and creeks collapsed 3 times. We examined (a) whether more events occurred in a particular condition, (b) how many groups in each condition experienced at least one event, and (c) how experiencing one of these events may have been related to individual learning outcomes.

Total Number of Events. The total number of events did not significantly differ by condition: Game 1, Explore-First: 20 events, Lesson-First: 27 events; $\chi^2(6, N = 32) = 3.87$, $p = .695$; Game 2, Explore-First: 21 events, Lesson-First: 17 events; $\chi^2(5, N = 32) = 1.34$, $p = .931$.

Groups With at Least One Event. The total number of groups that experienced at least one event did not differ significantly by condition: Game 1, Explore-First: 10 groups, Lesson-First: 10 groups; $\chi^2(1, N = 32) = 0.21$, $p = .647$; Game 2, Explore-First: Seven groups, Lesson-First: Eight groups; $\chi^2(1, N = 32) = 0.00$, $p = .982$.

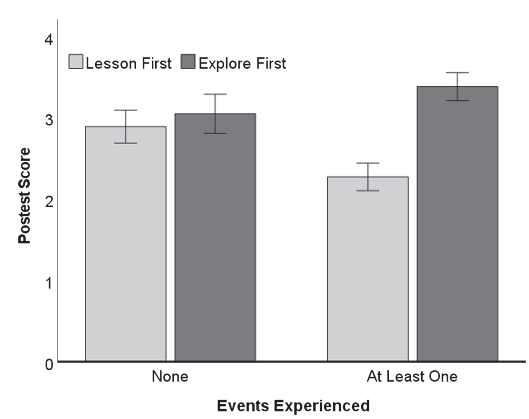
Learning Outcomes. The preceding analyses indicate that participants in the Explore-First and Lesson-First conditions experienced approximately the same number of events. To determine whether participants may have differentially learned from these events, we conducted a follow-up analysis, in which experiencing at least one event was treated as a moderator. We reanalyzed a subset of the learning outcomes using separate 2 (*condition*: Explore-First, Lesson-First) × 2 (*event:* none, at least one) factorial ANOVAs for Games 1 and 2. The results and conclusions for Games 1 and 2 were highly similar. We therefore report Game 1. Game 1 is also informative because it was participants' first opportunity to learn from experience. We restricted this analysis to the two learning outcomes that discriminated between conditions (i.e., essay social concepts, essay transfer), to understand how experience may have contributed to these outcomes. We used a Bonferroni correction when probing interaction effects.

The analysis was not significant for transfer, Fs < 1. For essay social concepts, as before, there was a main effect of condition (Explore-First: $M = 3.22$, $SE = .15$; Lesson-First: $M = 2.58$, $SE = .13$), $F(1,123) = 10.28$, $p = .002$, $\eta_p^2 = 0.08$. There was no overall difference associated with experiencing an event (none: $M = 2.97$, $SE = .16$; at least one: $M = 2.83$, $SE = .12$), $F < 1$, $p = .475$, $\eta_p^2 = 0.00$. However, these observations were qualified by a Significant Condition × Event Interaction, $F(1,123) = 5.81$, $p = .017$, $\eta_p^2 = 0.05$. As shown in Figure 6, across both conditions, participants who experienced no events performed similarly on the social concepts essay assessment (Explore-First: $M = 3.05$, $SE = .24$; Lesson-First: $M = 2.89$, $SE = .20$), $t(123) = 0.54$, $p = .617$, $d = 0.15$ (evaluated at Bonferroni-corrected $\alpha = .017$). In contrast, when participants experienced at least one event, participants in the Explore-First condition scored higher than those in the Lesson-First condition (Explore-First: $M = 3.39$, $SE = .17$; Lesson-First: $M = 2.28$, $SE = .17$), $t(123) = 4.93$, $p < .001$, $d = 1.04$. From Figure 6, it appears that participants in the Lesson-First condition may have exhibited worse understanding of social concepts in groups that experienced an event during Game 1. This effect did not reach conventional significance levels (i.e., Bonferroni-corrected $\alpha = .017$; none: $M = 2.89$, $SE = .20$; at least one: $M = 2.28$, $SE = .17$), $t(123) = 2.31$, $p = .021$, $d = 0.58$. However, this pattern is suggestive of a potential lack of improvement in the Lesson-First condition.

