Gaming the Industrial Revolution: Participatory Design with Historical Data For Classroom Learning

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Abstract: Industrial Re:evolution is an educational game developed by a collaborative team of educators, historians, game designers, and developers. The game allows students to hypothesise about the underlying causal mechanisms of the Industrial Revolution while managing population and resources across 19 discrete regions in England and Wales from 1600 to 1851. The game was developed through a series of participatory workshops, which led to a gameplay concept based on a comprehensive model of the Industrial Revolution, centred on key theoretical frameworks. Through role-playing, problem solving, and in-class discussions, students are encouraged to explore various factors that contribute to the Industrial Revolution and their interdependencies. It helps them develop a deeper understanding of the intricate relationships between different causal factors, improving their ability to explain and analyse complex historical events, and promoting quantitative skills. The game is an open-ended historical simulation based on state-of-the-art research, providing students with the opportunity to interact with real historical data. To enhance classroom implementation, the game is provided with structured activities, lesson plans, student booklets, and multimedia materials, while an online platform will eventually offer a community for educators to share best practices. This study describes the design choices and development of the game.

Keywords: Educational Technology, Gamification, Historical Learning, Educational Game Design, Participatory Design

1. Introduction

This article presents work from the research programme 'Gaming the Industrial Revolution' (GIR), which led to the creation of an educational game called Industrial Re:evolution. Designed to support and augment the teaching of economic history - specifically the Industrial Revolution - for secondary school students, the game serves as a hands-on learning tool suitable for classroom implementation. It was developed through research collaboration between the University of Cambridge, the University of Salford, game designers and developers, and a group of history teachers between 2019 and 2023. This collaboration facilitated the incorporation of role-playing, problem-solving, and class discussions into gameplay, providing a comprehensive approach to game design. This project marks one of the first attempts to purpose-build an educational game to measure the impact of gamification on learning attainment, cultural capital accumulation, and the development of higher-order thinking skills.

GIR was conceived to provide a resource that helps students articulate multiple causal chains in a game format, allowing them to explore causal links iteratively through play. Our aim was to assess whether the use of the game would allow students to discover and formalise the relationship between the variables of the games on their own, both in a formal school setting and at home. To build the game, we followed a participatory design methodology that involved the expertise and active participation of secondary school history teachers, historians, education researchers, game designers, and developers from the design stage through testing and implementation.

Thus, the core of the project consisted of a series of gamifications held in Cambridge and Manchester with teachers, game developers, and researchers. These gatherings allowed us to develop a concept, test a prototype, evaluate feedback mechanisms, and elaborate a pedagogical methodology for implementation. Thanks to this, we now have: i) a functional prototype of the game, which is available for free to all schools; ii) a network of schools and educators interested in the use of games for the teaching of history; iii) some tentative measures of engagement and impact used to promote best practices; and iv) strong contacts with institutional stakeholders to promote the use of these resources in the national curriculum.

In this article, we describe the collaborative and participatory processes that led to the creation of the game, the design choices made, and the adopted educational setup. The impact on students' attainment and engagement will be discussed in a future publication, when all the data have been collected. We have therefore not included any measurement or discussion of results in this paper.

2. Rationale for Building a Game

Over the years, there seems to have been a noticeable decline in the number of British secondary school history teaching the topic of the Industrial Revolution. This trend is all the more disconcerting because the Industrial Revolution marks a pivotal point in both British and global history. It is a moment in human history that holds the key to understanding the uplift in living standards over the past two centuries accompanied by growing inequalities, the relationship between demographic and economic growth, the dynamics of European colonial expansion and exploitation, and the extent of the environmental damages caused by the extensive 'mineralisation' of our economies.

Interviews carried out with a panel of teachers selected for this research project revealed that the diminishing emphasis on the Industrial Revolution may largely be due to its perception as a 'dry' and challenging topic by both teachers and students, who often find data-intensive literature difficult to navigate. Compounding this, is the fact that the more recent causal explanations of the Industrial Revolution (Allen, 2009; Wrigley, 2010b; Shaw-Taylor and Wrigley, 2014; Kelly, Mokyr, and O'Grada, 2014) combine complex multifactored and multi-scalar narratives. Thus, even where industrialisation is mentioned in the national curriculum (for example, A-level unit 1F Industrialisation and the people: Britain, c1783-1885), the pedagogical approach in the recommended textbooks is to offer a long list of causal factors, which may reflect the complexity of the historiography, but makes an overarching understanding of causality extremely challenging, as shown in Fig.4, which shows the best attempt at creating such a diagram by the author. No secondary school students could learn from this.

