# Serious Game to Prepare Citizen Registry Actors to transition to Quantum-Resilience

Lærke Vinther Christiansen[1,*], Marijn Janssen[1,] and Nitesh Bharosa[1,]

[1] *Delft University of Technology, Postbus 5, 2600AA Delft, The Netherlands*

**Abstract**

As quantum computer development progresses, so do the security measures needed to be undertaken to prepare for them. Many of our most ubiquitous present day cybersecurity systems are also amongst the type of security technology most fragile towards to the unique nature of quantum computing. Research to find solutions for these issues have begun, but they remain underdeveloped. Likewise, it is not merely enough to initiate developing solutions, there also needs to be a plan for the implementation of them. One such system that faces risk in the future is the citizen registry of the Netherlands. This paper explores what the critical components of a game are that can target awareness, comprehension, and collaboration amongst citizen registry stakeholders in order to update the relevant infrastructures to be quantum-resilient. The paper relies on hermeneutical theory to develop three design principles that can achieve the aforementioned goals through focusing on learning in the design of the game. The paper concludes that it is feasible to impact the players through these design principles and they can likewise be used to create other games addressing socio-technical transitions. However we identify some limitations within the goal 'collaboration' and recommend future research to focus more on bridging the gap between in-game knowledge and applied knowledge

**Keywords**

Quantum transition, digital government, serious gaming, hermeneutics

## 1. Introduction

As quantum computers continue to develop, the risk associated with them grow as well. In fact, it is argued that by 2026 there will be a one in seven chance of quantum computers being at a high enough level that they can break through most common place cryptographic schemes. These numbers are estimated to increase to fifty percent by 2031 [1]. It is therefore crucial that we already now start taking mitigating measures and prepare to transition to quantum-resilient platforms. This is true for sectors in both the public and private spheres, stretching from banking, to healthcare, to telecommunication, and to government. Governments are in a particularly challenged position as they provide some core services that many public and private organizations rely on to function. This includes databases like citizen registries, where information like person numbers, addresses, and civil status is stored. In the case of the Netherlands, the central citizen registry is called the Basisregistratie Personen (Personal Records Database) (BRP). Updating the system of any central government database is a complex task and the BRP is no exception to this. Due to the complex and highly decentralized actor system that surrounds the BRP it would almost be impossible to update the system without causing major issues for the actors that rely on the database. In principle, the solution is simple enough; have the actors that rely on the database update to equivalent standards, or ensure that the updated systems for the BRP are compatible with the known actors' systems. However, it does not unfold so simply off the page.

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EMAIL: l.v.christiansen@tudelft.com (A.1); m.f.w.h.a.janssen@tudelft.nl (A.2); n.bharosa@tudelft.nl (A.3);
ORCID: 0009-0006-6202-7657 (A.1); 0000-0001-6211-8790 (A.2); 0000-0002-3919-6413 (A.3)

The BRP has both public and private actors that rely on access to it, and only the public sector actors are subject to moderate governance for their ICT infrastructures. The private sector actors are under no governance for their ICT choices, but are responsible for having the necessary technological solutions to access the BRP, which is namely done through a *public key infrastructure* (PKI) connection.

This essentially means that the best option of having all actors simultaneously update their ICT to a quantum-resilient level is almost impossible to achieve, unless the actors can be brought together to knowledge-share and collaborate. Before this can fully be achieved, it is necessary to start by addressing the main points of tension for the transition. Overall, the main points of tension that need to be addressed for this transition to be successful is awareness, improving stakeholder comprehension of the issues, and collaboration[2], [3], [4], [5].

For this paper, actors refer to those organizations who utilize and depend on the BRP, and therefore have a stake and vested interest in its continued function [6], [7]. Not only do the BRP stakeholders lack awareness and comprehension of the severity issues ahead, they also lack knowledge of how they can collaborate moving forward in the transition.

