Frame Game as Teaching Methodology in Higher Education: The Case of RElastiCity

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Abstract. The objective of the study is to illustrate the use of the frame game, *RElastiCity* as a framework to learn about the resilience of urban areas and the shocks and stresses in those areas. The question is if use of the frame game as a basis for game co-design is a useful approach to explore complex systems and its dynamics. This study covers the exploratory application of the approach in two university courses in the Netherlands. The results show divergent student experiences between the two courses. The main difference between the courses was the scope of the co-design assignment and the amount of time students had to complete the design process. It was found that using frame games as a framework for understanding complex systems is useful if students have sufficient time to investigate the topic, develop the game and playtest the game.

Keywords: Co-design · Complex systems · Frame game · Teaching method · Urban resilience

1 Introduction

By 2050, 80 percent of the world population will live in urbanized regions. Cities are incubators for innovation; yet their interconnected infrastructures are vulnerable to shocks, particularly in deltas. According to statements in a press release on April 16, 2013 from the European Union, more than 5.5 million people between 1980 and 2011 were affected by floods in Europe. The costs of not adapting are expected to rise to 250 billion Euros per year in 2050. The need to adopt a comprehensive strategy to make cities more resilient cannot be postponed [1].

With this comes the requirement to teach engineering students about urban resilience and make them aware of the impact of engineering solutions on the urban system. For this research, the following objectives for urban resilience are adopted: well-functioning cities that ensure the security and safety of people, property and infrastructure, provide basic services such as public health, water, sanitation and electricity and guarantee basic norms and rights [2]. Students of urban resilience must think in interdependencies between systems and the expected and unexpected (negative) consequences of interventions in preparing urban areas for shocks. Gaming is seen as one of the methods to experience such complex systems and their dynamics [3].

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Many scholars use games as teaching methods in a variety of topics for knowledge, skills and changing attitudes. Besides using games, gamification or gamified approaches are used in classrooms to increase the motivation of learners. Another use of games in education is to design games to acquire skills like students' knowledge and skills in programming [4], to learn about mathematics [5] or teaching Human Computer Interaction Skills [6].

Research shows positive effects on learning skills and a positive attitude of students about the topic when using games in higher education. Some studies focussed on using game design to teach specific content-related topics such as in the field of construction and engineering [7]. By designing games, students improved their knowledge about the concepts and had a greater enjoyment because of the involvement of creativity and group work [7]. Game design in secondary education was used to teach students about informatics and society topics [8]. Using game design did not specifically lead to an increase in level of knowledge compared to not using game design, but that game design led to a higher degree of sensitisation although it took time to learn how to design games [8].

In professional settings, frame games have been shown to provide a combination of structure and flexibility that help practitioners to engage in shared learning about complex urban systems [9]. Game co-design has been used to gather knowledge about real-world issues for contextualization [10]. A frame game is a structured set of rules of a game into which different contents can be loaded, i.e. the frame contains the rules and procedures of the activity in which the desired information/knowledge to be transferred is placed [11]. The advantage of using a frame game is that students gain the creative and discursive aspect of game design by focusing on content and are not hindered by the lack of knowledge about the game design process.

The research question is: What can we learn about the use of frame games as teaching method to increase understandings of urban resilience? The research objective is to explore the use of a frame game as teaching method to teach urban resilience. An explorative approach is used to get a general understanding of the frame game as a conceptual model. *RElastiCity* is a game about urban resilience conducted in two different occasions in engineering courses in the Netherlands. At Delft University of Technology, a multi-session game was conducted where results and general observations of the co-design experience were collected. For the single-session game at the University of Twente, a short survey was used to collect data about the use of the frame game as a conceptual model. This paper begins with an explanation of frame games as conceptual models for simulating urban systems.

2 Frame Games as Conceptual Models

Simulation gaming can deal with complex, uncertain and unique issues and provides a language for combining the social-human with the physical, technological and economic knowledge domains and can represent socio-technical complex systems [12, 13]. Designing simulation games follows a generic design process: understanding the real world issue, developing a conceptual map of the situation, using that map for a conceptual game design, followed by the specification of the game and testing and application

[14]. The finished game can be used in classroom settings to learn about the behaviour of the real world dynamics and challenges (Fig. 1).