Cooperation

The equality of earnings is a common indicator of group cooperation or success in managing a limited resource (García-Barrios et al., 2011, 2017). To determine the extent to which group members shared

Figure 6
Social Concepts Essay Score as a Function of Experiencing at Least One Event in Game 1



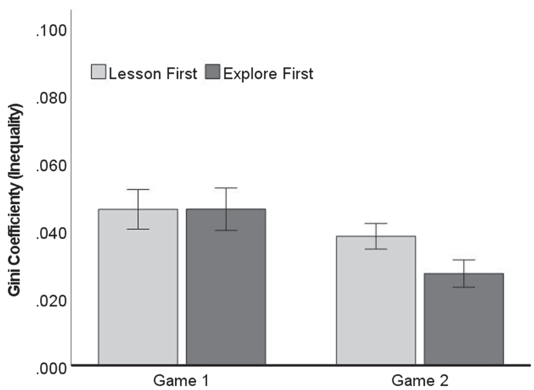
Note. Error bars represent standard error.

the available resources (earnings) equally, we computed the Gini coefficient of in-game earning inequality (Janssen, 2010). The Gini ranges from 0 to 1: Gini = 0.00 represents perfect equality (all four group members have equal earnings); Gini = 1.00 represents perfect inequality (a single person has all the earnings). Thus, lower scores indicate less inequality (i.e., more equal sharing of the resource). We computed this value for each group and compared the average Gini for the Explore-First and Lesson-First conditions. Note that with 32 groups ($n = 15$ explore-first, $n = 17$ lesson-first), the statistical power was low: a sensitivity test indicates that a moderate/large effect ($\eta_p^2 = 0.11$) is needed to detect an effect with this many groups. We therefore treat this analysis as descriptive and suggestive of future research directions.

We used a 2 (*condition*: Explore-First, Lesson-First) × 2 (*game*: Game 1, Game 2) mixed-factorial ANOVA, with game as a within-subjects factor, to investigate potential differences in resource sharing from Games 1 to 2 between conditions. We used a Bonferroni correction for follow-up analyses.

Overall, there was no main effect of condition (Explore-First: $M = 0.04$, $SE = .00$; Lesson-First: $M = 0.04$, $SE = .00$), $F(1,30) = .13$, $p = .296$, $\eta_p^2 = 0.04$. There was a main effect of game. On average, Gini scores decreased during Game 2, indicating improved resource sharing or equality (Game 1: $M = 0.05$, $SE = .00$; Game 2: $M = 0.03$, $SE = .00$), $F(1,30) = 7.11$, $p = .012$, $\eta_p^2 = 0.19$. This effect is equivalent to a 28.26% increase in equality. There was No Condition × Game Interaction, $F(1,30) = 1.20$, $p = .283$, $\eta_p^2 = 0.04$. However, as illustrated in Figure 7, the Gini scores were nearly identical between conditions during Game 1 (Explore-First: $M = 0.05$, $SE = .01$; Lesson-First: $M = 0.05$, $SE = .01$), but appear to differ nominally in Game 2 (Explore-First: $M = 0.03$, $SE = .00$; Lesson-First: $M = 0.04$, $SE = .00$). The Game 2 difference between conditions did not reach conventional significance levels, $t(30) = 1.96$, $p = .055$, $d = 0.55$. However, the increase in equality was equivalent to 17.39% in the Lesson-First condition, versus 41.30% in the Explore-First condition. Moreover, the apparent improvement to equality for the Explore-First condition from Game 1 to Game 2 (Figure 7), was significant (with Bonferroni-corrected $\alpha = .017$), and the effect size was large, $t(30) = 2.58$, $p = .015$, $d = 0.95$. Thus, there is tentative evidence that participants in the Explore-First condition may have improved equality, and therefore cooperation, compared the Lesson-First condition.

Figure 7
Gini Coefficient (Inequality) Game 1 Versus Game 2



Note. Error bars represent standard error.

Discussion

The world's most pressing ecological problems stem from social dilemmas (Ostrom, 1998). Yet, few people are aware of this contingency or the core features of such dilemmas (Hardin, 1968). Researchers and practitioners have begun to use serious social dilemma games to inform key stakeholders in real-world dilemmas (e.g., Flood et al., 2018; Meinzen-Dick et al., 2018). These projects seek to enhance stakeholders' understanding of complex social and ecological dynamics to improve cooperative outcomes and catalyze policy change. There is a need to understand when and how these interventions improve conceptual understanding (Anderies et al., 2011; den Haan & van der Voort, 2018). There is also a need to better inform the public in traditional educational settings, such as classrooms (e.g., Blackmore, 2007; cf. DeCaro et al., 2017).

We examined how playing a resource-based social dilemma game before (Explore-First) or after (Lesson-First) formal instruction about such dilemmas impacts conceptual understanding and knowledge transfer. We compared these conditions to a more traditional instructional method (Lesson-Only condition), in which participants received the same formal lesson and read an in-depth article about the real-world dilemma, without playing the game. The effect of switching the order of activity and instruction (i.e., exploratory learning) has been studied primarily in STEM education involving complex concepts (e.g., Hsu et al., 2015; Kapur, 2011, 2012, 2014; Schwartz et al., 2011; Weaver et al., 2018), where students typically explore math or science problems (Loibl et al., 2017). To our knowledge, such exploratory learning has not been investigated in the domain of serious social dilemma games. The current research, therefore, examined whether social dilemma games can be used as effective exploratory learning activities, while also providing further insights into the learning process.