Furthermore, teachers who submitted their teaching material on this subject overwhelmingly adopted a biographical perspective on the Industrial Revolution, illustrating the consequences of socioeconomic changes on the lives of specific individuals, often focussing on children. Although this approach may improve the engagement of the subject based on empathy, the teachers agreed that it made it more challenging for them to provide an understanding of the conceptual and theoretical aspects of the subject. To address these issues, we created a game that offers both an engaging and interactive approach to learning while making it possible for students to formulate hypotheses regarding the underlying causal mechanisms through gameplay.

3. Previous Work

Research supports the effectiveness of game-based learning in improving educational outcomes, fostering 'learning communities' when embedded in classroom teaching, and providing targeted support for less-advantaged groups. We will discuss each of these in the following subsections, and how Industrial Re:evolution was designed to be both engaging and pedagogically robust, while maximising the chances of a positive impact on student learning by ensuring that the game remains inclusive and accessible to a broad range of students.

3.1 Gamification and Learning

The integration of games into formal educational environments, particularly secondary education, has demonstrated the potential to improve student engagement and learning outcomes. Even commercial titles, like Sid Meier's 'Civilization' (Meier and Shelley, 1991), have found their way into history curricula (Botting, 2023). However, existing literature highlights several challenges in adopting commercial games, primarily designed for entertainment, in an educational setting (Taylor, 2003). Our project adopted a different approach by explicitly designing a game as a pedagogical tool for in-class learning. Our design team comprised historians,

history teachers, game designers, and students from our target audience, to produce a purpose-built tool for classroom implementation.

We also considered the recent research on effective game-based learning. For example, Hainey et al. (2011) and Wouters et al. (2013) demonstrated that game-based learning can improve both student motivation and cognitive outcomes. In addition, a meta-analysis by Clark and Greitemeyer (2016) reported that digital games can have a positive impact on learning outcomes, given that the incorporation of effective design features, such as Squire and Barab (2004) also demonstrated that gamification can improve attainment for key demographics. In their study, they showed that underserved urban students who engaged in learning world history through computer simulation games exhibited significantly improved knowledge retention and problem-solving skills. Finally, gamification can support learning beyond information retention and can promote high-level analytical and critical skills. Gee (2003) demonstrated that video games can teach valuable learning and literacy skills by engaging learners through active problem-solving.

In Industrial Re:evolution, we sought to incorporate the three key attributes of successful game-based learning experiences, as outlined in Taylor (2003).

- The game is interactive and allows students to engage with a dynamic representation of the Industrial Revolution and to understand the interplay of economy, geography, and technology.
- The game encourages active participation, progressively fostering a better understanding of the causality chains embedded in the simulation.
- It also promotes empathy by connecting students with historical characters and fostering a deeper comprehension of the multiple forces that shaped their lives.

4. Collaborative and Participatory Design

Crafting game-based experiences which are educational and perceived as ‘fun’ by students is a difficult undertaking. The academic literature on game-based learning has many examples of edutainment titles that do not perform on both fronts, resulting in dull gaming experiences with little educational value (Van Eck, 2006; Prensky, 2001). To prevent us from following the same path, - the project implemented a methodology designed to recognise and articulate the expertise of key stakeholders – scholars, teachers, game designers, and students in our targeted group.

The methodology used to successfully address the different and sometimes conflicting goals of all stakeholders was participatory design (PD), which was adapted for use in educational game design. PD originated in Scandinavian design in the 1970s and has since been applied in various fields such as software design, urban design, architecture, product design, graphic design, sustainability and planning. PD has much to offer in educational game design and has been used by an increasing number of researchers to design game-based learning experiences. However, successful implementation does not happen smoothly or automatically (Khaled et al., 2014)

The participatory design process of Industrial Re:evolution occurred in a series of four workshops held between April 2022 and April 2023. These workshops brought together 17 teachers from 15 schools, five game developers, two artists, three students, and five academics (three historians, one game designer, one researcher in education). During these workshops, we progressively moved from the initial ideas tested using quick paper prototypes to digital gaming experiences. We started this process by defining the key aspects or ‘substantive concepts’ of the Industrial Revolution to be included, as well as the educational objectives of the game. This first conceptual design level prevented us from rushing into designing a game without a clear definition of what students should learn by playing with it. The second phase focused on translating substantive concepts into interesting and meaningful game challenges. To this end, the team quickly prototyped different game mechanics, testing and evaluating the specific type of knowledge embedded in gameplay. Also, a key concern at this phase was to ensure that the game mechanics altered the game states at meaningful points of gameplay, gradually increasing the level of challenge while rewarding the player’s performance.

