Global Warning: a board game that changes student thinking on how to combat climate change

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Abstract

Purpose – This purpose of this study is to examine the educational impact of Global Warning, a climate change–themed board game that blends cooperative and competitive elements to foster transformative learning, critical reflection and systems thinking.

Design/methodology/approach – A pre/post-treatment design was used to compare a treatment group – who played Global Warning during four weekly sessions – to a control group with no gameplay. Participants completed a climate action survey before and after the intervention, and qualitative reflections were gathered from the treatment group's post-game reviews.

Findings – Results indicated that gameplay shifted students' perceptions of climate change as an existential threat, broadened their understanding of actionable solutions and clarified challenges in implementing these measures. Student reviews highlighted the game's capacity to promote collaboration, critical thinking and engagement with real-world issues.

Originality/value – By integrating realistic scenarios with both cooperative and competitive dynamics, Global Warning shows promise as a novel pedagogical tool for inclusivity and sustainability-focused learning in post-secondary contexts.

Keywords Climate change education, Board games, Sustainability, Cooperative learning
Pre/Post design, Higher education

Paper type Research paper

Introduction

In recent years, board games have emerged as innovative tools for enhancing science education, offering unique learning opportunities beyond those provided by traditional learner-centered pedagogies. These games often integrate social interaction, strategic thinking and a mix of competitive and cooperative dynamics (Allery, 2014; Despeisse, 2018). Randomized elements, such as die rolls, further ensure variability in outcomes, keeping gameplay engaging and unpredictable. Many educational board games also incorporate critical thinking and real-world scenarios, challenging players to connect gameplay to everyday life (Treher, 2011; Despeisse, 2018).

Educational board games have gained attention as tools for enhancing student engagement and learning, particularly in addressing complex and interdisciplinary topics. These games

hold significant potential to foster transformative learning by encouraging students to critically reflect on systemic challenges, explore equity-based solutions and develop action-oriented problem-solving skills (Dieleman and Huisingh, 2006; Mercer *et al.*, 2017; Despeisse, 2018). However, the use of board games in climate change and sustainability education remains underexplored, with few studies rigorously evaluating their effectiveness. Insights from related disciplines, such as biology and medicine, highlight both the promise and limitations of educational games. For example, a recent review of biology-themed board games by Teixeira *et al.* (2024) found that most studies reported only qualitative findings, raising concerns about the generalizability of their outcomes. Similarly, board games in medical education were often associated with improved knowledge of clinical symptoms and interpersonal interactions but lacked robust quantitative evidence of learning gains (Noda *et al.*, 2019). These findings underscore the need for rigorous methodologies to assess the educational impact of games, particularly in sustainability and climate science education, where tools like board games could promote critical thinking, systems thinking and sustainability-focused engagement.

Recent work by Pope (2021) positions tabletop games as an effective non-traditional instructional strategy for sustainability learning. Drawing on experiential learning theory, Pope – along with Treher (2011) and Tasnim (2013) – contends that board games integrate hands-on experimentation with intellectual analyses: players must grapple with disciplinary content even as they negotiate, strategize and collaborate within a rule-bound environment. Many empirical studies seem to support these claims. For example, role-play simulations have been shown to help learners translate abstract sustainability principles into concrete action (Dieleman and Huisingh, 2006); factory-management games can help sharpen trade-off reasoning (Despeisse, 2018); climate-negotiation games can facilitate better systems-thinking and conservation-thinking (Wu and Lee, 2015; Mazur-Stommen and Farley, 2016). Games can also provide arenas for rehearsing conflict resolution around things like contested resources (Redpath *et al.*, 2018; Chappin *et al.*, 2017). That said, many caution that competition-oriented games can lead to an oversimplification of complex socio-ecological systems, particularly if not paired with opportunities to reflect and debrief (Despeisse, 2018; Crookall and Thorngate, 2009).

Unlike in the fields of biological and biomedical sciences, there has been a dearth of studies on board games in climate and sustainability sciences. One study of the climate change card game *EcoChains: Arctic Crisis* found that learning gains from gameplay were comparable to those achieved through participation in a climate change reading group (Pfirman *et al.*, 2021). However, most sustainability and climate-related board games have not been rigorously assessed for their quantitative educational outcomes (Wu and Lee, 2015). For instance, work exploring a series of board games focused on environmental and sustainability themes found that players engaged in meaningful discussions about climate change and sustainability during post-game sessions, but no *quantitative* gains were documented (Fjællingsdal and Klöckner, 2020). Similarly, the game *The Settlers of Catan: Oil Springs* has been linked to changes in attitudes toward sustainability, though not necessarily to increased knowledge of sustainability concepts (Chappin *et al.*, 2017). In a 2013 review of a climate change game called "KEEP COOL," the author and game co-designer, Eisenack, describes the potential for the game as a "*tool for interdisciplinary research, public relations, public understanding of science, and, in particular, teaching,*" but provided no quantitative data to these ends (Eisenack, 2013). These examples highlight the scarcity of quantitative research on the educational impact of sustainability and climate change board games and underscore the need for more rigorous investigations into their effectiveness.

Despite the limited availability of quantitative research, climate change and sustainability-themed games show promise as educational tools. These games have the potential of immersing

players in realistic scenarios, fostering engagement and deepening their understanding of complex global challenges (Wu and Lee, 2015). Furthermore, simulation-based climate change games have demonstrated potential for improving comprehension of climate politics and systemic interactions (Meya and Eisenack, 2018), while sustainability-focused games have been linked to enhanced systems thinking and collaborative problem-solving (Scurati et al., 2023). Cooperative environmental games have also been shown to increase pro-environmental engagement, particularly among future teachers (Vázquez-Vílchez et al., 2021), and issue-based games have been associated with improved understanding of resource adaptation strategies (Cheng et al., 2019). Together, these findings suggest that climate change and sustainability board games can be powerful tools for environmental education, even as the field continues to call for the need for more robust and quantitative assessments of their impact.

In this study, the authors explore the educational impact of Global Warning on student thinking about climate change. Specifically, the authors addressed the following research questions:

RQ1. Does playing Global Warning influence students' perceptions of the urgency and severity of climate change?

RQ2. Does gameplay lead to changes in students' understanding of and intention to engage in climate mitigation actions, both personally and societally?

To address these questions, a mixed-methods design was used that included a pre/post climate action survey and student reflections. This allowed us to compare changes in student perceptions, intended behaviors and knowledge about climate change between those who played the board game and those who did not.

Global Warning: Description of the game
Global Warning is intended to be an educational board game to raise awareness about climate change problems and specific actions that humans can take to positively contribute towards mitigating climate-based problems. The main components of the game are:

- a deck of problem cards;
- a deck of solution cards; and
- a global temperature indicator (Figure 1).