As the people are key in a transition, we propose that using a serious game is a functional way to target these points of tensions [8]. A serious game can generally be understood as a game that pertains to serious matters and does not seek to entertain the player as its main goal [9], [10], [11]. In the case of the game proposed in this article, serious gaming encompasses the subgenres of policy gaming and educational games [11], [12]. The goal of the serious game is to target awareness, comprehension, and collaboration amongst the players. The game will utilize hermeneutical theory, specifically focusing on real-time hermeneutics in game play and learning through the hermeneutical circle, which resulted in three design principles for the game which was combined with the three goals of the game for maximum impact. The game was tested amongst a group of Dutch government employees to explore whether it can target the goals, and be successful in fostering collaboration between the stakeholders, while improving their knowledge and comprehension of the topic, through raising awareness of the issues related to the BRP and encouraging knowledge-sharing between the players. The purpose of the paper is to explore whether the game can impact awareness, comprehension, and collaboration and facilitate a centralized, collaborative approach to the transition. In order to address the issues outlined, this paper seeks to answer one main research question: To what extend can a serious game impact awareness, comprehension, and collaboration amongst BRP stakeholders in the quantum transition?

Moving forward, the paper will firstly go into a background section wherein the larger context of the BRP and the issues surrounding its transition to quantum resilience will be explored. In section three, we discuss the use of hermeneutical theory and how it was utilized in the game design principles. Next, the paper will move onto research methodology, where we will first cover the methods used for data collection, then go into the control parameters for the research sessions. In the fifth section, the paper goes over the findings from the game evaluation session and categorizes them according to the three goals; awareness, comprehension, and collaboration. Lastly, the paper end with conclusion and recommendations for further research.

## 2. Background

The BRP is a highly central database that many actors rely on in the Netherlands. Hundreds of public, semi-public, and private organizations rely on this database to draw personal information about citizens [13]. The BRP is used to store personal information on citizens, such as person numbers, addresses, civil status, and so forth. This information is used as core parts of the daily operations for many sectors, such as banking and healthcare. This means the BRP and the accuracy of the information stored in it is essential for the functioning of sectors that are vital to Dutch society. Should they no longer have access to the BRP they would be severely impacted in their abilities to perform their functions. To maintain access to the BRP all users need to ensure that they are employing consistently compatible technology and initiate any relevant ICT update that the BRP is subject to. However, doing so poses a difficulty for many of the users in the BRP actor network, as its highly decentralized. This means there are only a few established lines of communication [7]. There are a handful of key actors in the system that are responsible for maintaining and providing data for the database. The overview of key actors in the BRP actor system can be seen in **Figure 1**.

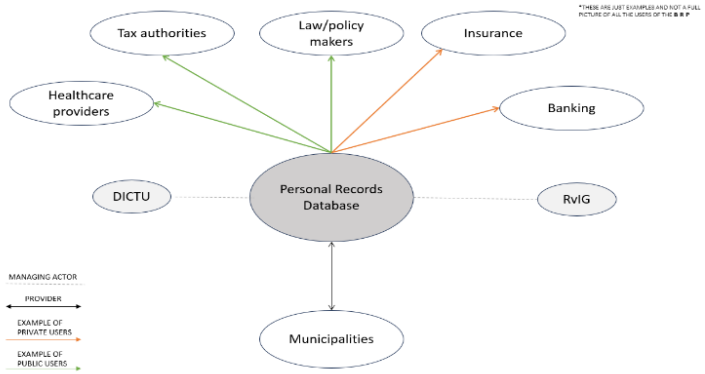


**Figure 1** Basisregistratie Personen Actor Network

The established lines of communication are represented on the bottom half of Figure 1, and goes as follows; The Dutch municipalities are the providers of data for the database. Whenever a citizen living in the Netherlands changes a part their personal information, such as a new address, they are obligated to report this change to the municipality who will update the information in the BRP. Officially the BRP belongs to the Rijksdienst voor Identiteitsgegevens (National Data Service) (RVIG). The RvIG, functions as a monitoring agent, wherein they systematically extract and verify samples of the data for correctness. Should they find incorrect information, they communicate the error to the municipalities who are then responsible for correction the information. For practical management and handling of the database the service is outsourced to Dienst ICT Uitvoering (ICT Implementation Services) (DICTU), which belongs under the Ministry of Economic Affairs and Climate.

From a technology governance perspective, decentralized systems pose their own set of challenges. In concept, it means that all actors in the system are free to make their own IT decisions or at the most are only subject to light governance guidelines [7]. This is the case for the BRP actor network where public actors are subject to light governance regulations from the government. Private actors are free to make their own decisions and are entrusted with the responsibility to ensure that their systems are compatible with the BRP[2], [8].

