Mind the Gap: Teaching High School Students about Wealth Inequality through Agent-Based Participatory Simulations

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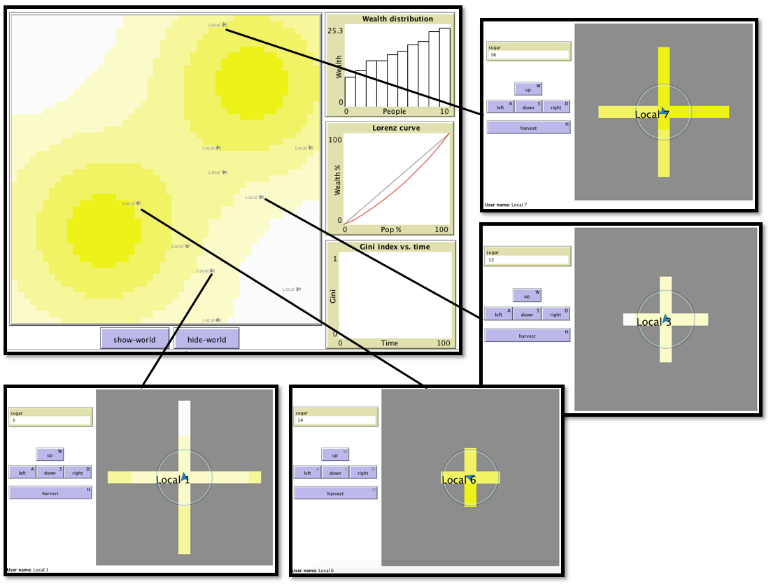
Abstract

This research paper presents a design-based research study centring on a constructionist curricular unit, called Mind the Gap (MTG), which was designed to help high school students learn about a complex and controversial social issue in the United States—wealth inequality. The four-day-long unit was implemented in eight economics classes with a total of more than 200 students across two high schools with vastly different demographics. In both schools, students' engagement with the unit was high. Preliminary data analysis has shown that students 1) made connections between their simulation experience and the real world to reason about wealth inequality, and 2) showed attitudinal changes favouring more equality after the unit.

MTG revolves around a series of three participatory simulations, which are microworlds that allow students to project themselves into through their own avatars like in a multiplayer online game and interact with the virtual environments in order to "figure out" the rules embedded in these simulations. This work contributes to both the literature of designing constructionist learning environment and people's perception and understanding of wealth inequality. In democratic countries, people's understanding of inequality is the key to achieve more equal societies.



Mind the Gap ABPS. Upper left: teacher's view; the other four: students' view

Keywords

Agent-based participatory simulation; wealth inequality; economics curriculum; complex social phenomena; artificial society

Introduction

Today, American people face many controversial social issues that deeply divide the country. Examples include wealth inequality, racial segregation, and climate change. Although natural and social scientists have been studying these problems and have provided accumulating evidence for causes and consequences, when people think about these problems, they tend to form very polarized views based on the vastly different local environments they are in (e.g., Xu & Garand 2010), political beliefs (e.g., Kteily, Sheehy-Skeffington, & Ho, 2017), and media coverage (e.g., Diermeier et al. 2017). The scientific methods and evidence, which can help people understand the mechanisms and consequences of many social issues, remain underutilized in people's reasoning about complex social problems.

Through the lens of complexity science, wealth inequality, racial segregation, and climate change can be seen as patterns that emerge from interactions among constituting elements. The system level patterns at very large scale can be strikingly different from the behavior of the constituting elements at the local level, making these complex systems unintuitive and hard for people to understand (Wilenksy & Resnick, 1999; Chi, 2005; Penner, 2000; 2001). Agent-based modeling (ABM) is a computational modeling method that scientists use to study these complex systems. With the ABM approach, elements of complex systems are modeled as autonomous agents, which have their own properties and behaviors. In an ABM, numerous such agents interact with each other and give rise to complex patterns at the system's level.

ABM is also an effective way to help students understand complex systems. Extensive research has been done on using NetLogo (Wilensky, 1999)—an agent-based modeling tool that dynamically simulate and visualize complex systems—to create instructional interventions in STEM education. Evidence show that these curricula supported students' understanding of complex phenomena in a variety of scientific subjects, including biology, chemistry, and physics (e.g., Wilensky & Reisman, 2006; Levy & Wilensky, 2008; Sengupta & Wilensky, 2009).