Two interdisciplinary teams were formed and tasked with producing playable gaming concepts. After several cycles of development, distinct ideas began to emerge (Fig. 1). In the first concept of the game, regions of England and Wales could be developed through resource tokens and by establishing spatial connections between them. In addition, a historical timeline triggered events at each turn, affecting regions locally or globally. The second team adopted a more abstract approach, focussing on the gameplay in a quantitative system defined by the interplay of a discrete set of variables. After testing and discussing the merits and

shortcomings of each prototype, we decided to blend both versions. Although the interaction with an economic model of the Industrial Revolution was deemed crucial from a pedagogical standpoint, the historical timeline and spatial relationships were also considered important. With much to continue working and refining, we finalised our first design workshop with a playable game concept.

Figure 1: Initial game concepts developed in workshop sessions

5. Defining the Pedagogical Remit of the Game

5.1 Content

Teachers surveyed in 2021 overwhelmingly concluded that understanding the notion of the 'Malthusian trap' (i.e., the relationship between demographic change and economic development) was essential for the ability of students to comprehend the revolutionary nature of the Industrial Revolution, but it was rarely taught to students due to its conceptual complexity and the level of pre-required knowledge. To grasp the Malthusian story, students must have some understanding of the concept of wages, core demographic notions such as fertility and mortality, and the notion of marginal decreasing return of labour in agriculture.

Therefore, Industrial Re:evolution was designed for both teachers and students to understand the connections between demography, energy sources, geography, and economic development in a progressive manner throughout the game and repeated directed play sessions. The game can then subtly introduce students to the three most influential meta-narratives of historical change, explaining the origins of the Industrial Revolution (Allen, 2009; Wrigley, 2010b; Mokyr, 2012). Through gameplay, students are encouraged to infer and formulate causal relationships based on these models, thereby transforming them into discursive units in classroom activities.

Our pedagogical survey also outlined 'industrial development before the Industrial Revolution', 'the geography of natural endowments' and 'Empire' as the second most desirable elements in the teaching of the origins of the Industrial Revolution. Based on this, we determined that the temporality of the game would cover the period from 1600 to 1851, and, in doing so, introduced students to early technological developments before the age of steam. Moreover, we added a strong cartographic dimension to the user interface, allowing students to compare maps of soil quality, coal deposits, market access, and waterpower potential to inform their decisions.

Finally, during the workshops, it became clear that for teachers, emphasis on chronology and memorisation was an essential factor in improving students' attainment. Therefore, we decided to develop a user interface with a prominent timeline and regular events that inform students of historical developments that we would like them to remember. We also embedded learning spot checks (see Fig. 2) in the form of quizzes, which allow players to unlock particular technological improvements and increase productivity in a tile or for a particular sector.

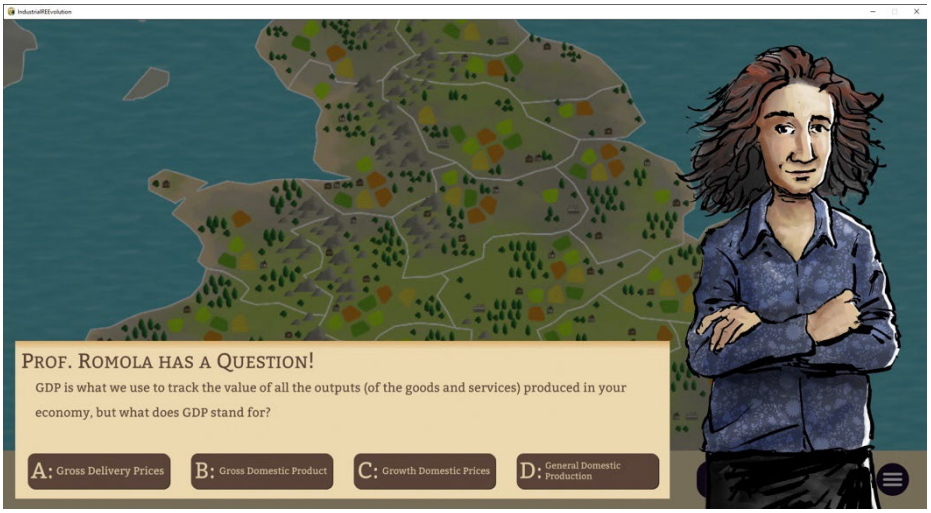

Figure 2: Embedded learning spot checks

5.2 Skills

Industrial Re:evolution addresses several challenges that students face in comprehending historical events, including understanding and articulating complex, interconnected causal relationships, as well as developing quantitative skills, such as chart reading, chronology, and inference making. In traditional history education, students often find it challenging to synthesise and analyse multiple factors and their influences on each other. This problem has been observed in both classroom discussions and written assessments, where students tend to describe isolated events rather than provide a holistic understanding of their causes and consequences.