At the onset of the game, four problem cards are dealt face-up on the board, and each player receives a certain number of *solution* cards for their hand, depending on the number of players in the game. A sequence of four events then happens during a player's turn. First, the player rolls a die and collects money corresponding to their roll (a higher roll results in more money). Second, the player draws a problem card and places it face-up on the gameboard. This problem, along with the four that were placed on the board at the beginning of the game, is a collective problem for all players in the game to try to solve. Third, the player draws a solution card and places it in their hand. Finally, if the player can *solve* a climate problem that is on the board (based on the colors and point-value of the solution cards in their hand), they take the problem card off the board and keep it for end-of-game scoring. Players may ask others for help to solve a climate problem, but only the player whose turn it is receives the credit for solving a particular climate problem. After each round, the points-value of all face-up problem cards on the board (i.e. the unsolved problems) are tallied, and the global temperature indicator is increased by a corresponding amount. If, at the conclusion of any
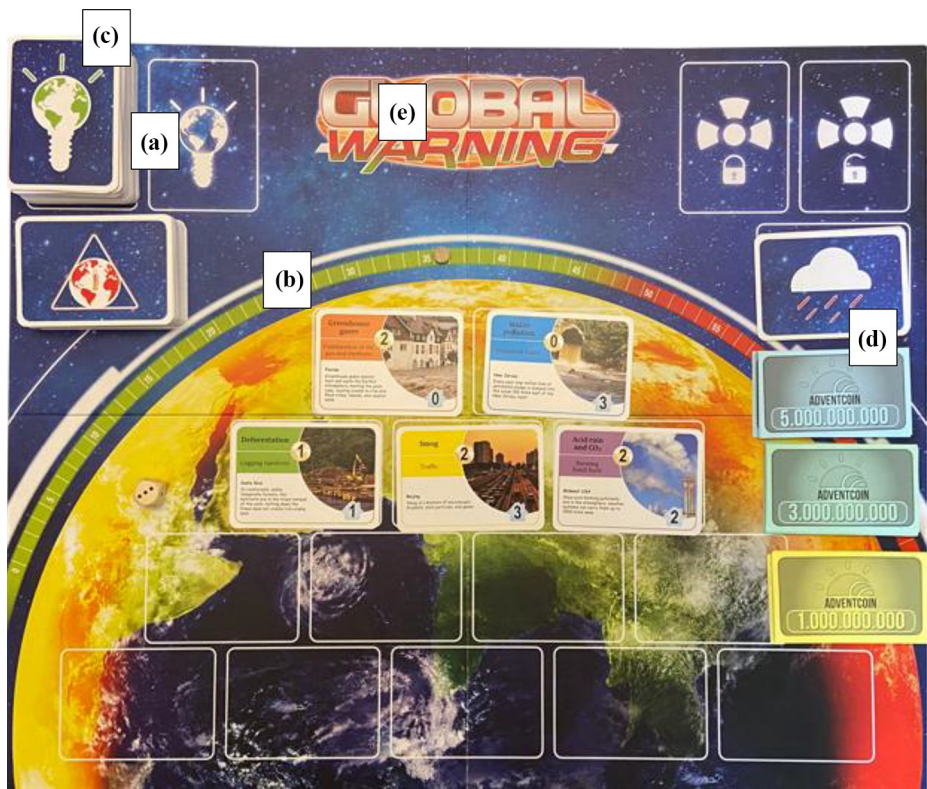
Figure 1. The *Global Warning* game board set up feature a series of (a) problem cards that are (b) played face up at various intervals during the game. These problem cards can be solved with (c) solution cards. Players roll a die to earn (d) in-game *AdventCoin* money that is also required to solve problem cards. After each round of the game, the (e) global temperature indicator rises, corresponding to the value of the problem cards that have not been solved

Source: Authors' photo of board game with labels added

round, the global temperature indicator gets too high, a global climate disaster occurs and the game is over; in this scenario, all players lose. If, on the other hand, a player reaches a certain points threshold before a global climate disaster occurs, then that player is declared the winner. Thus, players have an incentive to work together (i.e. to avoid a climate disaster scenario), but are also motivated to achieve an individual victory. It is not uncommon for players to face a decision of whether to let another player win *or* to accept the lose-lose outcome of a global climate disaster game ending. The game can be played by four to seven players, is rated for ages 10+ and lists a game playing time of 45–90 min.

Materials and methods
The authors assessed the impact of playing Global Warning amongst a group of second-year postsecondary students at Michigan State University. This study was reviewed and approved by the institution's Institutional Review Board (IRB#: STUDY00009384).

Cohort selection
Students in this study were enrolled in two sections of an introductory cell and molecular biology course, co-taught by the same two instructors (one of the instructors was the primary author of this paper, PJTW). The choice of course was intentional. This particular iteration of cell and molecular biology included no themes related to climate change, and no content that could interfere with student-learning associated with playing *Global Warning*. Furthermore, to the authors' understanding, their institution did not offer an earth science major or any courses at the first- or second-year level that included any content related to climate change at the time this study was conducted.

Treatment and control groups
Students were invited to participate in a board game playing group and were offered an "honors credit" for their involvement. Many students in the target course were also enrolled in the institution's Honor's College. Even though the board game playing opportunity was presented to students as an opportunity to earn an "honors credit," *all* students were invited to attend (irrespective of their Honor's College enrollment status). Students across the two course sections thus self-selected into two groups based on those who wanted to play the board game (a.k.a., the *treatment* group) and those who chose not to (a.k.a., the "*control* group").

Students in the board game playing *treatment* group met four 1½ -hour board game sessions from February to March 2024. For each session, four board game table-groups were formed, with either five or six players in each. The authors incentivized game play by awarding a free t-shirt for the winner of each board game iteration. The authors reasoned that some players might only be *going through the motions* and only playing to complete what they viewed as a *required assignment* to receive their honors credit. The authors felt that an award would encourage players to take the games more seriously (anecdotally, this seemed to achieve the desired effect; prize t-shirts became a coveted commodity amongst players). Two weeks after the conclusion of the final game-playing session, students in the *treatment* group were required to write a 500-word board game review and reflection assignment.

Study design
One week before the first board game playing session, all students were asked to voluntarily fill out a "Climate Action Survey" (**Box 1**). The authors drafted survey questions that focused

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Box 1: The climate action survey

Climate Action Survey

(1) Which of the below most closely represents your views on climate change: (circle <u>one</u>)?
   - Climate change is a serious, immediate and existential threat to humankind.
   - Climate change is a problem, but it is not catastrophic; it is ok if we take our time to identify solutions.
   - Climate change is real, but likely will not cause many problems for humankind.
   - Climate change is not real.
(2) What actions might we take, as a society, to make a positive difference in global climate change?
(3) What *changes* to your behavior or actions will you make <u>in the coming year</u> to reduce your personal impact on climate change?