There are a few established lines of communication within the actor network, but they are exclusive to the managing government actors and do not extent to the actors who use the BRP. Without these formal lines of communication for all actors in the system there is generally low awareness of other actors and their individual impact on the larger system. The BRP's digital infrastructure will inevitably require significant updating and when this time comes, the reliant actors will not receive the information in time. This will cost key social sectors, like healthcare and banking, access to the BRP, and potentially bring Dutch society to a standstill.

Currently, users of the BRP have one main security demand to access the database, namely a *public key infrastructure* (PKI) connection. PKI is a cybersecurity mechanism which allows for safe data communication between two parties. It relies on asymmetric encryption, wherein each user has two keys; one to authenticate their identity others and one to access data sent to them. This type of encryption very safe presently, but it is also fragile to certain algorithms that are run on a quantum computer strong enough to reach prime factorization [1], [2], [14]. PKI is one of the most ubiquitous cybersecurity tools globally. One reason for this is that those who employ PKI can tailor their application of the system to fit their exact needs and choose from many different vendors and service providers [15], [16].

For a database like the BRP it is then important to clearly state to users what the requirements are for being compatible with the PKI solutions they utilize. The same goes for the inevitable updated quantum-resilient versions of PKI. However, this highlights one of the key challenges for BRP actor system; the lack of established lines of communication with users. There is a chance that quantum-resilient PKI solutions will lack backward compatibility with traditional PKI options [2]. This would mean that should any users slower to update their PKI might not be able to access the database, which is undesirable. The upcoming quantum transition will happen in phases, so inevitably some users will be relying on traditional PKI when others have already transitioned to a quantum-resilient version [3]. As such, backward compatibility and interoperability between different PKI solutions will be key moving forward, and these are elements that will be difficult to target in the transition for a decentralized actor system. Because of this it is essential to increase awareness within the actor system of upcoming risks and the existence of other actors. This will also aid them in establishing sustainable lines of communication for knowledge-sharing and collaboration.

## 3. Hermeneutical theory

A core part of the game, are the three design principles, namely, *learning perspective*, *learning approach*, and *learning content* which were chosen to address the key challenges in the transition, namely awareness, comprehension, and collaboration. We approached creating these principles through the lens of hermeneutical theory, specifically relying on the two concepts called the hermeneutical circle and real-time hermeneutics.

When looking at real-time hermeneutics in gameplay, the theory argues that the players exist in a shared reality for the duration of the game, a sort of micro cosmos, which is impacted by their interactivity with it [17], [18]. Games rely on instant interpretation of the players' action from a clear feedback system, supported by the framework of the game, which in turn impacts the result of the game [17]. What makes an immersive experience successful is providing the players with the opportunity for control through imbedded mechanisms like rules

and goals. Through this, the experience will have flow and immersion which improves the players' ability to learn and develop within the framework of the game [19].

The hermeneutic circle presents an approach to learning where in it is argued that to understand 'the whole' one must first understand 'the parts' and vice versa. So to understand 'the big picture' one must seek out sub-context and use it to revisit the 'big picture' with increased understanding, to fully comprehend the meaning of a matter [20]. This is done by making a set of assumptions about what the relevant parts are, which lets us arrive at the whole [20], [21]. This meant determining what parts of the transition we wanted to highlight and what constituted the 'big picture', i.e., the whole. Lastly, each of the design principles targets a specific goal of the game, however each of the principles has impact on achieving the other goals, just to a lesser extent. The design principle *learning perspective* targets comprehension, *learning approach* targets awareness, and *learning content* targets collaboration.

For *learning perspective,* we were aiming to target the goal of comprehension. To do so we, firstly, we looked at the theoretical concept real-time hermeneutics and secondly, we looked at the hermeneutical circle. By providing them with a micro cosmos to assess, negotiate, and solve problems in their shared reality, the players can increase comprehension of what participating in the quantum transition takes. The feedback system of the game allows for the players to interpret the success of their actions in a fast-paced timeframe, intended to mirror a sped-up version of the projected time available in the actual transition. Through this, the game provides a space wherein the players can test and grow their comprehension of the quantum transition, test solutions, and rectify errors with no real-life fallout. As such, the game presents a sort of trial ground for testing conceptions of the transition and ideas for it in an instantaneous system, in contrast to the real transition which will take many years to complete [3].