Teaching about complex social phenomena is an understudied area (Hjorth & Krist, 2016). While social phenomena such as wealth inequality can be treated as complex systems, learning about these phenomena presents new challenges. Hjorth & Wilensky (2014) designed and taught urban planning and policy reasoning with an agent-based models and found that compared with physical or biological systems with constituting elements like molecules or animals, social systems—composed of people with wants and needs—are much more heterogeneous and therefore more difficult for students to reason about (Hjorth & Krist, 2016).

A special form of ABM—participatory simulation—can be especially promising for helping students understand complex social issues. Agents' behavior in regular ABMs are pre-programmed, but agents in agent-based participatory simulations (ABPS) are controlled directly by students, who project themselves in to the models by taking on the roles of the agents and acting out their behaviors. For example, the Disease participatory simulation (Wilensky & Stroup, 1999) models the spread of a contagious disease across a population. In this simulation, each student uses a computer to control an avatar's movements in a shared virtual world. When an infected avatar touches a healthy avatar, there is a certain chance that the healthy one also becomes infected. The simulation starts with nobody being infected, but when the teacher randomly chooses a student to infect, the simulation usually turns into a chasing game, in which the infected student tries to infect as many other students as possible. Once others are infected, they in turn chase those who are not infected. This participatory simulation teaches an important complex systems idea about logistic growth: no matter what the students do at the individual level, the larger pattern of infection across the population remains the same—the epidemic starts with a very slow spreading speed, but as it develops, it reaches a breakout point, after which the number of infected people skyrockets, and finally the progress levels off, when the whole population is infected. Such an approach not only teaches students' the dynamics of complex systems, but also brings out students' emotions, desires, and decisions, which can be productive elements that contribute to understanding complex social issues.

ABPS as Constructionist learning environments

Constructionist learning environments are designed to support students' constructing knowledge and artifacts (Papert, 1980). Core features of these learning environments include leveraging students' prior knowledge—tapping into students existing experience, closeness to objects (Papert & Harel, 1991)—bringing student close to objects that they can manipulate, and epistemological pluralism (Turkle & Papert, 1992)—valuing different ways of knowing.

Microworlds are a genre of constructionist learning environments in which students explore a very specific aspect of the world. In this sense, a microworld is a model of the real or a hypothetical world, in which the rules and regularities that govern the world are beneath the surface as far as the students' direct experience is concerned, but the rules and regularities manifest themselves by transforming the states of concrete objects as students interact with the microworld (Groen & Kieran 1983). Edwards (1995) citing Piorlli & Greeno (1988) and Pratt (1991) describes a fundamental aspect of microworlds as "the scientific or mathematical phenomenon which the designer intends to introduce to the learner is instantiated or embodied in computer code. It is by translating mathematical or scientific regularities into procedures and computational objects that the designer constructs a microworld, and this process involves a complex series of choices and design decisions." (Edwards 1995)

ABPS can be seen as a special type of microworlds, in which models can be executed by participants' following rules in the microworlds and acting out the behavior of elements that they are representing (Colella 2000). Students explore these powerful models by becoming part of them. Students construct specific runs, or instances, of the model by collectively acting out the rules. These runs become artifacts that can be replayed and investigated. In addition, in ABPS, students co-construct theories to explain the phenomena that they are part of. The explanation is grounded in students' individual experience of being part of the phenomena and interacting with others in the ABPS. Students construct publicly sharable entities and pay collective attention to these entities, which can either be projected on the big screen for the whole class to see, or exist ephemerally in the shared virtual space, such as the configuration of everybody's avatar in that space.

Mind the Gap Curricular Unit

We designed an ABPS curricular unit, called "Mind the Gap" (Guo & Wilensky, 2018a), for students to learn about wealth inequality—a complex and controversial socioeconomic phenomenon.

Previous studies have shown that most people have misperceptions and misconceptions about wealth inequality, such as severely underestimating the extent of wealth inequality in the U.S. and attributing the problem solely to individual characteristics, such as work ethic (e.g., Bullock 2008; Hauser & Norton 2017). Most existing instructional interventions on wealth inequality use multicultural or social justice approaches to engage students in knowing factual knowledge, analyzing their social environments, critically thinking about diversity, and advocating for possibilities for marginalized groups (Nagda, Gurin, & Lopez, 2003; Seider 2011; Mistry, Brown, Chow, & Collins, 2012). These interventions are important because they raise students' awareness of social issues, empower marginalized students, and help students avoid deficit thinking. However, students still have difficulties identifying or explaining the structural problems of wealth inequality after going through these curricula (e.g., Seider, 2011; Mistry et al., 2012).