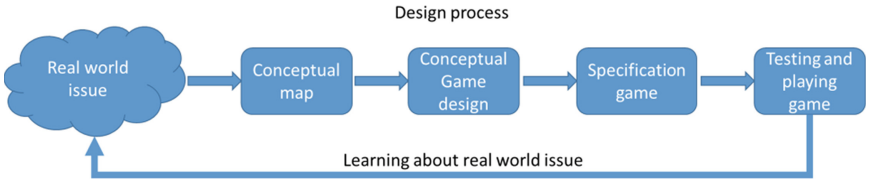

Fig. 1. Basic structure of developing simulation games and playing to understand the real world issue

Game design is a time consuming process and the designers need expertise. The use of a frame game makes it possible to easily adapt the content of the game to new issues or problem environment without changing the game mechanics and structure of the game [15]. This makes it possible to implement contextual variables of specific situations in an existing game environment. The design process of a frame game is slightly different in that the first design step uses the frame game as a structure for integrating real-world contextual issues (Fig. 2).

Starting with the conceptual game, the game elements have to be specified based on the real world issue. By putting all the elements together and after some tests, one gains a better understanding of the real-world situation from a system perspective, as the students define game elements and their relations with other elements. On a higher level of abstraction, students use higher order thinking specifically analyzing, evaluating [16] and creating to translate a complex real-world situation to this simplified representation.

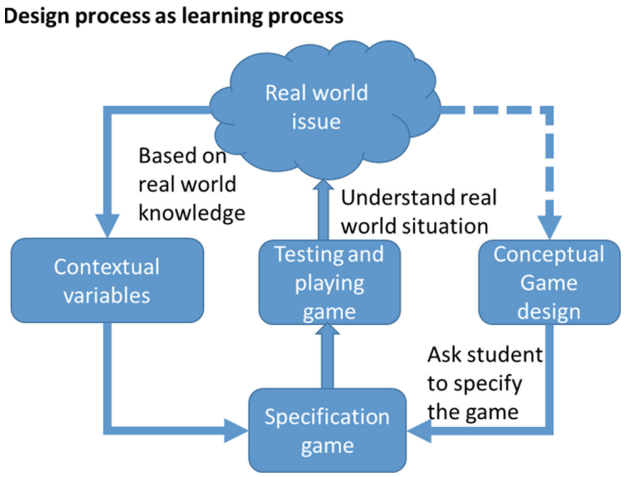

Fig. 2. Frame game for analysing the real world situation

The difference between using a frame game as teaching method in comparison to a game design assignment is that students are not distracted by the conceptual game design

and the knowledge required for game design. Giving students a framework provides a low threshold to start the assignment and a high ceiling of challenges as all elements have to come together [8]. Working with this framework, therefore, allows them to focus their attention on learning about complex systems. Although the novelty of the games is lower, this novelty is less relevant as the objective is to learn about urban resilience. This model of learning is applied in two different settings with the use of *RElastiCity*.

3 Frame Game, *RElastiCity*

RElastiCity (combination of Resilience Engineering, Elasticity and City) is a game about urban resilience [17]. The objective of the game is to understand the effects of shocks (such as earthquakes, heat, dam breaks and power outages) on the urban area, the measures to make the urban areas more resilient and the consequences. One of the learning outcomes is that urban subsystems are connected and problems in one system cause cascading effects in other systems.

The game has a basic version simulating a generic Dutch urban area with four subsystems (transportation, energy, water and built environment). The game is played with four participants, each participant being responsible for one subsystem. A participant has to take measures (adaptive, mitigation and recovery) by playing cards that prepare the urban area to deal with shocks represented by cards and to improve the environmental, social and economic resilience of the area. After an introduction, the game is played in 10 rounds. Each round consists of rolling a dice to determine if a shock happens (the further in the game, the higher the probability of a shock occurring). In case of a shock, the players need to check if they are sufficiently prepared or if they have to recover within the turn. Next, players can discuss and decide which measures they want to buy and implement and if they are willing to buy measures together. At the end of the turn, the players check if they recovered from the shock and have to update the resilience level of the city based on the implemented measures. After 10 rounds, the game ends and a debriefing starts in which the strategies, decisions and results are discussed.

RElastiCity is built as a frame game where the content used on the cards can easily be replaced with other content. New measures can be added to or replace the existing cards and new shocks or cascading effects can be added or changed. It is even possible to add an entirely new subsystem such as agriculture or coastal areas and develop appropriate shock cards and measure cards.

