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Designing a Large Multi-Player Simulation Game to Encourage Reflection and Critical Debate

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Abstract: There is great potential to design digital simulation games as part of professional training settings. However, there is little research on how a large group in a classroom or seminar can all play at the same time. In this paper we describe the design and first in-the-wild deployment of the 4Decades game, which involves up to 30 players simultaneously in a simulation of global climate economics. Using a network of shared devices and ambient displays, a fast-paced collaborative game enabled players to reflect on prior learning, strategy making and their critical understanding of the simulation.

Keywords/Key Phrases: serious games; multi-player simulation; game design; field study;

1. Introduction

A common problem in intensive training courses that span several days is putting into practice the multitude of theory presented in the lectures. Simulation games are often used to enable role-playing and provide an environment for active learning. In many cases, however, simulation games are difficult to integrate with the time constraints and social structure of a course, because they involve lengthy turn-taking or address only small groups at a time. In contrast, our approach was to develop a multi-player computer game that allowed a whole class of students to put into practice and reflect on prior learning using an interactive, distributed simulation of global climate economics. Specifically, our goal was to provide

- seamless interaction with the simulation
- fast-paced game-play with instantaneous feedback for everybody
- integration with the infrastructure of the setting (up to 30 learners in 1 room and 1 teacher)
- an engaging learning experience that fits in a 1 hour slot, including introduction and debrief

We found that the game engenders an in-depth debate among players about what goals to pursue in the game. By negotiating team strategies, players apply previous learning about the domain and reflect on their decision-making together. Moreover, by surfacing the way players interpret previously learned theory, the game can expose misunderstandings. This makes it a lightweight yet powerful diagnosis tool for teachers to detect opportunities for clarification and improvements to the curriculum.

In this paper we will first provide an overview of current literature on learning with multi-player simulations and games. Second, we will describe the design of the 4Decades game. Third we will describe the first deployment and evaluation of the 4Decades game. We conclude with a discussion about how effective the game was.

2. Background

2.1 Learning with simulations

A recent literature review about the use of simulations for learning is provided by Silvia (2010) who concludes that simulations can support high-level learning (Bloom & Krathwohl 1956) in addition to traditional teaching methods. Active learning with simulations can enhance the retention of factual information and help learners understand processes and operations in complex systems. In addition to domain-specific learning, simulations can help participants develop critical thinking about the implications and scope of complex models. For example, several co-located multi-player simulations have been developed and applied in business settings in order to foster leadership skills (Krain & Lantis 2006). However, these are largely paper based or rely on computer technology that is not suitable for providing large groups of students with real-time feedback. Further, one of the most frequently reported problems with the use of business simulations is the time required for preparation and during class (Faria & Wellington 2004). Participatory Simulations as proposed by Colella (2000) are a way to bring a large group together in a shared, real-time computer simulation. Using a network of devices, learners act out the roles of individual elements of the simulation, thus getting first-person experience with the simulation model.

2.2 Player motivation and values

When simulations are framed as computer games it is important to note that people play such games for various reasons. Competition can be a driver as well as the joy of discovery, role-playing, teamwork, socialising, analysing the game mechanics, etc. (Yee 2005). Calleja (2007) suggests that players' involvement can be informed by a number of aspects - tactical, affective, narrative, spatial, performative and shared. A player's situational relation to these aspects may shape their experience and decision-making in any given episode of game-play. According to Salen & Zimmerman (2004) players generate meaning through play and value possible choices in the game according to their curiosity, desire for self-expression or other personal reasons. Therefore players' behaviour may not always fall within the range of behaviours anticipated by the game designers. Barr (Barr, Marsen & Noble 2005) argued that games *promote* and *assume* certain values, and players are free to *subscribe* to those values to the extent they want. Players may even choose to make a statement by playing in opposition to the values intended by the designers. This so called *subversive play* has been praised as a good thing as it can promote reflection and a sense of autonomy (Flanagan 2009). The large number of players who take pleasure in subversive play (Flanagan 2005) across a wide range of games suggests that subversive play is also inherently motivating and should therefore be added to the list of factors that can inform decision making during a game. Flanagan suggests that subversive play should be embraced as part of the game design process in the sense that *designers*