(4) What *changes* to your behavior or actions will you make <u>in the coming week</u> to reduce your personal impact on climate change?

(5) How much do you agree or disagree with the following statement:

"Combating climate change requires me to make significant and difficult changes in how I live my daily life."
[Strongly disagree]——[Disagree]——[Neutral]——[Agree]——[Strongly Agree]

Source: Authors own work

primarily on the *actions* that students could take to mitigate climate change. Subjectively this seemed like a better litmus test on whether the board game would change student behavior than, for example, quizzing the students on the number of different climate problems they could name. Students were encouraged to provide complete answers, though no course points or other incentives were awarded for survey completion. The survey was administered a second time to all students, one week after the board game review and reflection assignment (completed by *treatment* group students) was handed in. This pre-treatment/post-treatment format allowed us to explore how answers changed in the *treatment* group compared to the *control* group.

Climate action survey scoring
The United Nations *Actions for a Healthy Planet* (www.un.org/en/actnow/ten-actions) was used as a rubric against which to score student responses to assessment questions 2, 3 and 4 (henceforth referred to as "The Actions"). The Actions outline 12 actionable behaviors that humans can undertake that would make a positive difference to slow climate change. The Actions, along with a short descriptive summary of each, are provided in Box 2. Each student response to questions 2, 3 and 4 were compared to the Actions and scored based

Box 2: *Climate Actions* **outlined by the United Nations that have the potential to make a positive impact when it comes to "***protecting the environment and slowing climate change.***" These actions were used as a scoring rubric for student responses to questions 2, 3 and 4 in the Authors' Climate Action Survey. Each action is listed, below, along with elements that students would need to include in their response in order for their answer to get a credit for that action. The authors found many instances where students would write "reduce emissions" without support context. The authors thus added this as its own category.**

Action 1: Save energy at home.
- Any form of energy saving at home, such as turning off lights more often, using less heat in the winter, using less air conditioning in the summer or using less hot water.

Action 2: Change your home's energy source.
- Any mention of alternate forms of energy, like solar or wind, to help power household needs.

Action 3: Walk, bike or take public transport.
- An increase walking, biking and public transport or a decrease in personal driving (i.e. carpooling would also be an acceptable answer).

Action 4: Switch to an electric vehicle.

- Active plans, aspirational plans or past experiences of having an electric vehicle as their primary mode of personal vehicular transportation.

Action 5: Consider your travel.

- Taking fewer long distance trips using airplanes or personal vehicles. Alternatively, students could mention taking the train or bus, or carpooling for long distance trips.

Action 6: Reduce, reuse, repair and recycle.

- Any mention of the key words in the above action (in the appropriate context), or a mention of generating less garbage, or shopping less (thereby reusing current items longer) and shopping at thrift stores.

Action 7: Eat less meat/more vegetables.

- Any mention of eating more vegetables, eating less meat *or* food that is less environmentally damaging.

Action 8: Throw away less food.

- Any mention of the key phrase listed by the action or any general description akin to "creating less food garbage."

Action 9: Plant native species.

- This category included mention of native species *and* any mention of engaging in habitat restoration efforts or just *planting more trees* in general.

Action 10: Clean up the environment.

- This was narrowly defined having to do with picking up trash and removing human-generated garbage from wildlife habitats (but distinct from *habitat restoration*, listed in Action 9).

Action 11: Make your money count.

- Buying goods and services from environmentally conscious vendors or vendors who used recycled materials. In this category, we also included ideations of "buying organic food."

Action 12: Speak up.

- This category included any mention of climate- or environmental-activism and protesting, voting for politicians or parties that have a positive environmental policy, engaging with friends and family about the issue of climate change, or educational initiatives surrounding climate change and environmental protection.

Action 13: Reduce emissions*.

- Students sometimes mentioned the phrase "reducing emissions/greenhouse gasses/CO_2 emissions" without supporting context to frame their thinking. Mentions such as these were placed in this category.

Source: Authors own work

on which, and how many, Actions they corresponded to. The authors found many instances where students wrote general phrases such as "reduce emissions" (or an analogous phrase) without providing any specific context or causal behavior. The authors thus added "Reduce emissions" as its own 13th category (Action 13) to capture these non-specific responses. However, if a student response clearly linked a specific behavior to the reduction of emissions (e.g. "*take the campus bus more to reduce emissions*"), the authors scored the response under the behavior-based action (e.g. "Walk, bike or take public transport" – Action 3), not under Action 13. By contrast, when no specific behavior was provided, the authors categorized the response under Action 13. This approach avoided double-counting while preserving the author's ability to track vague or non-specific responses.

Board game analysis
The United Nations *Actions for a Healthy Planet* was also used as a standard against which to categorize the *Solution Cards* from the *Global Warning* board game. Each solution card was compared to the Actions and given a score in one or more category, based on how many (and which) Actions were mentioned on the card. *Solution Cards* were also categorized based on whom they seemed to be targeted at. Here, the authors classified the cards into three designations:

(1) solutions that could be undertaken by individuals in society *and* could also be reasonable actions for post-secondary students to take;

(2) solutions that could be undertaken by individuals in society, but actions that post-secondary students would be unlikely to engage in (for example, because they may require a certain level of income or unique circumstantial opportunities); and

(3) solutions that required involvement from larger societal/governmental/industry entities.

Student review and opinion
The review and reflection assignment that each student in the *treatment* group completed was analyzed to determine student perception of *Global Warning*. For each reflection, the authors noted the positive game elements and the negative elements that were described; these were then compiled into a single list, for all students.

Results
Board game analysis
There were 85 *Solution Cards* in the *Global Warning* game. Of these, 54 dealt with at least one of the United Nations *Actions for a Healthy Planet*. The themes most commonly described in solution cards were "*reduce, reuse, recycle, repair*" (22 cards), "*reducing emissions*" (six cards) and "*saving energy at home*" (five cards). All other Actions (see Box 2) were described in at least one solution card except for "*consider your travel*," which encourages people to consider shorter trips and to use more eco-friendly methods of long-haul personal travel, which was not featured in the *Global Warning* game (Figure 2).