Building on a body of work on participatory simulations of social complex phenomena (e.g., Sterman 1992; Wilensky, 2002; Maroulis & Wilensky, 2004), we use ABPSs to teach the complex and controversial socioeconomic topic of wealth inequality. Participatory simulations in STEM education are shown to promote engagement (e.g., Colella, 2000; Klopfer, Yoon, & Perry, 2005), improve understanding of complex systems mechanisms (e.g., Wilensky & Stroup, 1999; 2002; Stroup & Wilensky, 2014; Berland & Wilensky, 2015), and high classroom participation (e.g., Fies & Langman, 2011). However, less is known about the affordances of participatory simulations in social science topics.

Mind the Gap (MTG) centers on a series of three ABPSs—microworlds in which students' avatars interact with the computer-based virtual environments that represent simplified economies. Instead of encompassing all the factors and intricate relations that may contribute to wealth inequality in the real world, these microworlds highlight three mechanisms of the phenomenon: 1) emergence, 2) randomness, and 3) feedback loops. These ABPSs serve as computational laboratories of social systems for students to play the roles of people with different socioeconomic status, explore the rules and the structures of the system, experience success and frustration, and make sense of the emergence of complex patterns from individuals' behavior.

The design of the three ABPSs are based on SugarScape agent-based models (Epstein & Axtell, 1996; Li & Wilensky, 2009a, 2009b, 2009c) that allow computational scientist to investigate complex social phenomena such as wealth inequality, migration, trade, and epidemics through a bottom up approach—agents' following very simple rules. It is surprising for people to see a small set of simple rules, when followed by each agent, can generate highly complex patterns at the system level, which are similar to real-world social phenomena.

The original SugarScape models represent a society with two major parts: 1) the "land", where resources (sugar) can be harvested to become people's wealth; 2) the people, which are computational agents that are pre-programmed to find the highest concentration of sugar around them and to "harvest" that sugar. The land is represented by a 51 by 51 checkerboard. Each tile on the checkerboard contains certain amount of sugar. The people have randomly assigned traits and are randomly placed on the checkerboard.

Our design of MTG ABPSs preserved the basic structures of the SugarScape models, such as the 51 by 51 checkerboard, the random placement of agents, the random assignments of agent traits, and most of the rules. However, in our ABPS models, agents are avatars that are directly controlled by students, who can make decisions of what to do next within the constraints of certain rules. Students are connected to the virtual space through the HubNet architecture—a client-server technology designed for participatory simulations (Wilensky & Stroup, 1999b). Therefore, in MTG ABPSs, students not only explore the simulations, they *become* parts of the simulation.

Figure 1 shows the teacher's view of the MTG Equality model. At the center of the view is the checkerboard. The grid is added to this figure to visualize the checkerboard. In the real model, the grid is not visible to either the teacher or the students. The unicolor of yellow shows that each tile contains the same amount of sugar. However, in the other two models, the shades of yellow can differ from tile to tile, representing different concentration of sugar—the darker the color, the higher the sugar. Students are not supposed to know about the resource distribution. The teacher can hide the checkerboard from the students by clicking the "hide-world" button, which makes the whole checkerboard grey and students' avatars invisible. After playing the simulation, in the discussion phase, the teacher can use the "show-world" button to show students what kind of world they were in.

The three plots on the right—a bar graph, a Lorenz curve, and a Gini index plot—show three frequently used forms of representation of wealth inequality in economics. The plots automatically update based on real time aggregation of the amount of sugar that students own. The "setup" and "go" buttons at the upper left corner prepares the model and runs the model. The "sugar-mean" monitor shows the average of sugar that students own, and the sugar distribution plot shows a histogram of tile sugar on the checkerboard.