Therefore, we incorporated various elements and activities that specifically target these skills. For instance, students are exposed to different charts, graphs, and timelines within the game, which requires them to interpret and analyse data, understand chronological developments, and make informed inferences to unlock bonuses, but also to participate in the classroom activities that accompany the game. By actively engaging with these elements, students develop a stronger foundation for quantitative skills, which are essential for understanding complex multivariate causal chains.

6. The Simulation

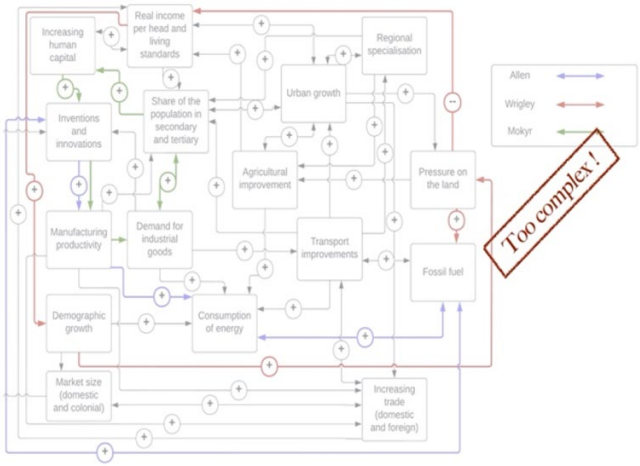

Figure 3: Original causal diagram

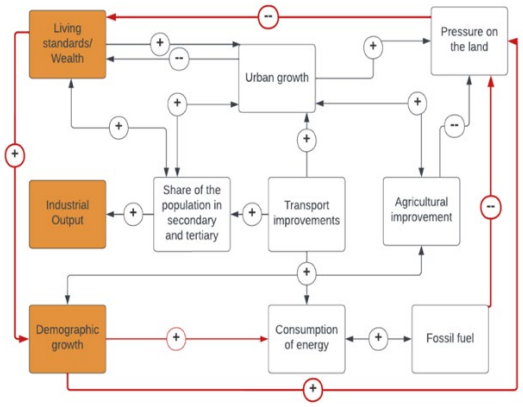

Figure 4: Simplified causal diagram

6.1 Using Historical Data

A unique aspect of this game is that it is based almost exclusively on data produced by researchers, and therefore exposes students to an unprecedented wealth of 'real' historical data. We draw on state-of-the-art historical research (especially from researchers from The Cambridge Group for the History of Population and Social Structure, also known as CamPop) on occupational change (Shaw-Taylor and Wrigley, 2014; Keibek, 2017), demographic growth (Wrigley, 1997, 2004), the role of natural endowment, such as coal, forest cover, water-power potential and soil quality (Wrigley, 2010a; Fuchs et al., 2013), and historical transport networks (Bogart et al., 2021; Alvarez-Palau and Dunn, 2019). We also use historical GDP estimates from the Maddison Project (Bolt and van Zanden, 2020). All character stories are derived from the collection of autobiographies collected by Emma Griffin (Griffin, 2014). Not only is the simulation running on 'real' historical data, but all the underlying data is also visible to the students through entries in an in-game glossary, which details the sources used and offers the students and teachers a more in-depth analysis of the data. For more complex entries, embedded hyperlinks allow students to play with the data in dedicated interfaces, such as www.populationpast.org, www.economiespast.org, and www.travelintimes.org.

Once collated, all historical data were aggregated to match the game's units (i.e. tiles) and benchmark dates (i.e. turns). These data then informed the simulation of each region.

7. Interacting With the Simulation

Once the historical data is encoded in the simulation and narrative components of the game, the following design challenge involves developing a system of rules to allow the player to interact with the data. For this, the design efforts concentrate on defining the internal variables to be exposed in the game interface and designing the modes of interaction to allow the player to affect them meaningfully. According to Salen and Zimmerman (2003), this is the primary goal of game design, the design of the processes by which players take action with the game's designed system and how the system responds to the action.