There were 31 *Solution Cards* in the game that described actions that did not overlap with the United Nations Actions (they are catalogued as "uncharacterized" in Figure 2b, c). All of these were actions that either required societal, governmental or industry involvement, or they were solutions that your typical post-secondary student might not engage in due to the circumstances inherent in their stage of life (e.g. lawn- and yard-care practices).
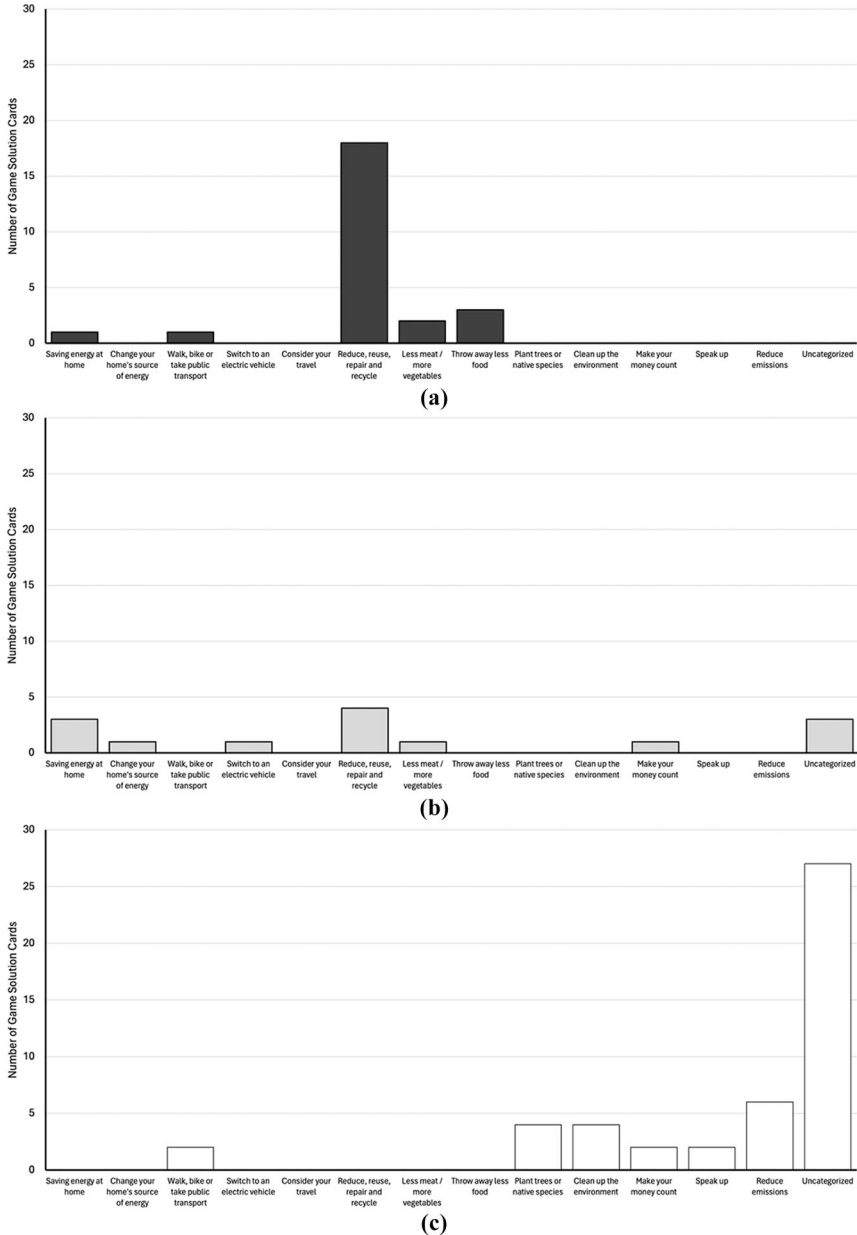
Figure 2. The *solution cards* of *Global Warning* were classified into the 13 *UN climate actions* that were explored in this study (Box 2). Any solutions presented on the *solution cards* that did not fit one of the "*actions*" was tabulated in the final column: "*uncategorized*." The cards were further sorted into solutions that could (a) be readily achieved by a college student, (b) be readily achieved by individuals in society but presented barriers of income or circumstance for college students and (c) required societal governmental/industry action or coordination to achieve

Source: Authors' own work

The *Solution Cards* that seemed most applicable to post-secondary-aged students (Figure 2a) were spread out across five categories with "*reduce, reuse, recycle, repair*" being the most common theme (18 cards), followed by "*reducing food waste*" (three cards), "*eating less meat/more veggies*" (two cards), "*walk/bike/public transport*" (one card) and "*save energy at home*" (one card).

The *Solution Cards* that could be carried out by individuals but were perhaps not as accessible to post-secondary students were spread out across six categories (Figure 2b; with "*reduce, reuse, recycle, repair*" being the most common theme). The top actions in the *Solution Cards* that could be best carried out by societal/government/industry involvement were:

- *uncharacterized* relative to the Actions (described above);
- dealt with reducing carbon/greenhouse gas emissions;
- involved cleaning up environmental disaster; or
- involved planting trees (Figure 2c).

Control and treatment groups
There were 55 control-group students and 20 treatment-group students who filled out *both* the pre- and post-versions of the *Climate Action Survey*. In the *control* group, 12 of the 55 students were enrolled in the Honor's College (but chose not to take part in the board game sessions). In the *treatment* group, 16 of the 20 students were enrolled in the Honor's College (four students decided to play the board game even though they earned no honors credit for it).

Climate action survey question 1 analysis
Almost all students in both the *control* and *treatment* groups indicated that climate change was a problem. Approximately two-thirds of students in the pre-survey in both groups indicated it was a "*serious, immediate and existential threat to humankind*," while the remaining approximately one-third indicated it was a problem but was "*not catastrophic*" (Figure 3). In post-surveys, 95% of students in the treatment group felt that that climate change was now a "*serious, immediate and existential threat to humankind*" (chi-square test comparing pre- vs post-distribution of responses, $p = 0.048$), whereas opinion in the control group was relatively unchanged (chi-square $p = 0.456$).

Climate action survey question 2 analysis
Students in both the *control* and *treatment* groups listed more Actions in their post-surveys than in their pre-surveys when asked about what actions we might take, as a society, to make a positive difference in global climate change (Figures 4 and 5).

Climate action survey questions 3 and 4 analysis
There were 90% of students in the *treatment* group and 84% of the students in the *control* group who listed one or more intended action in the pre-survey that they could change "in the coming year." In the post-surveys, there appeared to be a greater proportion of students in the *treatment* group who either listed a different behavioral change for the coming year *or* listed more ideas for behavioral changes (Figure 6a, b; this difference was not statistically significant; 2 × 4 contingency table, $X^2 = 4.04$, d.f. = 3, $p = 0.26$).