“...evaluate the game through the play tests and player comments. They verify that the values goals emerge through play, and revise goals and add or drop options based on feedback to ensure an engaging game and support the project values.” (Flanagan 2009)

In other words, Flanagan's approach aims to help designers draw inspiration from genuine subversive play in the service of the design's ultimate goal: to create games whose *promoted* and *assumed* values will be *subscribed to* by players, i.e. games that don't themselves call for subversive or oppositional play. This suggests that Flanagan's praise of an oppositional stance towards game values draws the line at games that are already 'value-optimised', if that is a fair thing to say. Indeed there seems to be a scarcity of empirical research concerning what triggers better discussions: playing an agreeable game or subverting a contestable game. Should we design games to be in-line with players' values to create common ground? Or do players need something to disagree with (or about)? This leads us to the following research question:

How can one design a simulation game that will encourage players to engage in a critical debate about the topic and the values implied in the simulation?

3. Design of the 4Decades game

In collaboration with the Cambridge Programme for Sustainability Leadership (CPSL) we designed the 4Decades game to be integrated with one of CPSL's 4-day professional training courses in the Climate Leadership Programme (CLP) series for business leaders. One of the main goals of this programme is to encourage knowledge transfer between managers with different professional and cultural backgrounds. A series of lectures and workshops aims to provide delegates with enough understanding of the science, economics and policy making around global climate change to effect more sustainable business strategies in their organisations. We had a 90 minute slot to deploy our game at the end of the second day, after a number of theoretical lectures on climate economics.



Figure 1: Two teams of players



Figure 2: Sharing an iPad

Our design goals, informed by the research question above were as follows:

3.1 Turn a real life scientific model of climate economics into a simulation game

As the mathematical basis of the simulation we used existing models that were taught in the lectures. This was in order to ensure scientific validity of the game. Specifically, we copied the interrelation between global cumulative CO₂ emissions, temperature increase and damage to the global economy predicted by the Stern Review (Stern 2006). The goal of the game is for players to balance investments in CO₂ mitigation, adaptation and repairs, in order to maintain a wealthy economy until 2050. The Global Greenhouse Gas Abatement Cost Curve (Enkvist, Dinkel & Lin 2010) was used to define the cost of CO₂ mitigation per gigatonne and decade. For the efficacy of adaptation investments in relation to global temperature no reliable data could be found in the literature, so we invented numbers for this factor that seemed realistic and iteratively tweaked them during play-testing to balance the game i.e. ensure that desirable strategies were rewarded with high scores (high global income by 2050).

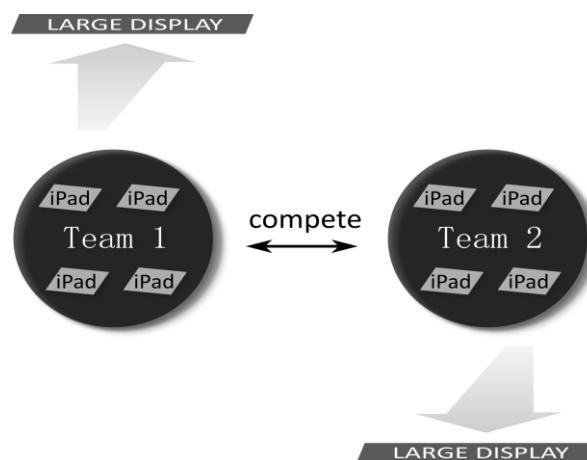


Figure 3: Room set-up

3.2 Design an intuitive multi-user interface that takes minimal effort to learn and use

We divided the group of 30 players in two competing teams and gave every team 4 tablet devices (iPads, see Figure 4) to share among them (see Figure 3). Each team represented a separate planet with its own economy, divided into equal quarters which we termed "Regions" on the planet, with one iPad assigned to each Region. The iPads served two purposes: a) to give players a real-time account of their planet's condition, including global temperature, regional CO₂ emissions, regional income, expected damage, etc. and b) to let players enter their regional investment decisions using simple buttons.