Learning Outcomes

We did not find differences between conditions on multiple-choice quiz items assessing social and ecological concepts taught in the lesson. Instead, we found selective benefits of exploratory learning on written measures of conceptual understanding—essays that required greater independent thought and relatively unguided conceptual recall. These benefits were selective to social dimensions of the dilemma, not ecological dimensions.

This dissociation between social and ecological learning may be due to the differential impact of experiential learning versus direct instruction. The core ecological dimensions (scarcity: e.g., limited spots to play tokens; tragedy: e.g., deforestation) were directly taught to participants in every condition during the core rule-set presentation and game instructions, at the beginning of the experiment. However, the social dimensions (self-interest; e.g., greed, rivalry; interdependency: e.g., player decisions affect everyone) were not taught during the initial instructions. Participants in the Explore-First condition first encountered these dimensions for themselves while exploring Game 1. In contrast, participants in the Lesson-First and Lesson-Only conditions were taught these concepts upfront. The dissociation between social and ecological learning, and the observed learning advantage in the Explore-First condition for social learning, may indicate that the benefits of experiential learning in this context are selective to the specific conceptual dimensions that are explored firsthand during the exploration activity. Participants may have been more likely to reason deeply about the core social features of the dilemma as they discovered them firsthand (DeCaro & Rittle-Johnson, 2012; Loibl et al., 2017), preparing these individuals to learn at a deeper level from subsequent educational instruction on those concepts (Schwartz & Bransford, 1998; Schwartz & Martin, 2004).

The lack of difference between the Lesson-First and Lesson-Only conditions suggests that the benefits of gameplay for conceptual understanding are driven by the exploratory learning involved in the game. If a lesson is included prior to gameplay, the conceptual benefits of playing the game may be diminished. This speculation is consistent with our exploratory analyses of participants' conceptual understanding after having experienced at least one major event (e.g., creek threatened, deforestation) during Game 1. Participants in the Lesson-First and Explore-First conditions experienced approximately the same number of events. However, compared to the Lesson-First condition, participants in the Explore-First condition exhibited higher social concept scores on the written essays during final assessment. This pattern was highest in groups that experienced at least one adverse event in Game 1. This finding suggests that participants in the Explore-First condition may have been more likely to learn from these events, whereas participants in the Lesson-First condition were not. The pattern for the Lesson-First condition resembles observations of social dilemma and learning studies, where individuals fail to learn from their mistakes, becoming entrenched in their misconceptions (e.g., Janssen, 2010; McNeil & Alibali, 2005; Pahl-Wostl, 2009; Yu et al., 2016; cf. DeCaro et al., 2017; Schwartz et al., 2011). This finding is also consistent with learning research demonstrating that instruction-first methods may lead to quicker but shallower, less connected, and less flexible comprehension, as individuals more passively process the information, with less conceptual elaboration (Bjork, 1994; Gerjets et al., 2004; McNeil & Alibali, 2005; Schwartz et al., 2007).

These findings align with others demonstrating conceptual learning in naturalistic decision-making settings (Klein, 1998; Ostrom, 1990; Ostrom, 2005), as well as educational theory, suggesting that a degree of firsthand discovery and novelty (e.g., violation of basic assumptions) may facilitate deeper conceptual development (e.g., Loibl et al., 2017; Schwartz & Bransford, 1998). Because participants in the Explore-First condition were told the core ecological dimensions of the game before they played, they may have expected features such as resource scarcity and ecological tragedy (e.g., deforestation) to occur. This foreknowledge could make these features less salient, resulting in more limited conceptual elaboration (Bonawitz et al., 2011). Thus, the benefits of experiential learning may depend, in part, on novelty and saliency of key concepts encountered in the game, not just realism, duration, or amount of exposure. Future research may inform this hypothesis by experimentally manipulating which dimensions, ecological, or social, participants encounter via exploration.

Knowledge Transfer

An important purpose for using serious social dilemma games as an instructional tool is to encourage learners to transfer that knowledge to real-world dilemmas. Failure to recognize social dilemmas has been identified as a barrier to their solution (Blackmore, 2007; DeCaro et al., 2017). The benefits of in-game exploration did not extend to our multiple-choice measures of knowledge transfer. Those measures tested whether participants would recognize additional resource dilemmas and apply their knowledge of the core features of a dilemma to identify public good dilemmas (e.g., taxes, charitable blood donations)—a type of dilemma not encountered in the current experiment. However, potential evidence of differences in conceptual transfer surfaced in the written essays. Participants in the Explore-First condition were more likely to mention connections (examples, applications, inferences) to real-world social dilemmas. Most of these connections referred to cattle farming in the United States and social–ecological dilemmas more generally (e.g., global). However, some connections referred to novel resource dilemmas.