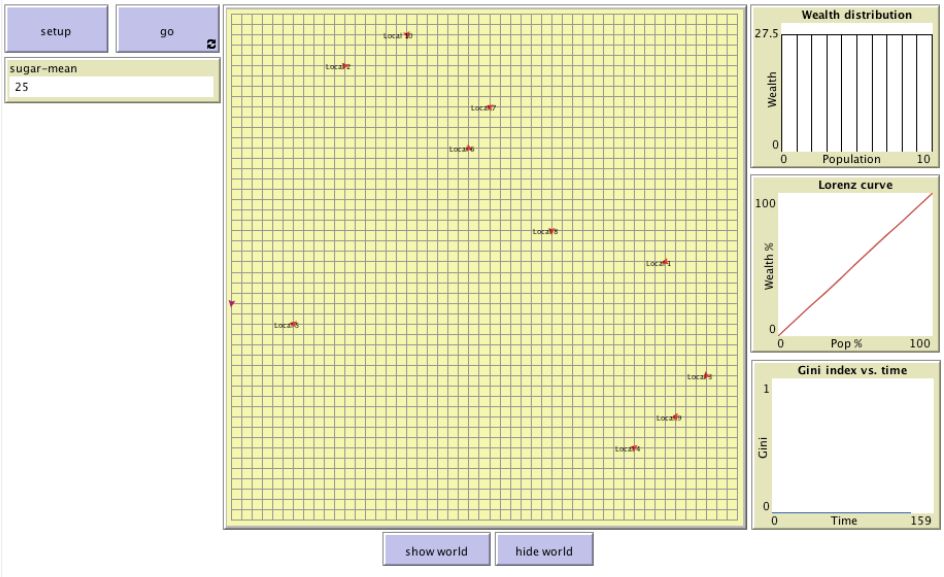


Figure 1. MTG Equal Opportunity model teacher's view (grid added to visualize the checkerboard)

Students see a different view from the teacher (Figure 2). The red arrowhead at the centre of the view is a student's avatar. Because the avatar has only imperfect local knowledge about its surroundings, it can only see a few tiles away in each direction. The yellow cross represents the field of view of the avatar.

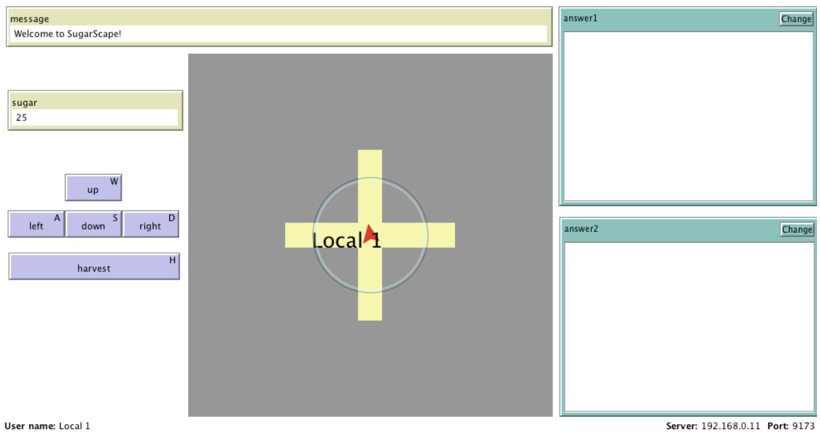


Figure 2. Students' View

A Student can use the "up", "down", "left", and "right" buttons on the left to move their avatar around and explore the surroundings. He or she can also use the "harvest" button to collect sugar from the tiles they are on. The "sugar" monitor above the buttons show the current amount of sugar that the avatar owns. The "message" bar at the top shows real time tips and warnings about the student's behaviour. The two big input boxes on the right are data collection tools, accepting students' typed answers to two open-ended questions posted by the teacher during class.

Students have a few attributes:

- Vision: how many steps (tiles) away a student can see.
- Endowment: how many units of sugar a student starts with
- Metabolism: how many units of sugar is needed for moving one step or doing one harvest

Students have some actions they can take:

- Move: by clicking the direction buttons or the keyboard shortcuts, students can move around. Each click moves the student by one step and burns metabolism amount of sugar.
- Harvest: by clicking the harvest button, students harvest all the sugar on the tile that he or she is standing on. One harvest burns metabolism amount of sugar.

MTG curricular unit consists a series of three models: 1) Equal Opportunity, 2) Random Assignment, and 3) Feedback Loop (with education as an example). Each subsequent model builds on the previous one with added complexity that more closely resembles the real world (Figure 3). At the beginning of the unit, students are asked an overarching question that drives their inquiry: Why are rich people rich while poor people poor?