There were 85% of students in the *treatment* group and 84% of the students in the *control* group who listed one or more intended action in the pre-survey that they could make "in the coming week." In the post-surveys, a greater proportion of *treatment* students either listed a
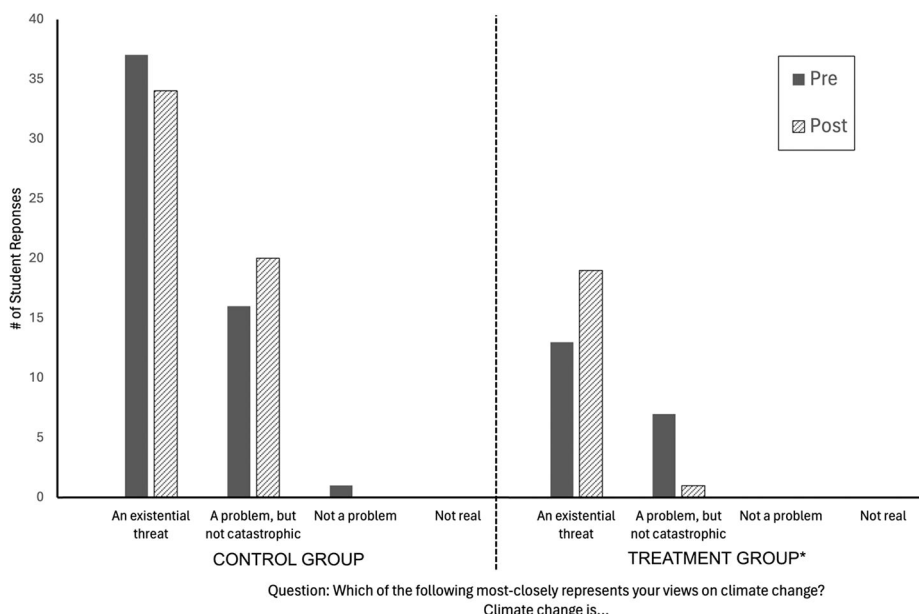
Figure 3. Student opinion about the gravity of threat posed by climate change changed in the treatment group after following their sessions playing the *Global Warning* board game (*chi-square [w/Yates correction] = 3.91, *p* = 0.048). Student opinion in the control group did not change (chi-square = 1.57, *p* = 0.456)

Source: Authors' own work

different behavioral change for the coming week *or* listed more ideas for behavioral changes (Figure 6c, d; 2 × 4 contingency table, $X^2 = 8.16$, d.f. = 3, *p* = 0.043).

Climate action survey question 5 analysis

Almost all students in both the control and treatment groups either "*agreed*," "*disagreed*" or were "*neutral*" to the statement that "*Combating climate change requires me to make significant and difficult changes in how I live my daily life*"; only a small proportion of students "*strongly agreed*" or "*strongly disagreed*." Given this, the *agree* and *strongly agree* categories and the *disagree* and *strongly disagree* categories were collapsed into single categories to increase the power of a chi-square statistical analyses.

The distribution of student answers in the *control* group were virtually identical in the *pre-* versus *post-surveys* (chi-square = 0.067, *p* = 0.967, Figure 7). The distribution of student answers in the *treatment* group seemed to shift from the *pre-* to the *post*-survey; fewer students answered *neutral* in the post-survey (chi-square = 0.4760, *p* = 0.093).

Student review and opinion

Students in the treatment group cited an average of 3.0 positive aspects of the game and 1.2 negative aspects per review. The positive aspects of the game most cited were:

- its learning and educational value of the game; and
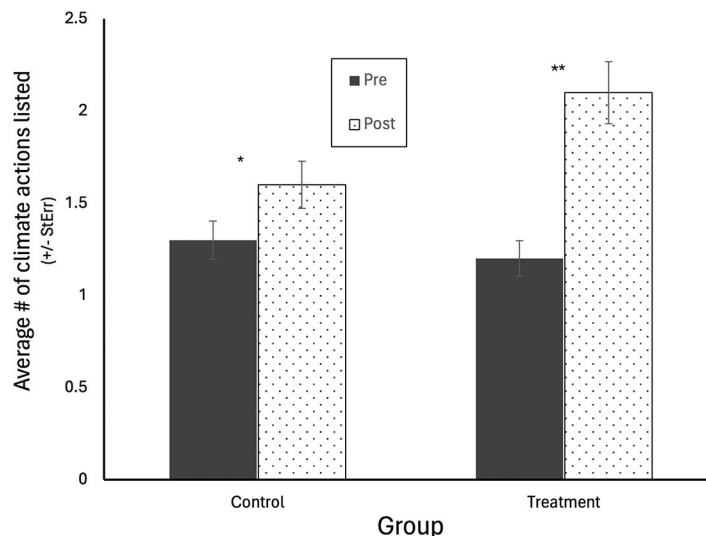- its unique competitive-cooperative nature (Table 1).

Figure 4. There was a significant difference in the number of climate actions listed by students in the *pre-* vs post-survey for both the control group (* average difference of 0.4 items listed per student paired *t*-test, $t = 2.91$, $p = 0.0053$) and the *treatment* group (**average difference of 0.8 items listed per student; pair *t*-test, $t = 2.89$, $p = 0.0095$)
Source: Authors' own work

The negative aspects of the game most cited were:

- some aspects of the instructions seemed unclear; and
- the boring or repetitive nature of the game.

In terms of a game rating, 18 of the 20 reviews provided a numerical score for the game. The average score given by these reviews was 7.6/10 (median = 8.0/10, lowest score = 4.0/10, highest score = 9.8/10).

Discussion

This study aimed to assess whether playing *Global Warning* influenced students':

- perceptions of the urgency and severity of climate change; and
- their understanding of and intention to engage in mitigation actions, both personally and societally.

The findings suggest that the game had an impact on both fronts. First, students in the *treatment* group shifted their thinking in terms of climate change being an "existential threat." Second, they exhibited a near twofold increase in the number of climate mitigation activities that society could take. Third, *treatment* group students tended to change their ideas about what they could personally do to impact climate change. Finally, they shifted away from having a neutral stance on whether combating climate change would require them to make significant changes in how they lived their lives.