A further challenge is finding the right balance between procedural understanding and fun. To be used successfully in the classroom and provide a meaningful learning experience, a game not only gives students access to a historical data model but also requires an intrinsically motivating environment to learn. Using the frameworks from Malone and Lepper (1987) and LeBlanc, Hunicke, and Zubek (2004) as references, the team defined four design goals:

- **Challenge:** the game activity is driven by goals which are uncertain and depend on player performance to be achieved (for example, "Can you prevent England and Wales to fall into the Malthusian trap?").
- **Discovery:** the activity is designed to capture the player's attention, modifying their cognitive structures to understand the industrial revolution in a different way.
- **Control:** the game activity provides a range of possible outcomes based on the actions and decisions of the player, a goal closely related to the concept of *meaningful play* developed by Salen and Zimmerman (2003).
- **Narrative:** the game recounts stories and connects players empathically with characters from the past.

7.1 Defining Game Mechanics

Generally, game mechanics can be defined as "methods invoked by agents, designed for interaction with the game state" (Sicart, 2008). Following conventions of strategy games described by Rollings and Adams (2003), the game employs an abstraction model of interaction. The player interacts with the underlying simulation data and statistics both directly and indirectly, has no in-game avatar or agents, and, in an omnipresent role, directly influences the game world via actions that modify the parameters of the simulation. Through a top-down perspective, the game communicates the current state of the simulation and the economic properties of each of the 19 discrete geographical regions (each with variances such as economic sector productivity). The current version of Industrial Re:evolution allows students to interact with the map and, through this set of actions, develop their own version of the industrial revolution, covering a period from 1600 to 1851. The core gameplay mechanics centre on the management of the population and resources (food and energy) and represent the player's toolset for altering the simulation parameters. The map provides a high-level abstraction and visualisation of the simulation (presenting semiotic and numeric data) and provides two of the three core gameplay mechanics, migration of population, and trade of resources (Fig. 5). Upon selecting a region, the game interface displays key economic indicators such as living standards, GDP, population, and unemployed labour, and facilitates the allocation of unemployed population to a specific economic sector. Additionally, icons representing the migration of unemployed population and trade of resources are presented on each region, these can be dragged by the player to another region (combining the selection of the source, the target, and action into a single operation) to quickly execute a compound action. Although the player's agency is restricted to a few possible actions, such as migration of populations, resource trading, and labour allocation, their combination and the emerging effect on each region and the whole map lead to many possible outcomes. During each turn, players can decide how they will influence the game world. They can assign unemployed populations to various economic sectors, relocate them to different regions, or exchange produced resources with other regions connected by transport links. Once the player has made their decisions, they press a button to advance the game. This action advances the historical simulation forward 25 years, initiating events from the historical records that occurred during this timeframe. These events are presented to the player through textual and visual descriptions of what took place—historical famines, civil wars, scientific discoveries, or industry advances—reflected in the simulation and imposing new challenges on the player. Thus, the game establishes a dialogical relationship between the factual historical record and exploratory and alternative versions of the past emerging from the game.

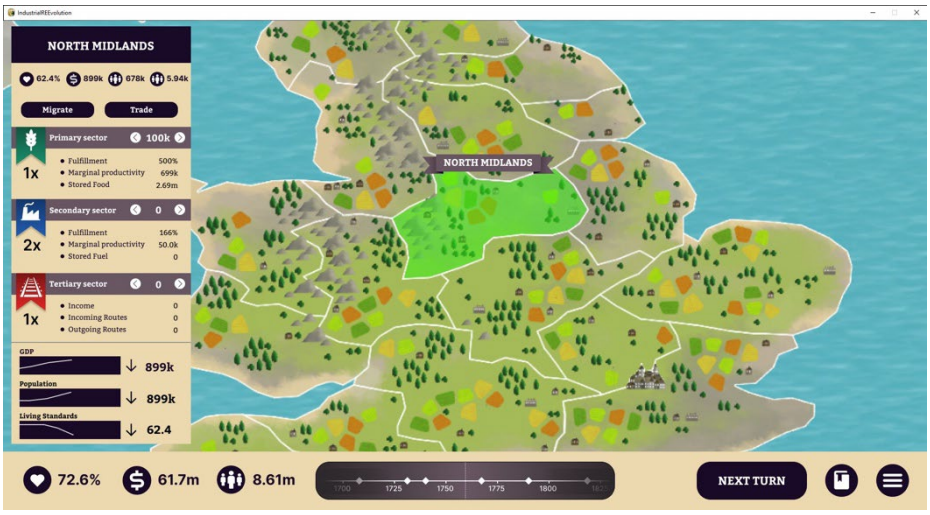

Figure 5: Industrial Re:evolution's main interface.