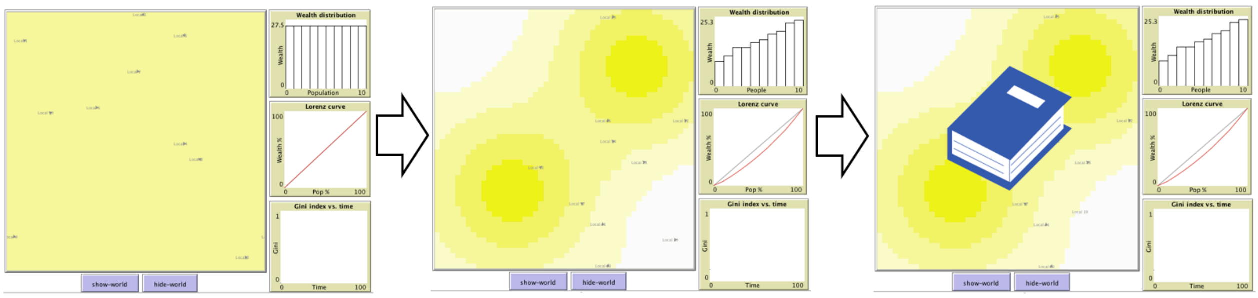


Figure 3. A series of three MTG models.
Left: Equal Opportunity model; middle: Random Assignment model; right: Feedback Loop model

The Equal Opportunity model (Guo & Wilensky, 2018b) allows students to experience that even everybody starts with equal opportunities, inequality can still emerge due to individual differences. In Equal Opportunity, sugar is evenly distrusted, as shown by the unicolour yellow. Students are randomly placed on the checkerboard with the same personal traits, including equal vision, endowment, and metabolism. Students strive to become the richest in the class by harvesting as much sugar as possible. Inequality inevitably emerge due to differences in students' strategies, understanding of rules, and motivation. To answer the question about why rich people are rich while poor people are poor in this simulation, given that everyone starts with equal opportunity, it is fair to say that personal differences, such as intelligence, efforts, and work ethics determine wealth status.

The Random Assignment model (Guo & Wilensky, 2018c) allows students to experience the power of an uncontrollable force that contributes to wealth inequality. In this model, sugar is unevenly distributed across the checkerboard. Students are randomly placed on the board and are also randomly assigned different visions, metabolisms, and endowments. Therefore, the initial conditions that a student starts with to a large extent determine the student's course of life in this simulation. Students should realize that when faced with the force of randomness, the draw of luck, instead of personal abilities, usually shapes the course of life.

The Feedback Loop model (Guo & Wilensky, 2018d) allows students to experience another type of strong force that shapes people's course of life. Feedback loops, usually called virtuous circles or vicious circles, are systematized or institutionalized forces. Unlike randomness, which is not biased against anyone, feedback loops are usually socially constructed, privileging certain groups of people at the cost of oppressing other groups. This model uses education as an example to let students experience that depending on the cost of education, it can become a force that either closing or widening the gap between the rich and the poor. This model gives students the opportunity to "go to school" by pressing a button. While going to school has benefits, such as boosting earning per harvest by 130% and expanding vision by one step, it also has monetary and opportunity costs. When education is less expensive, all students can make use of it to improve their vision and earning. However, when education is expensive, it becomes a virtuous circle for the rich and a vicious circle for the poor. As the result, the rich become richer and the poor become poor, closely reflecting a crucial inequality issue in the real world.

For each model, the teacher facilitates the students to go through a five-step inquiry cycle: introduction, 2) question, 3) simulation, 4) reflection, and 5) connection (See Figure 4).

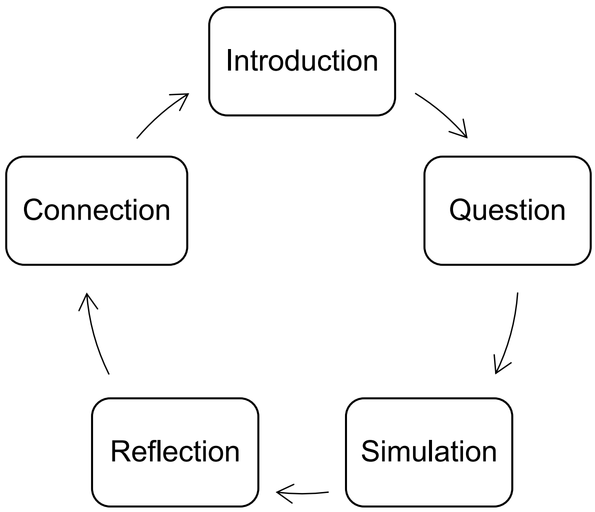


Figure 4. A Five-Step Inquiry Cycle.