Field research suggests that transfer is more likely when serious social dilemma games are combined with postgame debriefing and discussion, in which players and members of the broader community actively discuss connections to their real-world situation (e.g., Meinzen-Dick et al., 2018; cf. den Haan & van der Voort, 2018; Flood et al., 2018). Exploratory learning with a game might encourage similar connections, increasing sophisticated conceptual representations in which individuals link their abstract conceptual knowledge to real-world examples. If so, then exploratory learning techniques, with subsequent formal education (akin to debriefing), may partially substitute for more rigorous and demanding summative dialog. However, if there is an important social learning component to knowledge development and transfer in this domain (e.g., García-Barrios et al., 2011, 2017; cf. Pahl-Wostl, 2009), then it is also likely that combining exploratory learning with rigorous summative dialog would yield superior learning outcomes. Because we did not specifically ask participants in any condition to make such connections, we cannot be certain that the observed difference in frequency of these "spontaneous" connections is not due to another factor, such as essay question wording. Future research would be helpful to more systematically test knowledge transfer in this domain, as well as whether transfer can be further enhanced with postgame debriefing and discussion.

In addition to recognizing social dilemmas, future research should examine learners' ability to specifically identify key features of various described social dilemmas (e.g., scarcity, interdependency). Doing so might provide more information about transferability, because knowledge of core features could aid identification of these features in other types of dilemmas. Such knowledge might also facilitate resolution of dilemmas, because solutions typically target and address the core features of the dilemmas, such as issues with scarcity and interdependency.

Motivational Outcomes

Participants recognized the importance of the topic, rating the topic as highly important in all conditions. They also exhibited equal support for conservation policies, serving as a proxy for potential policy change. However, participants who played the board game (Explore-First condition, Lesson-First condition) expressed greater interest than participants in the Lesson-Only condition. These findings align with those sometimes found in the serious games literature (Wouters et al., 2013). Individuals who played the game engaged in an interactive system with other players. Their actions within the game triggered important events, with tangible social and financial consequences. These factors might have heightened interest, which represents a potentially important outcome itself. Interest is a strong driver of persistence, which can have longer-term benefits in encouraging continued learning, retention, and conceptual mastery beyond the immediate lesson (Deci & Ryan, 2000; Hidi & Renninger, 2006).

It is informative that greater interest in the Lesson-First condition did not translate into higher conceptual learning outcomes compared to the more passive Lesson-Only condition. This finding may suggest that individuals in the Lesson-First condition were motivationally engaged but lacked some important aspect of cognitive engagement. For example, exploring before instruction may have supported participants' cognitive engagement by drawing attention to key features (Loibl et al., 2017; Roelle & Berthold, 2015; Schwartz et al., 2012). Exploring may also have helped participants construct ideas for themselves, via various forms of conceptual elaboration (e.g., questioning, experimentation, reflection; Chi & Wylie, 2014). Both processes could improve conceptual knowledge beyond the immediate motivational effects of interest. These ideas are consistent with our exploratory analyses, which indicated that individuals in the Explore-First condition learned better from in-game experience.

Limitations and Future Research

This research represents a promising step in designing methods to educate students and stakeholders about social dilemmas. However, there are limitations in this study that may be addressed in future research.

Assessment

First, we did not observe condition-based learning differences with the multiple-choice assessments. Though we cannot be certain, we suspect that this lack of difference may be due to potential measurement issues. The multiple-choice assessment was novel. We sought to measure a range of concepts covering different aspects of the game and social dilemmas, rather than use multiple items to achieve convergent measurement of a particular concept. This decision may have introduced imprecision ("noise") into the measurement, decreasing diagnostic capability (cf. Nunnally, 1978). In the future it may be wise to create subscales for each core concept/feature (i.e., self-interest, interdependency, scarcity, and tragedy). Additionally, the wording of multiple-choice questions and response options can provide conceptual cues, which may aid recall and understanding, especially in conditions which may benefit from additional recall cues. Finally, the ecological portion of the multiple-choice quiz more directly assessed basic concepts of the core rule-set (e.g., placing more than two cattle on a creek collapses the creek), not higher-order concepts (e.g., scarcity, tragedy). This design may have resulted in odd performance patterns in the present study, with participants scoring better on ecological dimensions in the multiple-choice portion but scoring better on social dimensions in the essay portion. This issue may be addressed in future research by improving the assessment of higher-order concepts during the multiple-choice assessment.