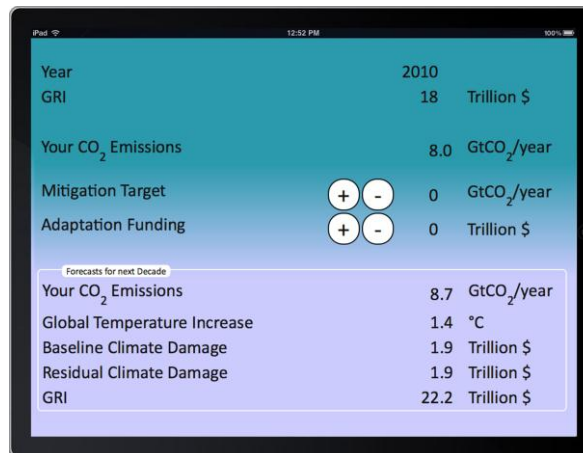


Figure 4: Simple iPad interface

3.3 Encourage knowledge transfer and give a voice to minority opinions

This way of distributing information means that players within a team need to talk, move around or pass the iPads in order for everybody to know what the other Regions are doing. We seated half the players at square tables with one iPad at every corner and let the remaining players move around freely in the room, to encourage different modes of communication between the Regions. Another incentive for communication between Regions is inherent in the simulation: The way the maths work out, it is generally cheaper for a team if all Regions invest the same amount in mitigation rather than having different mitigation values within one round. This encourages teams to agree on a joint strategic decision.

3.4 Enable a single teacher to facilitate whole classroom learning through an ecology of displays

In addition to the iPads, each team had their own large projection screen on which a history of game data was projected. Figures 1, 6 and 8 depict one of these screens. The other one is located at the opposing wall as sketched in Figure 3. The game is structured in rounds and after each round the displays update, showing their respective team's regional investments, global temperature, regional income, etc. for every previous round. These *ambient displays* allow a teacher to see from any point in the room what strategy a team is employing, how the simulation reacted to the regional decisions and how well the regional decisions are coordinated. The teacher can use the displays when talking to teams about aspects of the simulation.

3.5 Encourage extended dialogues amongst the teams using real-time visualisations of game data as the game progresses

Players can use the growing set of data on the displays to reflect on their own strategy and compare it with strategies employed in previous matches. They can also use the other team's display to draw conclusions about winning strategies.

3.6 Make the reward system coherent, logical and rational but somewhat contestable

The current version of the game rewards sustainable strategies involving early investments in mitigation, keeping emissions and the global temperature low, as promoted in the lectures. Specifically, early mitigation pays off better compared to late mitigation. However, we left a loophole in the strategic space by allowing unlimited investments in adaptation, which effectively means that players can fully insure themselves against any climate disasters no matter how high the temperature rises. This idea is in stark contrast to the theory taught in the course and allows what we called the Evil Strategy: spending nothing on mitigation and just enough on adaptation to cancel out the resulting damage in every round. This Evil Strategy achieves a slightly higher score than any sustainable strategy (see Figure 5) due to the way the maths work out. One way to eliminate the Evil Strategy would have been to limit the amount a Region can invest in adaptation. But we decided to leave it in the game as a contestable element for the following reasons. First, we hypothesised that due to the way the game is introduced and learned, the Evil Strategy would not be obvious to players from the start. Second, the margin to be gained using the Evil Strategy is not very large (see Figure 5) and the input values required are eccentric, so it would require careful observation and experimental gameplay to discover its benefit. Finally, even if the Evil Strategy was discovered, the whole team would have to follow through with it to make it feasible - given the strategy's contestable nature it could be difficult to persuade the whole team.