In Step 1, students are introduced to the interface and rules of the model. In Step 2, students are asked to think about what makes rich people rich and poor people poor in that specific model. In Step 3, students play the simulation and compete to become the wealthiest person. In Step 4, whole class discussions are held for students to reflect on their experience in the model: who was the richest in this round? How did s/he achieve it? What was his or her starting condition? Who was the poorest? Why did s/he end up being poor? The richest and the poorest students are asked to share their stories in the simulation with the whole class. In Step 5, group discussions and whole class discussions are held for students to make connections between their simulation experience and the real-world: What are the real-world analogies of vision, endowment, metabolism, and the color of the starting tile? What is a real-world version story of the richest student? What is a real-world version story of the poorest student?

Students go through these five steps of inquiry cycle in each activity and keep revisiting the question about why the rich are rich while the poor are poor in different models. The increased complexity in each activity is expected to contribute to students' more sophisticated thinking about the question.

Method

The central goal of this design-based research study (Cobb, Confrey, diSessa, Lehrer, & Schauble, 2003) to investigate high school students' learning processes and outcomes in the MTG unit.

Research questions

With this curriculum design, we ask two research questions:

- How do students connect their simulation experience with their real-world experience?
- Does the unit improve students' understanding of wealth inequality and change their attitude toward it?

Participants

We implemented this curricular unit in eight high school economics classes with a total of more than 200 students across two schools with vastly different demographics. So far, we only finished preliminary analysis on the data from one school with two participating classes, so in this paper, we only report the implementation, analysis, and findings based on this corpus of data.

The two classes are in a public high school located in a highly ethnically diverse suburb of a large Midwestern city in the U.S. Students in these two classes are mostly sophomores and seniors, who are taught by the same teacher for their regular economics curriculum. All 51 students were invited to participate in this study. Fifty (50) students consented to participate. Forty-four (44) completed the demographic survey: There are 19 females and 25 males. Twenty-one (21) self-identified as Asian, 14 White, 4 biracial (2 Asian and White, 1 Black and White, and 1 unspecified), 1 African American, and 1 Hawaiian or other pacific islanders. 13 students speak a language that is different from English at home (including Assyrian, Bangla, Cantonese, Gujarati, Romanian, Serbia, Farsi, Tagalog, Telugu, and Urdu). A majority of 32 students identify with the Democratic Party, 3 with the Republican Party, 4 with Other parties, and 6 with None.

Implementation

The implementation of the MTG unit spanned four days with 42 minutes of class time on each day. The first 20 minutes of the first day and the last 15 minutes of the last day were used for students to take the pre- and post- questionnaires. The first author taught the unit following the 5-step inquiry cycle described in the section above.

Data collection

Multiple types of data were collected. The pre- and post- questionnaires collect data on students' knowledge and attitudes toward wealth inequality before and after the unit. During the unit, students' typed responses to questions about each simulation are collected through input boxes built in the MTG models. Computer log data of all students' interactions with the models (including key strokes and performance) were collected. Whole class video recordings captured the class dynamics throughout the four days. A total of 20 students (10 from each class) were selected in consultation with their economics teacher as focal students to represent the racial and gender diversity. Two additional types of data were collected from the focal students: 1) Pre- and post-clinical interviews, in which researchers probed students' thoughts and attitudes toward wealth inequality through structured and follow-up questions. 2) Screen recordings: Focal students' computer screens were recorded using Camtasia screen grabbing software, which records on-screen behaviour and conversations between students.

Analysis

We analysed the pre- and post- questionnaires for evidence of attitudinal change towards wealth inequality before and after the unit. In both pre- and post- questionnaires, students were asked to rate a series of statements about wealth inequality on Likert scales. Questions include "On a scale of 1-7, with 1 being extremely unfair and 7 being extremely fair, please rate": 1) How fair is the wealth distribution in the U.S.?, 2) "The rich deserve their economic status", 3) "The poor deserve their economic status", 4) "In America, anyone can advance, regardless of their family of origin, economic status, or ethnicity", 5) "It is possible to move from poverty to affluence thorough hard work", and 6) "Poverty is a sign of personal failure". Students' ratings were summarized with two histograms, one for the pre-, one for the post. Because 44 students completed the pre-test and 43 the post-test, the histograms were normalized (converted to percentages) for easier comparison. Summary statistics were generated to describe the mean and the standard deviation of the pre- and post- results. The pre- and post- means were then compared.