Learning Versus Other Outcomes

Second, our outcome measures were limited to cognitive aspects of learning about social dilemmas. Social dilemma games can also be used to educate and assess relational (i.e., interpersonal) and normative (i.e., ethical) knowledge (Baird et al., 2014; Blackmore, 2007; den Haan & van der Voort, 2018). When resolving complex social–ecological dilemmas, it is necessary to build trust (relational knowledge) and moral responsibility (normative knowledge) to facilitate robust social learning and cooperation. Social learning and cooperation are needed, so that competitive or disjointed stakeholders can learn to coproduce knowledge and collectively devise solutions to shared dilemmas (Ostrom, 1998; Pahl-Wostl, 2009). Few members of the public have intimate experience engaging in such activities (e.g., Baird et al., 2014; García-Barrios et al., 2011, 2017; cf. Cohen & Wiek, 2017; Reed, 2008). This study found some tentative evidence that playing the cattle farming game, especially in the Explore-First condition, may have improved cooperation, in the form of more equal resource sharing (earnings). Prior research indicates that achieving equality in such dilemmas typically arises from ethical principles of fairness (Dawes et al., 2007; García-Barrios et al., 2011, 2017). Thus, it is possible that participants in this experiment developed better understanding or appreciation for equality or distributional fairness, especially in the Explore-First condition. Future research could further examine whether exploratory learning facilitates such knowledge development.

Communication

Third, communication was limited in our experiment. Players were asked not to communicate during Game 1, so that they could experience the pitfalls of social dilemmas and learn from them. Later, players were allowed to communicate during Game 2. This design feature was incorporated to simulate communication patterns often observed in real-world dilemmas and emulate prior research and applied practices. Communication typically improves cooperation and social learning (DeCaro et al., 2021). In social dilemmas, communication can facilitate information exchange, enhancing conceptual understanding (e.g., García-Barrios et al., 2011, 2017; but see Meinzen-Dick et al., 2016). Effective group communication allows individuals to share pertinent conceptual insights and correct individual misconceptions. Groups may also pool their knowledge to reach higher concepts not as easily obtained alone. However, in the current experiment, most groups rarely communicated. Communication is typically allowed before, during, and after each game, providing ample time for players to initiate discussion, without time pressure or constraints. Participants might have communicated more frequently if we had provided the same opportunity.

Although we designed the experiment in keeping with prior studies and field observations, more research is needed to test how essential communication is to the exploratory learning effects observed. If receiving direct educational instruction about social dilemmas before the game better enables learners to learn via communication (Lesson-First condition), then subsequent conceptual understanding may be improved. Alternatively, if exploring a social dilemma game prior to educational instruction (similar to what is practiced and observed in real-world dilemmas; e.g., Cardenas et al., 2013; Meinzen-Dick et al., 2016, 2018; Ostrom, 1990) better prepares individuals to learn via communication (Explore-First condition), then there may be more improvement in this condition. Communication might also be important for alternative outcomes, such as building relationships and trust, in addition to potential cognitive outcomes. In the future, the potential relative and joint contributions of communication and timing of instruction should be systematically tested by treating these as separable factors.

It is also important to consider the delay between onset of communication versus instruction. In the current experiment, participants in the Explore-First condition were able to communicate immediately after receiving the lesson (prior to Game 2). In contrast, participants in the Lesson-First condition experienced a delay: they received the lesson prior to Game 1 but communicated in Game 2. This delay between instruction and communication might have resulted in a different communication dynamic, because the lesson may have been less salient at that time. We believe this delay is unlikely to be the determining factor in the present study, because participants in the Lesson-First condition appeared to learn less effectively from events triggered during Game 1 than their counterparts in the Explore-First condition, despite having a potential advantage of receiving the lesson immediately prior. However, the relative onset of communication and instruction may still be an important factor to test in future research.

Laboratory Versus Classroom Context

Fourth, the current research was conducted outside the classroom environment in a laboratory setting for greater experimental control, and most participants did not know each other. In addition, the current experiment used actual monetary outcomes, in keeping with standard experimental practice in behavioral economics. Payments may not be feasible in classroom settings. Anecdotally, when we use the Sierra Springs game as an exploratory learning activity in the classroom, with acquainted participants (i.e., classmates) and without payment, we notice an important observation: gameplay is livelier and more eventful (e.g., more deforestation and creek collapse events, more communication), like games played among community members in real-world dilemmas. Thus, the educational benefits of gameplay may be more pronounced in a classroom setting, even without actual money. Students may feel more comfortable to explore game dynamics with fellow classmates. Gameplay also complements ongoing course objectives, providing a richer experience and conceptual learning environment. Thus, future research may benefit from conducting controlled experiments in the classroom, with different incentive structures. Such implementation would also educate a wider audience, paving the way for education research and application in elementary, secondary, and college settings, where this knowledge is much needed (e.g., Weber & Stern, 2011 cf. Blackmore, 2007; DeCaro et al., 2017).