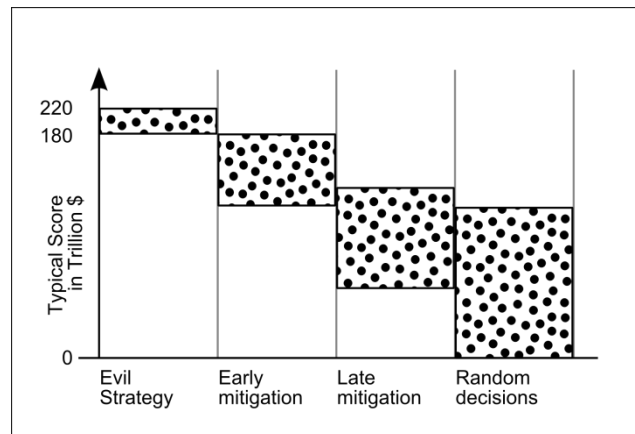


Figure 5: The strategy/reward space (schematic)

3.7 Encourage negotiation by letting players follow different goals but requiring the consent of team mates

We assumed that the Evil Strategy would give players an entry point for critical debate. While we think that the game generally represents quite a plausible simulation in-line with the values assumed and promoted by the course, this specific narrow, somewhat hidden, shady corner of the game space clearly contradicts. We reckoned that to any course participant after two days of lectures the idea of a climate-unfriendly strategy being rewarded should seem so counter-intuitive that it must seem like a misunderstanding. Our hope was that this would trigger a discussion among players, and that this discussion would surface player's personal beliefs and interpretation of prior learning.

We structured the game in 4 matches. Each match starts in 2010 and has 4 rounds. Each round represents one decade, i.e. 2010, 2020,... We defined that the team who achieved the highest score in any of the matches would be the overall winner. We chose this way of determining the winner (rather than e.g. summing the scores) because it encourages experimentation and perseverance by keeping the challenge up even after a series of losses.

Alpha Centauri Team name

Score displayed at end of match 1

MATCH 1		decisions per iPad				outcomes												Final GPI 176.2						
Mitig	Adapt	Emissions				°C	Baseline Damage				Residual Damage				GRI									
2	2	2	2	1	1	1	1	6.7	6.7	6.7	6.7	1.2	1.7	1.7	1.7	1.7	0.0	0.0	0.0	0.0	23.2	23.2	23.2	23.2
1	1	1	1	2	2	2	2	7.0	7.0	7.0	6.0	2.3	4.2	4.2	4.2	4.2	0.0	0.0	0.0	0.0	31.1	31.1	31.1	30.1
2	3	1	3	3	2	2	3	6.2	5.2	7.2	4.2	3.3	8.1	8.1	8.1	7.9	0.0	0.0	0.0	0.0	40.0	39.0	42.0	36.6
3	2	0	3	4	2	4	4	4.5	4.5	8.5	2.5	4.1	13.2	12.9	13.8	12.1	5.2	8.9	5.8	4.1	44.1	43.1	48.2	40.6

MATCH 2		Emissions				°C	Baseline Damage				Residual Damage				GRI									
4	1	3	3	2	1	2	2	4.7	7.7	5.7	5.7	1.1	1.6	1.6	1.6	1.6	0.0	0.0	0.0	0.0	16.2	24.2	20.2	20.2
2	2	3	3	4	2	2	1	4.0	7.0	4.0	4.0	2.0	2.6	3.9	3.2	3.2	0.0	0.0	0.0	0.2	18.4	31.4	23.9	24.7
1	2	1	1	1	2	1	1	4.2	6.2	4.2	4.2	2.7	4.0	6.9	5.3	5.4	0.0	0.0	0.0	0.0	25.5	41.5	33.1	34.1
1	4	1	1	1	2	2	2	4.5	3.5	4.5	4.5	3.5	7.0	11.5	9.2	9.4	0.0	0.0	0.0	0.0	34.2	49.5	44.8	46.2

MATCH 3		Emissions				°C	Baseline Damage				Residual Damage				GRI									
1	1	1	1	1	1	1	1	7.7	7.7	7.7	7.7	1.3	1.8	1.8	1.8	1.8	0.0	0.0	0.0	0.0	24.2	24.2	24.2	24.2
1	1	1	1	1	2	1	1	8.0	8.0	8.0	8.0	2.6	4.9	4.9	4.9	4.9	0.0	0.0	0.0	0.0	33.4	32.4	33.4	33.4
1	1	1	1	2	2	2	2	8.2	8.2	8.2	8.2	3.9	10.3	10.3	10.3	10.3	0.0	0.0	0.0	0.0	45.3	43.9	45.3	45.3
1	1	1	1	9	9	9	9	8.5	8.5	8.5	8.5	5.2	18.8	18.2	18.8	18.8	0.8	0.2	0.8	0.8	53.9	52.5	53.9	53.9