Within this shared reality created between them, following the logic of the hermeneutical circle allows for the players to engage with the knowledge in a reflective and interactive way. The levels of the game were implemented to employ this mentality as the player initially starts at a higher level of abstraction in one level, from a macro governance perspective, and in the next level it goes into a micro level perspective, and follows this back-and-forth the whole game. By following this circular structure, the players can take a reflexive approach to the topic and continuously revisit this highly complex case with a fresh perspective. Ideally, this will allow the game to target the goal of comprehension, as this approach to the topic as their current understanding of the issues are constantly challenged and put as subject to reevaluation in the structure of the circle.

For *learning approach*, we were targeting awareness. We decided to do this by considering what topic should be introduced at what level of the game, relying on the structure of the hermeneutical circle. It needed to be cohesive to ensure the flow of the game and it also needed to be true to how the transition realistically could transpire. Simulation games often create very 'real' experiences for the players and what they experience in the games can be conceived as the 'real world' [22], therefore the game needed to represent the stages of a real transition as closely as possible. Since, the players all had little-to-no knowledge of the case prior to playing, but some knowledge of the 'quantum threat', the levels were designed to start with the most foundational knowledge and then continued to add complexity throughout the game.

We added to this the perspective provided by the hermeneutical circle. With this in mind, the approach of the game was decided to begin at the fundamentals with the macro-level governance perspective as the 'big picture' and meso-and micro level governance as 'the parts'.

Structuring the levels of the game like this allowed for the players to be introduced to further complexity within the case and thereby increasing their awareness, without causing the overwhelm.

For *learning content*, we were targeting collaboration, which meant considering how the content of the game could builds connections and foster collaboration between players. We did this once more through lens of the hermeneutic circle. We had already decided what constituted 'the whole' [20], [21] in the hermeneutic circle as a part of the learning approach. This meant the topics were already decided, it was only what examples were provided that needed to be ascertained. These were developed with the help of stakeholder input. Collaborative stakeholders from the Dutch government were actively involved in the design of the game, and provided insight to what they perceived to be the most relevant and impactful examples to utilize in the levels. The input was used to choose examples that we collectively agreed spoke to the core purpose of the game: preparing citizen registry stakeholder for the quantum-transition through targeting awareness, collaboration skills, and comprehension. To do so effectively, we needed the examples and tasks in the game to be as realistic as possible, as simulation games often become reality for the players, and if done efficiently the flow of the game can extend beyond the boundary of play-time and into real life [19], [22].

Previously, Christiansen et. al. [8] explored what requirements would be necessary for a serious game to facilitate in the transition to quantum-resilience for Dutch PKI users. Broadly, the requirements were awareness, technological perspective, interdependencies, and real world implementation. Furthermore, the study largely identified a lack of knowledge, knowledge-sharing, and the underutilization of networks as the main causes for the difficulties found in the impending transition [8]. Thus, utilizing these requirements and the on-going collaborative design input from stakeholders, the game sought to create realistic examples and tasks that should be able to extend beyond microcosmos of the game and into real-life.

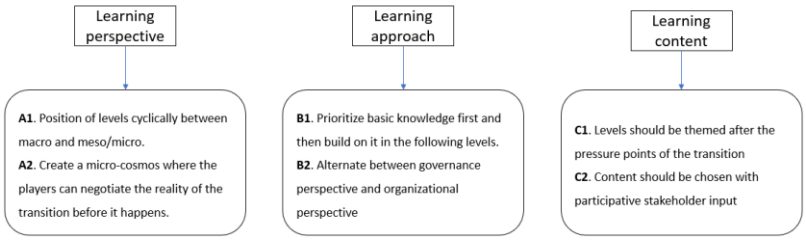


**Figure 2.** Key take-aways from the design principles

## 4. Research Methodology

This paper looks into what the critical components of a game are, that can impact awareness, comprehension, and collaboration amongst stakeholders to the BRP in relation to its transition to quantum-resilience. However, this is still an on-going process and therefore the research approach in this paper is largely explorative. The impact of the game was tested using intake and outtake surveys, which relied on the player to self-evaluate. For this study we used the data to assess the players' own perception of their skills and knowledge, and how these were impacted by the game. The sections below will first explain our approach to surveys, participant observation, and deductive reasoning. The second part will explain how we approached

controlling the testing environment as best we could to ensure the game experience was as similar as possible for all players and thus comparable.