Guided Discovery

Finally, our results are limited to a specific type of guided discovery learning. Participants in the Explore-First condition experienced elements of discovery learning and didactic instruction. We selected this instructional method because pure discovery learning (without instructional guidance) may have lower learning outcomes for complex concepts than guided discovery methods such as exploratory learning (Kirschner et al., 2006; Mayer, 2004). However, care must be taken to ensure that exploration activities are not too taxing, or the benefits of exploring can be nullified, or reversed (e.g., Ashman et al., 2020; Bego et al., 2022; Fyfe et al., 2014). Future research using serious social dilemma games should take into account the degree of conceptual scaffolding and cognitive load that participants experience during exploration.

Conclusions

Solutions to society's most pressing ecological issues require conceptual understanding of their social and ecological dimensions. Direct instruction (e.g., lecture before practice) is the default educational paradigm in many educational settings (e.g., Stains et al., 2018). However, active learning is rapidly gaining popularity, due to its potential benefits for student engagement, conceptual insight, transfer, and knowledge retention (Bonwell & Eison, 1991; Freeman et al., 2014; Prince, 2004). Gamification is one method currently gaining traction (Sailer & Homner, 2020). Serious social dilemma games allow dilemma stakeholders and members of the public to learn the core characteristics of these dilemmas more rapidly and with greater insight than may otherwise be possible (den Haan & van der Voort, 2018; Flood et al., 2018). Our research demonstrates that exploratory learning has the potential to enhance the conceptual benefits these games provide.

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(*Appendices follow*)

Appendix A

Learning Quiz and Open-Response Coding Rubric

Quiz

****Important Instructions****

Next, we will test your understanding of key concepts. The questions in this quiz test your knowledge of concepts from the Cattle Farming Board Game, the real-world situation that the game is based on, and other information you saw or experienced in today's experiment.

The questions in this section have correct and incorrect answers.

There are three short essay questions, and 15 multiple choice questions. *You will be paid $0.50 (50 cents) for each short essay question, and $0.15 (15 cents) for each multiple-choice question you answer correctly. If you answer all questions correctly, you can earn $3.75 for this quiz*. Try your best to get each question correct.

Essay Questions (Recall)

Short Essay Questions

There are three questions in this section. You will receive $0.50 (50 cents) for each question in this section.

Items were shown individually in the following order.

1. What are the key features or characteristics of a situation that make it a social dilemma? Briefly explain each feature.
2. Briefly explain how the Cattle Farming Board Game is a social dilemma. What aspects of the game make it a social dilemma? Give examples from the game to explain your answer.
3. Briefly explain how the Cattle Farming Board Game is a complex environmental situation.

Multiple-Choice Questions (Recognition)

Multiple-Choice Questions

There are 15 questions in this section. You will receive $0.15 (15 cents) for each question you answer correctly.

Social Dimensions

Correct answers bolded.

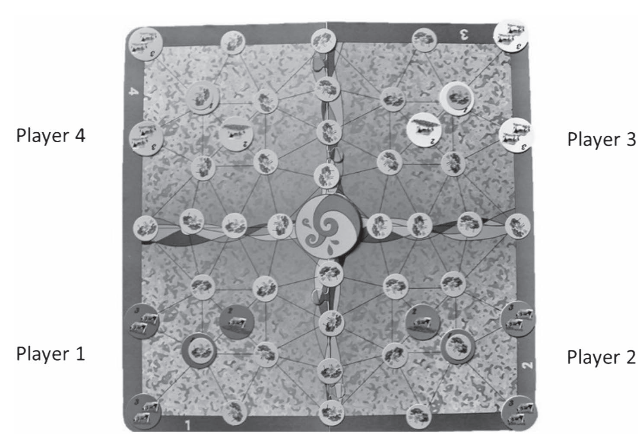
1. What is a social dilemma?
   a. A situation where one person does not get what he or she wants.
   b. A situation where people are fighting.
   c. **A situation where individual goals conflict with what is best for the group.**
   d. All of the above.
2. Which of the following situations is a Resource Dilemma?
   a. Each roommate in a sorority house needs to contribute some time and energy to get all the chores done.
   b. **Students in the library must wait for an open computer station, in order to use a computer.**
   c. Several students enter a bus, and there are plenty of seats for everyone.
   d. Several students are having an argument about something they learned in class.
3. True or False: In social dilemma situations like the cattle farming situation in the United States' Ogallala Aquifer and the Cattle Farming Board Game …

• People's decisions do not affect other people	T	**F**
• Cooperation is guaranteed	T	**F**
• If each person acts selfishly, everyone could suffer	**T**	F
• Groups get better outcomes (e.g., more money) if everyone works together	**T**	F

4. In the Cattle Farming Board Game, one of the Players tends to have an advantage in the game. Who is it?
   a. Player 1
   b. Player 2
   c. Player 3
   d. Player 4

Item 4 was removed from analysis because there is technically no single/true answer.