In addition, we conducted interaction analysis (Jordan & Henderson, 1995) based on the whole class video data. The first author watched the videos to identify interesting moments during students' class discussions, in which students utilized resources from both their experience gained from the simulations and their real-world experience. These interesting moments were then transcribed. Below, we provide an excerpt of class video transcripts that illustrate these moments.

Findings

Changing attitudes

Overall, students' ratings shifted toward a more pro-equality attitude in the post questionnaire. More students rated wealth distribution in the U.S. as less fair and showed stronger disagreement toward the subsequent statements. We calculated and compared the means of pre- and post-ratings based on the assumption that the 1-7 scale is an even continuum, and the same rating shows the same degree of agreement for all students.

Figure 5 shows the comparison of pre- and post- rating distribution of the fairness questions.

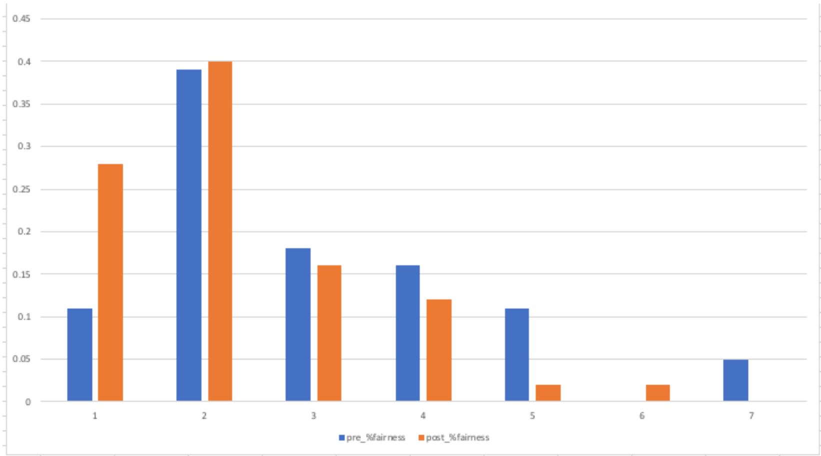


Figure 5. Pre- and post- comparison of students' rating distribution of the fairness question.

No.	Statement	pre	post	shift
1	fairness	2.95	2.28	0.67
2	The rich deserve	4.25	3.74	0.51
3	The poor deserve	2.66	2.56	0.1
4	Anyone can advance	3.8	3.4	0.4
5	Get rich by hard work	4.93	4.47	0.46
6	Poverty is failure	2.2	2.02	0.18

Table 1. Attitude shifts on all six Likert scale questions.

In Figure 5, the left bars (blue) show students pre- ratings and the right bars (orange) show post ratings. Although most students came to the unit already believing that wealth distribution in the U.S. was somewhat unfair (an average rating of 2.95), after the unit, students believed it even more strongly (post mean = 2.28). The average rating changed by 0.67 towards left, which means students think the wealth distribution is more unfair. The biggest change occurred in the lowest rating category (extremely unfair). Before the unit, only 11% (5 students) thought the distribution was extremely unfair. After the unit, the percentage increased to 28% (12 students).

Shifts in attitudes toward all statements followed a similar pattern, as shown in Table 1. These shifts are evidence that after the unit, students had more realistic perceptions of the fairness (Q1) and the opportunity structures in the U.S. (Q4 and Q5) based on understanding of mechanisms of wealth distribution and exposure to real-world data during the unit. Minimum changes were observed in negative statements about poor people (0.1 in Q3 and 0.18 in Q6). Students' pre-unit ratings of these questions were already very low (2.66 and 2.2, respectively). The minimum changes may have less to do with understanding the mechanisms that students learned from the unit, but have more to do with empathy that the students already have toward the poor.

Making connections between simulation experience and the real world

Below we present an excerpt of whole class discussion about the real-world meaning of students' experience in the MTG Randomness model. Kate was one of the richest persons for this round. The teacher asked her to share her experience in the simulation and asked the class to find a real-world story that matches Kate's simulation experience (all names are pseudonyms).