MATCH 4		Emissions				°C	Baseline Damage				Residual Damage				GRI									
1	1	1	1	1	1	1	1	7.7	7.7	7.7	7.7	1.3	1.8	1.8	1.8	1.8	0.0	0.0	0.0	0.0	24.2	24.2	24.2	24.2
1	1	1	1	1	1	1	1	8.0	8.0	8.0	8.0	2.6	4.9	4.9	4.9	4.9	0.0	0.0	0.0	0.0	33.4	33.4	33.4	33.4
1	1	1	1	2	2	2	2	8.2	8.2	8.2	8.2	3.9	10.3	10.3	10.3	10.3	0.0	0.0	0.0	0.0	45.3	45.3	45.3	45.3
1	1	1	1	9	9	9	9	8.5	8.5	8.5	8.5	5.2	18.8	18.8	18.8	18.8	0.8	0.8	0.8	0.8	53.9	53.9	53.9	53.9

4 rounds

4 matches

Evil Strategy

Figure 6: Screenshot from team Alpha Centauri's ambient display at the end of the game. From top to bottom: 4 matches consisting of 4 rounds (i.e. decades) each. From left to right: Players' decisions regarding mitigation and adaptation, the consequences in terms of CO₂ emissions and global temperature increase, baseline damage (the loss of regional income if there was no adaptation investment), residual damage (damage despite adaptation investment) and finally the resulting Gross Regional Income. 4-number columns represent the 4 regions of the planet, i.e. the 4 iPads. The "Final GPI" to the right (Gross Planetary Income = sum of all GRIs in the last round) is used to determine the winner of a match. The record of decisions shows the 'Evil Strategy', matches 3 and 4: The team minimised investments in mitigation, relying on excessive adaptation to cancel out damage. Also note how a minor flaw in coordination (match 3, round 2, adaptation) was corrected in match 4.

4. Deployment and evaluation

In January 2011 the CLP course took place at a conference centre (Møller Centre) in Cambridge, UK, with the 4Decades game scheduled on day two after a series of lectures and workshops about the economics of climate change. The course schedule did not allow time for interviews or extensive questionnaires but we were given consent to take video recordings. In addition, log files of the game data were kept, a delayed post-questionnaire survey was conducted online and two researchers took ethnographical notes. We also received a summary of ratings and comments participants gave in the feedback forms that were part of the course evaluation. Studying the log files of both teams individually and in comparison gave us an overview of how strategies evolved over time, how successfully team decisions were coordinated, and when strategic breakthroughs and breakdowns occurred. Based on identified critical incidents we then looked for explanations in the video data. We also analysed the statements players made in the debriefing discussion and in the feedback forms. We identified themes concerning players' reflection on prior learning, their decision-making and attitudes to values promoted by the simulation.

4.1 Player satisfaction

Overall the game activity was well received by the participants. There was much laughter and joking, players were engrossed in game-play and everybody participated. The ratings in the feedback forms showed good participant satisfaction. On a Likert scale from 1 to 5 asking how useful they found the activity, the game received an average score of 4.1 which is close to the whole event's average rating of 4.23. Out of 20 responses nobody gave the lowest score of 1. We received several invitations from delegates to deploy 4Decades in their organisations and CPSL asked us to deploy 4Decades again in their next course. Further, questionnaire responses said that players preferred the game to a lecture on the same topic.

4.2 Usability – no problem

Players found it easy to share the iPads in pairs and small groups. At times we observed up to 6 players focused on a single iPad. One surprising theme was that when one player pressed buttons on the touch screen, they typically removed their hand immediately afterwards to see the values changing on the interface. Consequentially, the screen was then immediately free for other players to view and touch (see Figure 7). We figure that this behaviour was beneficial for equity of participation and resulted from the placement of the buttons in the middle of the screen. We did not see anyone having difficulty using the iPads or ambient displays. Nobody reported any usability issues in the debriefing or questionnaires. All players had a clear view on their own team's ambient display and some could read both ambient displays from where they were sitting or standing.