5. Here is a picture of the Cattle Farming Board Game. Which Players can affect *Player 1*'s earnings? *Select all that apply*.



(*Appendices continue*)

a. **Player 1**

b. **Player 2**

c. **Player 3**

d. **Player 4**

6. In the United States, some of the actions cattle farmers take directly (or indirectly) increase competition and make it harder for other farmers to earn money.

   Use what you have learned today about cattle farming to select each action that increases competition among farmers:

   - **Putting a lot of cattle in a single area of your pasture. [X]**
   - Cutting down a few trees from your forest for timber. [ ]
   - **Letting your cattle drink from the creek that is shared between you and other farmers. [X]**
   - **Cutting down a forest to make room for more cattle on your pasture. [X]**
   - Removing some cattle from your pasture and planting some new trees/forests. [ ]

Ecological Dimensions

Correct answers bolded.

1. What happens when a lot of forests are cut down to make room for more cattle?

   a. There is more open land for cattle grazing, so the farmers can earn even more money by taking more cattle to the market.

   b. **The area cannot sustain the cattle or farmers because the soil and land becomes barren.**

   c. More forests will grow back and replace the old forests.

   d. Nothing. The number of trees or forests has no effect on cattle or farmers.

2. In the Cattle Farming Board Game, why can't you place two High Cattle Tokens near each other (connected by a line) in the pasture?

   a. **There would be too many cattle to sustain enough plant life to feed the cattle.**

   b. There is not enough physical space for the cattle. They do not fit.

   c. Having too many cattle attracts predators that might eat the cattle.

   d. Having too many cattle in one area creates an over-supplied market, decreasing their value.

3. In the Cattle Farming Board Game, what happens if there are two cattle tokens in the same creek? *Choose the single best answer.*

   a. Players (farmers) can continue to put as many cattle on the creek as they want until it is full.

   b. The cattle have access to fresh water, so they become healthier (High Cattle Tokens), which are worth more money at the market.

   c. **If anyone puts more cattle on the creek, the creek will dry up and the cattle will die.**

   d. Nothing. Players (farmers) are not allowed to put any cattle in the creeks, because of pollution it might cause.

Transfer

Identifying Social Dilemmas

Next, we would like to see your ability to recognize real-world social dilemmas. Some of the situations we show or describe in this section are social dilemmas like the one in the cattle farming board game, others are different kinds of social dilemmas, and others are not dilemmas at all.

Please try your best to identify the social dilemmas.

You will earn $0.15 (15 cents) for each correct answer.

1. Most people in the world use fossil fuels (e.g., petroleum and oil) to fuel their vehicles, transport goods, and power machinery for making other goods. There is a limited supply of fossil fuel in the world. Many countries, companies, and people want to use the valuable fossil fuels.

   Is this a social dilemma? **YES** NO {*Resource Dilemma*}

2. On Black Friday in the United States, a limited number of highly desired electronics (e.g., video game systems, televisions) go on sale for 1 day. These products are discounted substantially, so many people come to stores, camping out the night before, in order to be the first person to get in the store and reach the sale items.

   Is this a social dilemma? **YES** NO {*Resource Dilemma*}

3. The City needs to raise about $4.3 Billion in order to fix old water delivery pipes and sewer pipes, pumps, and water treatment facilities. To do this, the City may raise taxes, and the Metropolitan Sewer District may raise its monthly fees. Everyone would benefit from improved water systems, even people who do not pay for them, or pay less.

   Is this a social dilemma **YES** NO {*Public Good Dilemma*}

4. In a typical blood drive, hospitals would like as many people as possible to donate blood for people who need a blood transfusion in a medical emergency. Everyone can benefit from the blood that is donated, but few people donate their blood.

   Is this a social dilemma? **YES** NO {*Public Good Dilemma*}

(*Appendices continue*)

5. Instructors sometimes require their students to work in groups, for a group project. Everyone in the group gets the same grade, even students that do not do as much work.

   Is this a social dilemma? **YES** NO {*Public Good Dilemma*}

6. A group of college students has gathered for a party. There are a lot of people there, and just as many boxes of pizza, bags of chips, drinks and other food for everyone. The party is being held in one of the largest sorority houses on campus, late into the night. A few people get into an argument about something one of them posted online in social media.