> Teacher: Can You share your story?
>
> Kate: So I was kind of very near the dark yellow, so I just moved over and a started harvesting.
>
> Teacher: Ok, so basically you spawned and you saw dark yellow right next to you. You moved over and started harvesting, right? And what was your vision?
>
> Kate: One.
>
> Teacher: One? OK, Interesting! Very interesting.
>
> …
>
> Teacher: Now let's get into groups and talk about: Is there a real version of their stories in the real world. let's think about her story. She started right next to the darkest yellow. She just went over and started harvesting.
>
> [Students discussed in groups of three for 2 minutes]
>
> Teacher: Which group wants to share their story of the rich in the real world? Go ahead.
>
> Jack: We kind of thought of like really specific, like Sam Walton's kids have a bunch of money coming from Walmart and so as long as they don't mess up and move away from the wealth they have, they can keep that wealth and build on it and like how Kate just moved over one spot to build on the wealth that she already had.
>
> Teacher: You guys agree? That's pretty much true right? It is like a kind of the inheritance thing, right? So, if your parents are super wealthy, they will give you a lot of resources. Just make sure you don't do too stupid things to move away from them. Make use of it, then you're probably pretty well off, right? Ok, yeah, I think that's a great story. Any other things to add? Any other things about the rich story?
>
> Amy: Not about the rich, but sort of in general, I think that it's interesting that even if she was in a very good neighbourhood, but she had very limited vision. I think that was like kind interesting, because I think that's almost less realistic rather than more realistic, because I think if the simulations were more like real life, if you have a high vision, you are more likely to be in a very yellow area and have a low metabolism. it wouldn't be randomly assigned.
>
> Teacher: I think this is a great point. In [MTG Randomness model], everything is random. It's possible that you are born in a very rich place but with a very limited vision. In the real world, do you think that happens that often? Not really, right? Because if you were born in a very resourceful place, you probably get better education. Your parents are probably well-educated, and you probably know a lot of people. Your vision is actually a lot better than a lot of other people. I think that's a great point. Thank you for bringing it up.

This excerpt shows that students' engagement with the simulation is quite sophisticated. Jack and his group understood that spawning near a dark yellow area in the simulation is analogous to being born to a rich family in the real world. It is easier for those who were born rich to build on the wealth they inherited to obtain more wealth. The MTG Randomness simulation helped students relate randomness in the simulation and in the world that can make life easier just by chance. However, Amy had deeper thoughts about the analogy between the simulation and the real world: she pointed out that random assignment in the model was not realistic, because things are correlated in the real world. If the simulation were more realistic, then "if you have a high vision, you are more likely to be in a very yellow area and have a low metabolism", which can form systematic, rather than random biases that work for or against people.

In this case, the less realistic feature of the simulation is not a drawback of the design. Instead, it is precisely the nature of a microworld and a computational model, which foreground certain aspects of the system being modelled to highlight its basic mechanisms. The MTG Randomness model highlights randomness as a strong mechanism that contributes to inequality. The students were able to identify its limits and provide real world mechanisms in contrast. The discussion triggered by comparing the simulation with the real world is a valuable learning opportunity about the mechanisms of wealth inequality and the scientific practice of modelling for the whole class.

Conclusion and Discussion

Mind the Gap agent-based participatory simulation curricular unit is our attempt to address people's understanding and attitude toward complex and controversial social issues through designing constructionist learning environments. The implementation of this unit in eight high school economics classes showed students' high engagement with this type of design. Preliminary evidence has shown that students' attitude shifted toward a more pro-equality stance after learning the unit. Students also showed sophisticated thinking about rules and conditions in the simulation and in the real world in their discussions when making connections between the virtual and the real world.

Wealth inequality is an example of a myriad of social issues that people face in today's society. This pioneer work shows what learning pathways and learning outcomes are possible to achieve with this type of ABPS constructionist learning environment. We will continue data analysis to discover more evidence of students' knowledge and attitude change. With a better understanding of the learning affordances of ABPS learning environments, we can use it to teach other complex and controversial social topics, such as racial segregation, climate change, and gun control. Equipped with better understanding of mechanisms of these social issues, people in democracies can exercise their rights more responsively to achieve more equal societies for everyone.

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