Figure 7: Touch-screen devices were found easy to share between two players. Bystanders could peek in from an angle.

4.3 Collaboration within teams

Collaboration happened within pairs, as players helped each other make sense of the interface on the iPads. As the roles within a team swapped after each match, i.e. players who had been sitting stood up and vice versa, pairs and small groups around the iPads often stayed together, trying and discussing local strategies before sharing them in the whole team. To help coordinate team decisions, some players temporarily took on mediating roles between two or more iPads, by standing or walking between them. Coordination worked well in team 'A'. The 4 Regions of team A were able to streamline their efforts towards a joint team strategy in 8 out of 16 rounds, including the entire last match. A player from team A said in the debriefing:

"There was a lot of really good collaborative policy making going on, probably on both teams. Especially after the first [match] everybody started to kind of communicate across the table. And that fairly rapidly got us towards [a winning strategy]".

Team 'B' on the other hand managed a consensus in only 5 rounds and appeared more split up into several loose clusters. Often there was one Region that entered slightly different numbers than the others, which became sort of a running joke on that table. One player at some point made the exclamation *"Shall we all do 3-1 now! Are we together? Are we unified?"*, as if to expect yet another breakdown in coordination. Another player from team B later reflected in the debriefing: *"You think you've made an agreement and then... you know... and then a region changes their opinion"*.

4.4 Role of the teacher

After briefly introducing the game, explaining the narrative, roles and how to interact with the simulation (under 7 minutes) the teacher used an initial practice match to let players familiarise themselves with the simulation and the interfaces. After the first round he walked players through the data on the ambient display field by field, explaining to the players what each field meant and how it related to the decisions they just made on their iPads. At another instance the teacher compared data between the two teams' displays, thus encouraging awareness between the teams. The teacher was free to announce the start and end of each round (his announcements were effected by a researcher sitting in a corner at a computer). During the rounds the teams were engrossed in game-play without needing the teacher's assistance. Questions were typically sorted out among peers with the effect that the teacher never had to split his attention at any point in the session. Moreover, the teacher could easily get the whole group's attention between the rounds and matches as the iPads were then in a non-interactive mode. Sometimes the teacher used these moments to throw in bits of theory related to the simulation, make comparisons with real life global policy, clarify a player's question or encourage helpful practices such as the use of pen and paper. At no point did the teacher barge in on a team's iPads or their strategy making. The ambient displays allowed the teacher to stay abreast of each team's strategic development during gameplay and in the final debriefing discussion the displays were used as reference points by teams to discuss their strategies with the other team and the teacher.

4.5 Knowledge sharing between teams

After a few game rounds players discovered that they could use the ambient displays to spy on the opponent's strategies. They typically did this alone or in pairs, either by walking over to the other display or standing at central positions in the room. One pair of players in team A stood out as they spent an extended amount of time discussing a previous match of the other team (see Figure 8). They apparently understood what the other team's strategic intentions had been and what the other team had done wrong. Consequentially, they optimised the strategy, by eliminating all mitigation spending – and so the Evil Strategy was discovered by two spying players. Together they managed to persuade their team to adopt the strategy and the match was won for team A. Remarkably, all players in team A followed the strategy. Some players went along with it despite their own misgivings (evidenced by counterarguments). What surprised us was that team B did not make an effort to learn from team A in the same way by copying A's winning strategy. They clearly despised it as unfair play and kept mitigating emissions. In fact, team B continued to improve their sustainable strategy almost to perfection, far better than the sustainable strategies A had employed before they 'turned evil'.



Figure 8: Two men in the front using the record of game data on the opponent's wall display to learn from the opponent's previous strategy.

4.6 Surfacing players' values

We found a variety of player types with regard to leadership behaviour, socio-emotional engagement in the team, competitive attitude, interest in data analysis, amount of verbal participation and other factors. Surprisingly, not all players appeared to subscribe to the explicitly stated task goal. Rather, they seemed to construct meanings of the task while playing, as described by (Salen & Zimmerman

2004). Some players clearly wanted to win and were focused on the game score, i.e. global income, debating which way of treating the planet would lead to greater wealth. Other players seemed to identify deeply with a self-introduced narrative of civic responsibility, possibly influenced by the context of the venue and prior lectures. One player from team B addressed his team with the words:

"It's a climate change game. The answer has to be: mitigate – a lot – early."