Even before playing the *Global Warning* game, the surveys showed that students understand climate change to be a problem. In the pre-surveys, across both groups, all but
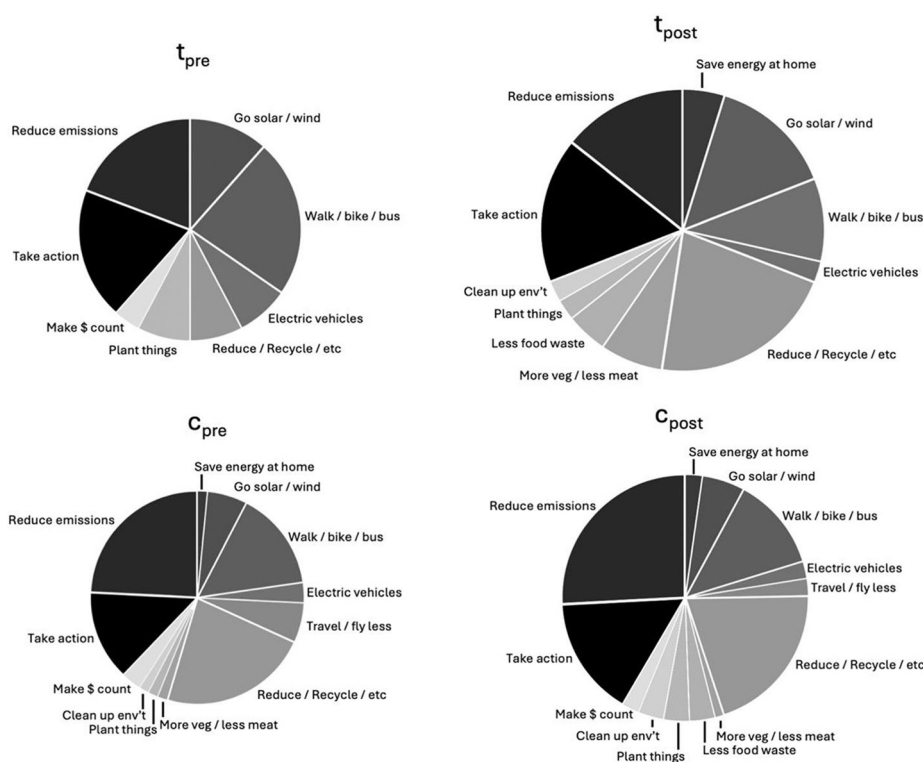
Figure 5. The distribution of ideas for actions that society can take to mitigate climate change in the treatment pre-surveys (t_{pre}), treatment post-surveys (t_{post}), control pre-surveys (c_{pre}) and control post-surveys (c_{post}). The relative area of each pie chart corresponds to the relative number of climate actions provided per student (as shown in Figure 2)
**Source:** Authors' own work

one student indicated that climate change either posed an "*immediate and existential threat*" or that it was "*a problem*," though perhaps not posing an imminent threat. The finding here is in line with prior studies that show that anywhere from 67% to 80% of post-secondary students view climate change to be a pressing problem that requires a solution (Cordero, 2008; Wachholz *et al.*, 2014). Here, the percentage of students identifying climate change as a "*existential threat*" significantly increased in the *treatment* group (after playing the board game), but not in the control group. The idea that climate change is an "*imminent and existential threat*" seems to align with the themes, imagery and potential outcome of the game. In terms of imagery, both the front and back of the game box include warnings about the impact of climate change, with messages like "*WE MUST WORK TOGETHER… TO SLOW THE RATE OF GLOBAL WARMING… AND PREVENT CLIMATE DISASTER!*" and "*CRITICAL TEMPERATURE, SAVE YOUR PLANET*" (all-caps is used on the box). The background image on the gameboard is that of the planet heating up to shades of fire-red. The back of every *Problem Card* shows a hazard-like symbol of a red-hot earth and a thermometer. The message implied in the game imagery is unavoidable: the earth is heating
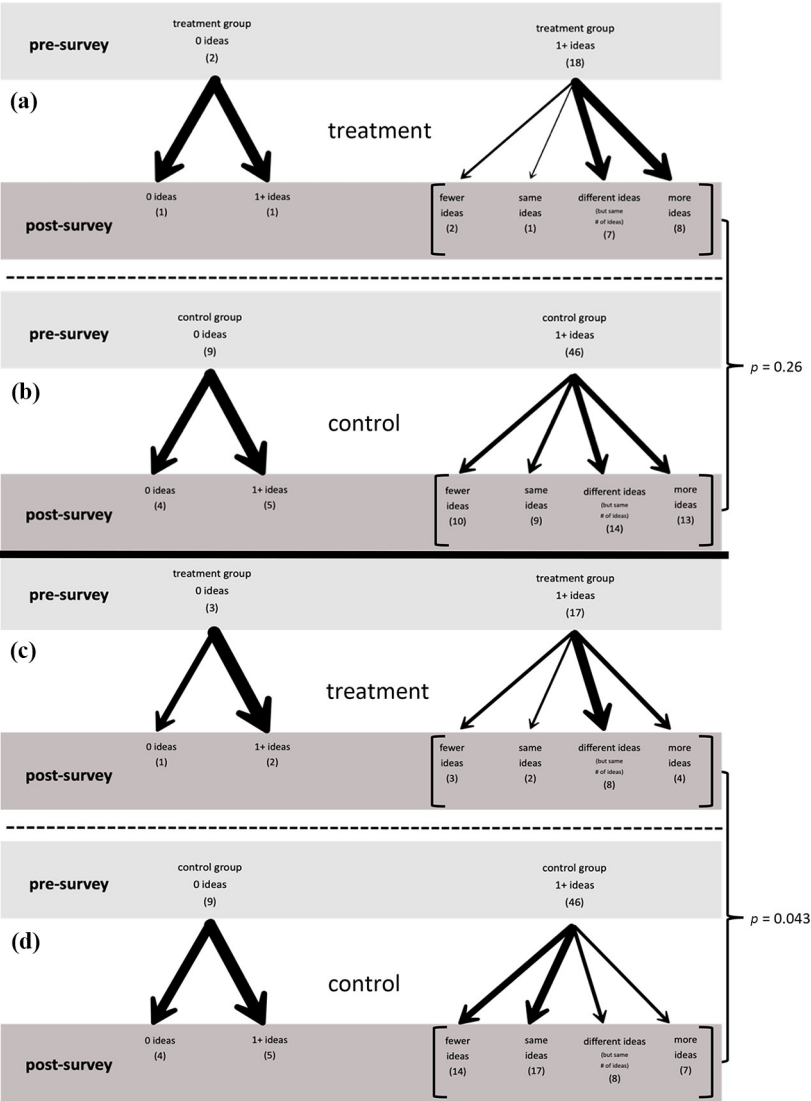
Question 3: number of behavioral changes in the coming year.
Question 4: number of behavioral changes in the coming week.