4 Two Applications of *RElastiCity* in Higher Education

In the academic year 2020 – 2021, *RElastiCity* was used as a teaching method in two different courses, Integrated Project for Environmental Engineering in the first semester and Urban Resilience in A Changing Climate in the second semester. The way it was used and the experiences of using it as a teaching method are described below.

4.1 Integrated Project for Environmental Engineering

Integrated Project is a first-year Master course at Delft University of Technology about integrated engineering and students learn about problem structuring and project management. The course is given in two periods. In the first period, students selected an urban area and made an initial concept map, followed by an analysis of shocks and stresses in the urban area leading to different trend reports about a specific area. In the second period, the students developed a game based on *RElastiCity* by using the trend reports for defining the game elements and exploring the interaction of the different shocks and stresses analyzed in the first period. They developed 34 trend reports and 10 different games and presented the games at the JIRC conference in November 2020 [18].

Data of the experiences of the students was collected in feedback sessions and discussions with them and from the opinion of the course manager of the results. The students were asked about what they learned by using this frame game in their project.

Students used the elements of the game to search for specific information. A student group told us that they design stress cards based on actual journal articles; shock cards were based on news articles and measures based on policies of the municipality under study. This group found that this was a creative way to communicate and another group observed that the game opened the discussion about integrating other factors than the key performance indicators (KPIs) given in the format. A third group found that the game helped them to prepare for the worst. All groups learned about 'the complexity of urban resilience' and 'how integrated everything is' while designing the game.

The course coordinator observed that using a frame game stimulates students to think analytically as conceptualization and abstraction is required rather than merely listening to information which is a risk with writing reports. Students were more motivated to work on a game in comparison to writing a report. They have to place the information in context and consider the relationships and integration. Working in a group to design a game supports collaboration and communication. In many group work situations, students divide the work and the different outcomes are loosely coupled. In game design this does not work.

Although results are based on generic feedback sessions, we observed using the frame game gave a context for students to co-design and discuss the content. The frame serves as a framework for analyzing the system and as a starting point for discussion. These discussions were focused on the content and designing relations between elements of resilience challenge which is in line with our objectives and hardly on discussion and confusing about the game concepts.

4.2 Urban Resilience in a Changing Climate

The Urban Resilience course is an 8-week Master course at the University Twente in different topics such as conceptual modelling, measures and effects. One of the workshops in the course was 'Evaluating the Impact of Resilience Measures – a game design exercise' whose objective was resilience measures and to explore and discuss the impact of these measures.

RElastiCity was used as framework for the workshop which lasted two hours and was conducted online. The idea was that a group of students select a (published) trend

report of the Integrated Project Course. With this information as starting point, students worked in groups to develop 'measure cards' for the game. This meant that they had to think about type of measures, costs and effects of these measures. Students discussed and developed a list of measures in Excel sheets about shocks, stresses and potential effects, but could not develop playing cards due to lack of time.

The survey instrument of 11 questions with a 7-point Likert scale (1 means totally agree, 7 means totally disagree) was completed by 13 students after the session. It had two ranking questions and one question of 10-point Likert scale (1 means totally agree, 10 means totally disagree). The objective of the workshop was to learn about shocks, measures and effects of measures on urban resilience. The students did not agree or disagree that they gained a deeper understanding of the measures or the impact of shocks on the system (Table 1). The students slightly agree that they could evaluate the impact of the measures from the indicators of economy, community and nature.

Table 1. Average score of learning effects

	N=	M=	SD=
Q2. I gained a deeper understanding of the measures for which I filled in game	13	3.6	1.50
Q3. While filling in the game cards, I gained a better understanding of the impact of the shocks I selected on a specific urban (sub) system:	13	3.7	1.25
Q4. The performance indicators (economy, community, nature) were an effective means of evaluating the impact of the measures:	13	2.8	0.55

The second group of measures was about the use of the game as conceptual framework (Table 2). The students somewhat agreed that the assignment was useful and that filling in the cards was an engaging way to learn about measuring resilience. They somewhat disagreed that they had enough time. They said that it was difficult to fill in the excel sheet as more explanation was necessary and that they need more time to do the exercise. They assessed the exercise with 5.7 out of 10 and stated that the exercise was useful to learn to measure resilience in an integrated way. Taking a closer look at the individual answers, the average is highly influenced by one participant scoring extremely low and in complete disagreement with each statement.