   Is this a social dilemma? YES **NO** {*Foil*}

Open-Response Coding Rubric

Coding definitions used to score presence of the four social dilemma features, and spontaneous conceptual transfer. For Questions 1 and 2, participants received 1 point for each dimension correctly identified and explained in each question. Question 3 was scored separately, because it did not ask about the core dimensions. Transfer was scored as a separate indicator across all three questions, using the Transfer coding definition listed for each question.

Questions 1 and 2

Question 1 asked what the core characteristics of a social dilemma are. Question 2 asked participants to explain the Cattle Farming Game is a social dilemma.

Dimension	Participant accurately states/defines/discusses:
Social dimensions	
• Self-interest	Acting selfishly, competition/compete, temptation to do so.
• Interdependency	People affect one another, linked, decisions/actions linked.
Ecological dimensions	
• Scarcity	Limited land resources (i.e., spots), and or/limited water, forest resources; or limited opportunities (e.g., for cattle). Zero-sum game (i.e., if someone takes a resource or opportunity, others lose it).
• Tragedy	If situation escalates or gets out of hand, then it can result in worse situation for oneself or everyone. Your earnings, or everyone's earnings, will be reduced. Total environmental collapse/degradation (e.g., water dried up, creek collapse, deforestation, etc.).
Transfer	Participant discusses the relevance of the game to the real-world U.S. cattle farming dilemma situation (or another real-world dilemma), real-world implications, or examples. Evident that conceptual application/connection goes beyond the game.

Question 3

Question 3 asked participants to explain how the Cattle Farming game represented a complex environmental situation.

Ecological element	Participant accurately states/defines/discusses:
General threshold (or interdependency)	Discusses the idea that there are environmental thresholds, or interdependencies, without giving specific details or identifiers.
Deforestation threshold	Mentions that regional deforestation is not a problem (i.e., crisis) until a threshold is reached (e.g., too many cut down).
Creek threshold	Mentions that putting cattle on a creek is not a problem (i.e., crisis) until a threshold is reached (e.g., too many cattle).
Deforestation interdependency	Mentions that people jointly determine risk of regional deforestation.
Creek interdependency	Mentions that people jointly determine risk of creek collapse.
Cattle interdependency	Cattle placed anywhere has potential to block another player's cattle, or affect where other player's play their cattle.
High cattle conflict	Mentions that high cattle compete for space; cannot be placed in adjacent spots.
Transfer	Participant discusses the relevance of the game to the real-world U.S. cattle farming dilemma situation (or another real-world dilemma), real-world implications, or examples. Evident that conceptual application/connection goes beyond the game.

(*Appendices continue*)

Appendix B

Survey Items

Interest

Interest and Enjoyment

In today's experiment, you were exposed to information about cattle farming social dilemmas through a variety of methods. The next questions ask how interesting and enjoyable you felt these methods have been.

1. Today's experiment has been interesting.
2. I have enjoyed today's experiment.
3. Today's experiment really captured my attention.
4. Today's experiment kept me engaged.

7-point scale (1 = *strongly disagree,* 2 = *disagree,* 3 = *somewhat disagree,* 4 = *neutral,* 5 = *somewhat agree,* 6 = *agree,* 7 = *strongly agree*).

Importance

This experiment has been about cattle farming and potential social and environmental problems associated with it. How important is this topic to you?

4-point scale (0 = *not important at all,* 1 = *a little*, 2 = *moderately*, 3 = *very important*).

Policy Preferences

General Support for Cattle Farming Policies

The board game you played ["learned about" (*Lesson-Only Condition*)] today was similar to real-world situations seen in places like the Ogallala Aquifer in the United States (Nebraska, Kansas, Oklahoma, New Mexico, Texas). Various policies have been proposed to manage cattle farming in these regions of the United States. For these next questions we would like to ask preferences for some of these general policies.

We are interested in your honest reaction to the policies. There are not right or wrong answers. Thus, please answer according to your honest opinion.

1. If you were a farmer, would you be willing to support policies that reduce the number of cattle raised in the Ogallala Aquifer region of the United States?
2. If you were a farmer, would you be willing to support policies that monitor your water use and require water conservation?
3. As a consumer (or potential consumer) of beef cattle products (e.g., hamburger, steaks), would you be willing to pay higher prices for cattle and beef products, if the money was used to improve farmers' livelihoods and the conservation of water, forests, and other aspects of the environment?
4. As a consumer (or potential consumer) of beef cattle products (e.g., hamburger, steaks), would you be willing to pay higher prices for cattle and beef products, if it reduced the number of forests cut down to make room for farms?
5. Do you believe that cattle farming in the United States should continue operating like it currently is?
6. Do you believe that cattle farming in the United States should be increased, with more cattle and more large-scale farms?

4-point scale (0 = *no, not at all,* 1 = *yes, a little*, 2 = *yes, moderately*, 4 = *yes, completely*).

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