Figure 6. Panels a and b show the shift in the numbers of behavioral changes students would be willing to make in the coming year to combat climate change (student n in parentheses; difference in answer distribution of control vs treatment in post surveys is not significant; $X^2 = 4.04$, $p = 0.26$). Panels c and d show the shift in the numbers of behavioral changes students would be willing to make in the coming week to combat climate change (student n in parentheses; difference in answer distribution of control vs treatment in post surveys is significant; $X^2 = 8.16$, $p = 0.043$). Thickness of the arrows is proportion to the students who moved to each outcome within each arrow diagram
Source: Authors' own work
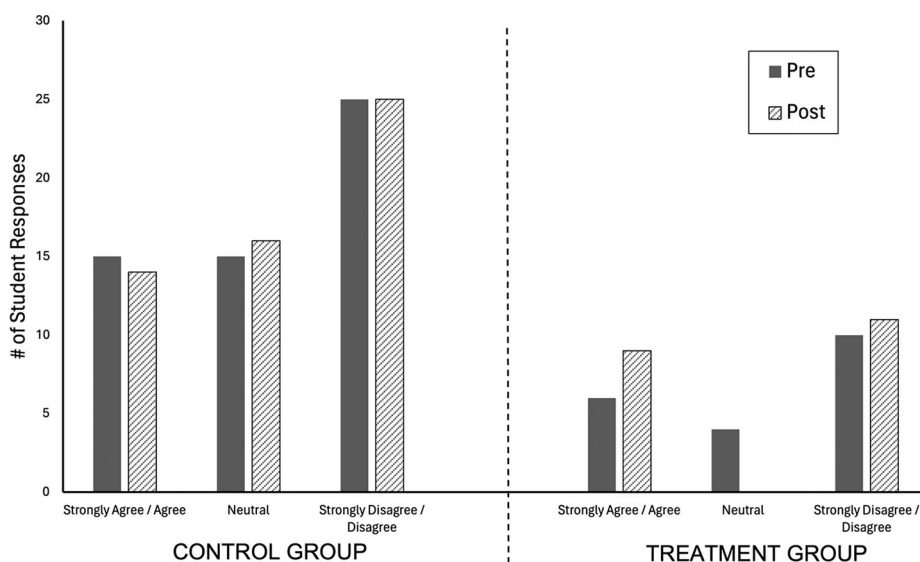
"Combating climate change requires me to make significant and daily changes in how I live my daily life."

Figure 7. The pattern of student responses in the *control group* did not change from pre- to post-surveys regarding whether they felt combating climate change would require them to make significant changes in their daily lives (chi-square $p = 0.967$). There was, however, a shift in student responses in the *treatment group* away from the "*neutral*" choice (chi-square $p = 0.093$)

Source: Authors' own work

up, and this is a serious problem. When it comes to gameplay, the level of difficulty of the game is such that victory for any given gameplaying session is far from guaranteed; in each of the game play sessions, there was at least one game table that experienced a climate disaster loss, reinforcing the notion that *saving* the planet is not necessarily a foregone conclusion. Even when a climate disaster loss is not triggered, there is a very real sense of increasing concern with the rising temperature of the earth as the game proceeds. The idea that an alignment between board game aesthetics and board game themes is important is not a new one. Costikyan (2011) argues that board game aesthetics are often a valued part of the gameplay experience for "simulation" types of games, and the accuracy of board game imagery has elsewhere been linked to players making connections between board game themes and real life (Friedersdorff *et al.*, 2019). This alignment appears to be a feature of *Global Warning*.

Another notable trend was that students in the *treatment* group tended to change their answers in terms of what "society" could do to impact climate change (Figures 4 and 5). The ideas that students tended to add in their post-surveys seemed to correspond to the themes of the game *Solution Cards* (Figure 2), particularly Actions like "*reduce, reuse, recycle, repair*," "*save energy at home*," "*eat less meat/more vegetables*," "*create less food waste*" and "*clean up the environment*." The first of these is recognized as an important practice in combating global climate change (Gore and Robinson, 2009; Eneh and Oluigbo, 2012; Lamma, 2021) and often emerges as one of the most popular ideas people propose to help

Table 1. The positive and negative elements of *Global Warning* cited in student reviews (*n* = 20)

	No. of reviews
Positive	
Learning value/raises awareness for climate change	19
Cooperative and competitive elements	14
High quality imagery and/or game craftsmanship	13
Fun and engaging	7
Quick and/or easy to learn	5
Innovative	1
Negative	
Unclear or complicated aspects of game instructions	8
Boring or repetitive	6
Low die rolls slow game down	5
Low-quality game parts (e.g. the die and in-game money)	2
Low-quality imagery and/or game craftsmanship	1
Not reflective of the real-life scenarios	1
Difficult to achieve victory	1

Source(s): Authors' own work

reduce planet warming (Crosman *et al.*, 2019; Venkatesan *et al.*, 2021; Tolppanen *et al.*, 2022). But the emphasis of this practice is far from universal. For example, in a recent multi-country survey of 18 possible climate policies that governments could pursue to mitigate the impact of climate change, "recycling and waste management-practices" are not listed (Flynn *et al.*, 2021). The theme of "recycling" is also given short shrift in a recent IPCC (2023) report on climate change. The other ideas – from "*saving energy at home,*" to "*cleaning up the environment*" – seem to be more common in climate public awareness surveys. But the change seen in the treatment group supports a narrative that post-secondary-aged students might be primed to support policies that encourage the reduction of waste, the reusing of products and the recycling of non-renewable resources.

Perhaps, one of the more puzzling results of this study was a shift in treatment group students' perceptions of how difficult it would be to make daily changes to mitigate climate change (Figure 7). After the board game sessions, students in this group were less likely to respond "*neutral*" to the statement "*Combating climate change requires me to make significant and difficult changes to how I live my daily life*." While some might dismiss this shift as "non-significant" based on the *p*-value (0.093), it is important to consider the broader context. *p*-values, originally intended as guides rather than rigid thresholds (Fisher, 1925), merely represent the probability of observing the result assuming the null hypothesis is true. This particular case is further complicated by low statistical power (a post-hoc analysis revealed a ~50% chance of a Type II error). Given these limitations of the statistical testing, the authors believe it is worthwhile to explore the observed pattern. The hypothesis behind this question was that students might recognize, after gameplay, that small changes to daily life could contribute to combating climate change. This aligns with themes from the Solution Cards targeted at actions achievable by students, such as improving recycling practices (Figure 2a). Unfortunately, without qualitative data to probe students' reasoning, the authors can only speculate on why neutrality decreased. One possibility is that certain climate actions, while simple for some, may seem daunting for others based on personal circumstances. For example, only 75% of Michigan's population had access to recycling services in 2023 (Department of Environment, Great Lakes, and Energy, 2023). Students

from municipalities without recycling options may view recycling as a significant change, while others might find it trivial. Similarly, rural students with limited access to public transit may perceive "reducing car usage" as impractical. These findings highlight that perceptions of feasibility are highly context-dependent, underscoring the need for further research to better understand individual variability in responses.