The number of respondents of the survey has been limited, however based on the overall numbers, we conclude that in principle the idea of using this game as a frame to discuss urban resilience can work. However, we and the teachers experienced that time for doing the exercise in this workshop was too limited to dive into the topic completely.

Table 2. The game as conceptual frame-work

	N=	M=	SD=
Q9. I found the assignment useful for understanding the impact of measures on the resilience of an urban (sub) system:	11	2.9	1.22
Q10. I thought that creating the game cards was a fun way to learn about measuring resilience:	11	3	1.95
Q13. I had sufficient time to complete this in class assignment	11	4.4	1.56
Q14. How likely are you to recommend this assignment to other students or your friends? (10 point scale)	11	5.7	2.02

For Q9, Q10, Q13 (7-point Likert scale) and Q14 (10-point scale)

5 Discussion

RElastiCity was used as a conceptual framework to analyze the resilience of an urban area with a focus on shocks and stresses. The game functioned as a starting point to explore measures and analyze their effects in an integrated way. This concept was studied in two different ways. In the first situation, the game gave structure to an extensive analysis and design process while in the second situation the game was used in a two-hour workshop.

One of the difficulties for students when they start a project or explore a complex system is to choose a focus when everything seems interesting. Students in a frame game are given an open framework within which to think and explore. Students apply it to a specific urban area and that provokes discussions on complexity of the topic and how to simplify that into a game. The openness of the game concept grants students the flexibility to explore topics of interest to them but also the structure to guide them in the translation of real-world issues into the game environment. The game opened discussions with conference participants about how to integrate social factors like health and well-being with engineered systems. This way of thinking demonstrated by the students shows the current resilience conversations within municipalities, representing an important link between their education as engineers and real-world impact. Social considerations of health, well-being and justice will be fundamental as cities are set to encounter increasing shocks and intensifying stresses in the decades to come.

Second, it is necessary to include the interdependencies and integration by developing a game. In the Integrated Project course, all elements had to be connected, and if not, students needed to discuss. In the second course, the effects of measures were discussed, although these were more per measure and not about the integration of the measures with the existing system.

Third, students can engage in game design without previous training or a specific skill set by using a simple game concept. Starting game design from scratch requires prerequisite knowledge, training and time to develop a concept. By excluding this step, students can focus on learning and communicating about interdependencies and dynamics of a complex system.

Big differences between the two setups were observed. In the Integrated project, the results were better and students were more engaged due to the time spent on this

exercise. The students had the time to analyze a specific area and its urban resilience. They had sufficient time to translate this to the game elements, could playtest the game and reflect on the system analysis in the first part of the course. In the limited time of a two-hour workshop, this process was not possible. The proportion of time in a two-hour session to understand the teaching method is much greater than in a semester-long course where more time can be spent on experimentation and iterative learning. Although using a frame game as a framework can be time saving from a game co-design perspective, it takes time to engage in important processes of learning about the real-world issues, negotiating with group members to decide how to fill in the framework and playtesting to understand the interdependencies. This iterative process contributes to learning about complex urban systems.

6 Conclusion

Based on two instances of using *RElastiCity* as conceptual framework to study Urban Resilience, students could experience structured shared learning and communication about an urban area using a game concept as a starting point of a game design process. It supports setting boundaries which is always a challenge for students, enabling more attention to specific elements, while granting space to include other elements. All elements have to be integrated for playtesting and reflection by the students. This can be applied without detailed instructions about game design or a lot of time to create a conceptual game. Finally, in general students enjoy the game design process.

Students must have sufficient time to do the complete loop of analysis, design, play, reflect, redesign and replay, as this contributes to the learning process. In short sessions, the time to become acquainted with the conceptual game is relatively long because less focus can be given to the content and its discussion. Just as for other simulations and models, choices have been made about what to include and what to exclude which must be discussed in the debriefing of the exercise.

In conclusion, conceptual game customization is an engaging and fun alternative to more traditional modeling approaches. The level of engagement generated from students and the integral understanding of the interrelations shows that the frame game is well suited for learning about complex systems and their interdependencies.

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