In this quest to drive the industrialisation of England and Wales, players can access graphical representations of gameplay and historical data. Key metrics such as GDP, population, and living standards were recorded at every turn and displayed in comparison with the historical data for each of these metrics. This allows the player to monitor his or her playing session and raises further questions: What drove the development of certain regions and not of others? By encouraging students to raise and heuristically explore these questions, our goal was to drive them to follow the same processes and modes of thinking as professional historians when interpreting the past.

In its top-down and omnipresent interfacing, the game follows the conventions of 'God games', a perspective criticised by some authors for its depersonalisation of violence (Friedman, 1999) and a lack of empathy. In the case of our historical game, how can we make students care about people's fates when they are only visible to them as abstract quantities? To achieve this goal, we introduce historical characters associated with scripted and emergent events. The characters are designed to connect with players through textual narratives, allowing children to perceive the human effects of decisions taken during gameplay and triggered by historical events (Fig.6).

Figure 6: Example of an exogenous event in the game

7.2 Explainer Animations

We also developed animated scenes for use at various times during the game. In the current game iteration, cutscenes introduce students to key theoretical aspects embedded in the game's procedural dynamics, such as the Malthusian theory (Fig.7), and bring a sense of narrative closure to a full playing session.

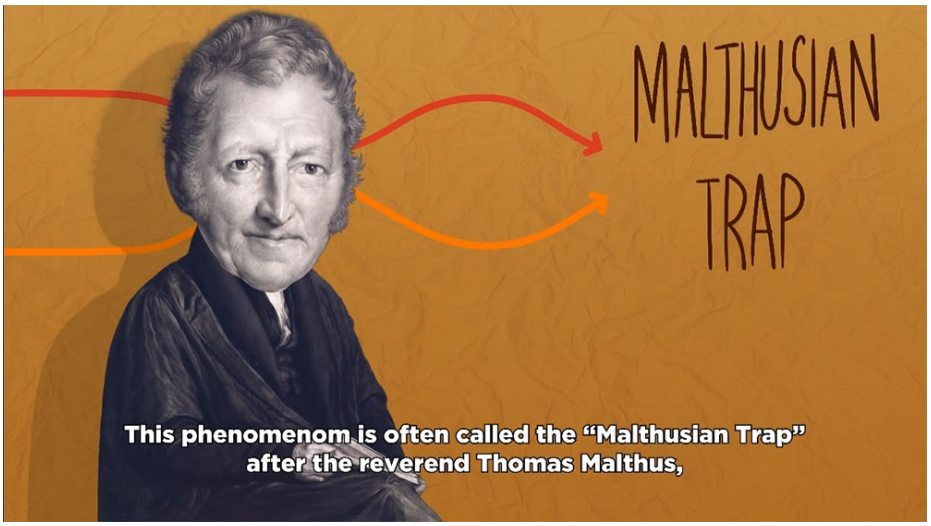

Figure 7: Explainer animation describing Malthus economic theory

Accordingly, when the game timeline ends, the player is rewarded with an animation of London's Great Exhibition of 1851. However, this scene does not adhere to history. Depending on the player's performance, instead of a showcase of industrial progress, the player can see different types of exhibitions corresponding to a non-industrialised agrarian country, society with low living standards, and very high levels of pollution (Fig.8).

Figure 8: Alternative outcomes depending on the player's performance

8. Conclusion

From the perspective of participating schools, Industrial Re: Evolution is an easy-to-implement, comprehensive solution to teach the causes of the Industrial Revolution. It comes with structured activities, accompanying lesson plans, student booklets, and multimedia materials, including embedded lectures by Cambridge academics and selected reading material which teachers can integrate into their existing curriculum or adopt the full educational package provided.

The next step will be to evaluate the efficacy of this new teaching tool, by assessing the academic results and the engagement of two comparable cohorts, one exposed to the game, and the other taught using the traditional textbook material. We are now in discussion with over 20 schools in England to roll out the game and we hope to begin this trial in the academic year 2024-2025.

Data Availability

The current version of the game can be downloaded from our website at www.ireevolution.com.

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