On team A, after the team had long stopped worrying about global warming, one player tried to draw her teammates' attention back to the idea of minimising temperature increase:

"Look, the best temperature was 3.5 after match 2."

One of her team mates, who had been arguing for an income-focused strategy, replied:

"Yes, if you got a bonus for that, it would be a different game."

Overall we had the impression that when expressing their opinions as arguments, players related to their personal gut feelings, prior lectures, real-life politics, game mechanics or game narratives.

4.7 Players' reflections on game-play and the simulation

As the comments in the debriefing discussion and questionnaires showed, players from both teams realised that the feedback from the simulation contradicted prior lessons of the course. As one player of team A summarised:

"We were slightly surprised that a bit more spending on mitigation in the early decades didn't deliver a better result, which is what you'd have thought from what we were hearing and discussing today. So that was a bit counterintuitive."

We were glad to find that players made their own judgements rather than subscribing to the game's proposed values. Different values within a team were evidenced by this statement of a team B player:

"The money was a driver, but... i think we didn't... erm... we certainly could have made a lot of our decisions based on trying to keep the temperature down."

A player from team B indicates a strong identification with the player-constructed narrative that competed with the game's official objective:

"We made slightly less money than them, but considerably... erm we have... you know, saved the planet."

Another team B player demonstrated an awareness of the limited scope of the simulation while criticising that the opponent's strategy was not sustainable with regard to the future beyond the end of the game:

"If there'd been a fifth decade, I wonder what... how your team would have then fared."

Several comments illuminated how players reflected on their exploration of the strategic space and how they thought of the game as a *black box* that rewards certain inputs with certain outputs.

"I didn't think there was enough penalty. We were trying to think well actually, trying to manage temperature earlier, but that wasn't coming through in terms of the results."

None of the players asked for an explanation of the formulae that generated the unexpected and undesired results. Apparently the inner workings of the simulation-based game were perceived as something that players were not meant to dissect. The experiment didn't confirm our expectation that, as a result of game-play and discussion, players would identify what was wrong with the game, take ownership of the problem and think of possible solutions. Instead, the fact that players repeatedly used words like *penalty*, *reward* and *punishment* may indicate that players perceived the relationship between game designers and players as essentially behaviouristic.

5. Conclusion and future work

We presented 4Decades, a simulation-based game which was designed to engage a large group of business leaders in critical debate about the simulated topic and the model underlying the simulation. Feedback from participants and stakeholders suggests that the game was successful in providing an engaging experience that integrated with the schedule and learning agenda of the course. The unique way information and control were distributed across the room allowed every player to participate meaningfully and also enabled the teacher to facilitate group learning. By contrasting feedback from the simulation with knowledge from prior lectures, players quickly discovered a flaw in the strategic space of the game that we had introduced in order to trigger a discussion. Our impression of the discussion and questionnaire comments was that, although many players rightly criticised the consequences of the flaw, surprisingly few players demonstrated the ability to pinpoint its cause. What we particularly missed in the discourse was a shared vocabulary that would allow players to distinguish between the scientific models and the game designers' decisions. It has been argued that this distinction is necessary for players to gain a deeper understanding of how real-world phenomena are simulated (Colella 2000; Turkle 2003). Toward this goal, we plan to conduct a follow-up study where we allow players to collaboratively modify their own game. Specifically, we are going to let players revise the numbers that we (as the game designers) chose to define adaptation efficacy, so that players can actively implement their own vision of a plausible simulation, based on the given scientific models. Making the underlying maths transparent and understandable to players will be a major design challenge, since neither integrals nor Java code will be appropriate for the audience. Moreover, we are planning to let players make decisions regarding the game interface, particularly, which of the simulation's variables should be shown on the ambient displays and the iPads. This way we hope that players learn by experience how scientific data and design decisions together shape players' experiences in a simulation-based game. In other words, we hope to support a less behaviourist, more constructivist stance toward playful learning with simulations.

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