Student opinion

Global Warning was generally very well received by students. On average, student reviews listed more than twice as many positive game aspects than negative game aspects. The positive aspect most commonly cited by students (i.e. in 19 of 20 reviews) was that the game had educational value or value in "bringing awareness" to the issue of climate change. It is also notable that none of the reviews claimed that there was *no learning* associated with the game or that the game seemed unlikely to achieve educational outcomes. While there can often be a disconnect between student *perception* of learning and student *performance* of learning (Persky *et al.*, 2020), these seem to be relatively well aligned in the case of *Global Warning*.

The next most commonly cited positive aspect of *Global Warning* was the intriguing competitive-cooperative nature of the game. Readers of this paper who are familiar with board games know that *cooperative* board games are relatively rare and would likely be even more hard-pressed to cite an example of a game that has *both* cooperative *and* competitive (explicit) goals. In this respect, *Global Warning* is somewhat unique. It is also possible that this unique feature contributes to the positive student learning outcomes that were observed. Cooperative- and peer-learning typically results in better learning gains than non-cooperative/ peer learning (Vickrey *et al.*, 2015), and when it comes to mitigating *climate change*, real-world solutions typically require *both* individual- *and* societal-based actions (Whitmarsh *et al.*, 2021). It thus seems that the game's blend of cooperative and competitive elements could be synergistic with the game's goal of impacting student thinking on climate change.

Negative aspects most commonly cited by students were related to unclear game instructions, the repetitive nature of the game and unlucky die-rolls. While this may be a signal for the game designers that a revision of the game rules could be helpful in future editions of the game, the other negative aspects do not seem necessarily unique to *Global Warning*. Many board games are repetitive (and for some players, that could make them boring), and unlucky die-rolls can diminish the enjoyment of *any* board game for a particularly unlucky player. In these latter two cases, the authors cannot say whether these were features that were *particularly* problematic with *Global Warning* or whether they are simply a frustrating feature of board games more broadly that some players are more sensitive to than others.

Limitations, considerations and suggestions for further research

There were several factors that limited the richness of the data that were ultimately collected in this study. First, this study examined a single cohort of students, and the *treatment* group sample size was low. While this increased the chance of making Type II errors, it also gave each of the *treatment* data points high leverage in influencing the trends that were observed in the *treatment* data. It is also possible that there was an actual qualitative difference between the students themselves in the control vs treatment groups that caused different patterns that were observed (i.e. factors unrelated to board game playing). More notably a higher percentage of *treatment* group students were enrolled in Michigan State University's *Honor's College*, which itself can have an impact on both student success and critical thinking skills (Seifert *et al.*, 2007; Diaz *et al.*, 2019). The authors therefore cannot rule out the possibility that the unique gains seen in the *treatment* group from the pre- to post-surveys are caused by some other factor and is merely a *correlate* of membership in the board game-playing *treatment* group.

Second, students were not given any incentive to give complete or comprehensive answers to the *Climate Action Survey*. Instead, the survey was given out at the beginning of class, with an explanation that it was part of a study looking at student perception of climate change (per the study's IRB), and students were verbally asked to give answers that were "*as complete and comprehensive as possible*." The authors have no confidence that the responses received in response to the questions represented a deep probing of student knowledge for survey questions 2, 3 or 4. It is possible that after writing down one or two answers (or in some cases, single words), many students simply felt like their answer was "*comprehensive enough*." Neither were students asked to "*provide as many ideas as possible*," for example, in their written responses. It is therefore very possible (and perhaps likely) that student answers for these questions were simply the first few things that students thought of. Follow-up interviews would have helped clarify how students interpreted these questions and why they responded as they did. In addition, interviews could have provided valuable insight into student engagement during gameplay, including how they processed tradeoffs, strategies and group dynamics. Unfortunately, such interviews were not included in the study's IRB approval, which was limited to surveys and in-class written reflections. Adding interviews would have required an amendment and re-consent process, which was not feasible given the study's timeline. In hindsight, this represents a missed opportunity to better understand both the student learning experience and the cognitive processes behind their survey responses.

Third, this study did not include a comparison to other climate change learning modalities, such as classroom lectures, readings or digital simulations. While the design allowed us to detect changes in student responses after gameplay, the authors are unable to assess whether those changes were greater, lesser or qualitatively different than those that might have occurred through traditional instruction.

Fourth, there were limitations when it came to the actions suggested by the UN "Actions for a Healthy Planet" framework and the solutions posed in the Global Warning game itself. Several UN actions, such as "Clean up your environment," are more aligned with general environmental stewardship than with climate change mitigation specifically. Likewise, the board game includes problem scenarios like oil spills, which, while serious environmental concerns, are not major contributors to greenhouse gas emissions. The inclusion of these themes (particularly in the board game) might confuse or conflate the issues of climate change mitigation and broader environmental remediation. While the coding scheme sought to avoid double-counting (see Methods), this particular ambiguity may have subtly shaped student responses and introduced noise into the analysis of mitigation-related ideas.

Finally, the pre- and post-surveys were given in different calendar seasons. The pre-survey was given in February in Michigan; the post-survey was given at the beginning of April. Although Michigan experienced an unseasonably warm winter in 2023–2024, the average daytime temperatures in the weeks preceding the pre-survey were 5–10°F colder than the average daytime temperatures in the weeks preceding the post-survey. Local weather conditions can have an impact on how people view climate change (Borick and Rabe, 2014), and while the control group may provide a reasonable backdrop against which to compare the data from the treatment group, the authors cannot rule out some kind of interaction effect between the warming weather and board game playing or critical-thinking skills that could have impacted the answers given in the *treatment* group.

Conclusion

This study set out to evaluate whether playing Global Warning would (1) shift students' perceptions of the urgency and severity of climate change and (2) influence their

understanding of and intention to engage in mitigation actions. The findings of this study suggest that the game did both. Students who played the game demonstrated statistically significant and qualitatively important changes in how they perceived the urgency of climate change, as well as in the range and specificity of actions they believed could be taken to mitigate it. These gains were not observed in the control group, suggesting that the structured gameplay experience – not just prior knowledge – played a central role in fostering this shift. The game's blend of cooperative and competitive mechanics mirrors real-world climate negotiations, where individuals must weigh personal benefit against collective risk. Players are routinely faced with in-game ethical dilemmas – for example, choosing whether to pursue a higher chance of personal victory at the expense of group success – echoing the tensions that shape real climate mitigation actions and climate policy. This interplay, combined with the stochastic elements of die rolls and shuffled cards, ensures that each gameplay session introduces new climate scenarios and social dynamics. As such, the game promotes strategic thinking, trade-off reasoning and systems-level engagement in a way that is repeatable and adaptable across classrooms. *Global Warning*'s capacity to provoke shifts in both personal and societal perspectives suggests that it can serve not merely as a one-off teaching tool, but as a springboard for ongoing climate discourse and education.

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