## 4.1. Research Methods

For the data collection for this paper, three overall methods were used. We utilized a deductive approach to lift the necessary knowledge from the literature to create our design principles and ground them scientifically. In order to test this knowledge, we then tested the game and evaluated the results through surveys and observations. Below we will first explain our approach to surveys, then observations, and lastly, our deductive approach.

### 4.1.1. Surveys

To test the impact of the game the players were asked to perform both intake and outtake surveys, so that the results could be assessed in accordance with their own estimation of how the game had impacted them [9]. The surveys were structured to look at collaborative skills, organizational skills, technological knowledge, and knowledge-sharing impact. Each of the four topics had a dedicated section in the survey with three to four questions meant to measure the impact of this specific topic. The choice of these four categories was based on our previous research on the topic, wherein we were able to identify those four as the main pressure points in the transition according to expert stakeholders [8] The reason this style of intake and outtake surveys was chosen largely comes down to the iterative process of game design. In game design we can understand elements of output and input. Input are the elements that the designer use in the game such as roles, constraints, and resources, as well as the game-specific scenario. When players interact with and play the game, the developer has very limited control over how the provided inputs are interpreted and has to hope they were sufficient for the players. The output provided from the game consist of both qualitative and quantitative data and is very useful for the future development of the game [23]. Thus having them self-evaluate their position both before and after lets us know a lot about whether our inputs are being interpreted as intended and if they have the impact we were aiming for. If they do not, the output data is helpful in pinpointing areas for further development.

### 4.1.2. Observations

Two forms of observation were utilized for this study. First a passive, non-participant role as observer was utilized. This role was performed by the host of the game testing session, who observed the sessions as they carried out. This was to assess how the larger framework of the game session was doing, if it was generally successful in its intended purposes, and if it was creating the intended environment. Secondly, there was the role of the participant observer. Each group had a player that was also an active collaborator in developing the game. The purpose of placing these control individuals in the groups was to have an observer who knew what the intended purpose of the different mechanics were, and could assess if the input was being received as intended, and if not, what the disconnect seemed to be. Their role was not to try and interfere with the interpretation of the mechanics, but to observe the gameplay in the group and bring those observations into a plenary discussion later.

### 4.1.3. Deductive Approach

This paper utilized a deductive approach. This means, the paper first looked at literature to draw conclusions about the input necessary for the game to bring about the desired outcome. By reviewing literature on the topics, selected on the basis of our theoretical approach, hermeneutics, serious game research, and empirical input from the field, we were able to deduce what impact goals were important to focus the game on and how to utilize the theoretical approach to do so. As can be seen in Figure 3, we grounded our theoretical approach in hermeneutics, which we approached with the focus of our three impact goals. Combining these two led us to arrive at three design principles to base the game on. With these central elements defined, we then moved on to implementing them in the design. Upon having reached consensus on the design with the stakeholder collaborators, the game was then tested and evaluated by a group within the target audience. This evaluation was supported by the aforementioned surveys and observations, to assess if the game truly was successful.

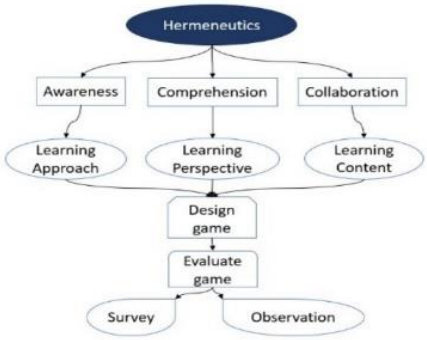


**Figure 3.** Research Process

## 4.2 Game testing approach

In a social setting such as a game testing session, it is impossible to control every element and every variable, but those variables that were manageable to control where carefully chosen and implemented to ensure that every group had an as equal experience playing the game as possible. These were the control elements we took into consideration: 1) *Players categorized according to four types of roles.* We categorized the players within four broader categories of actors, and then the players were distributed as equally as possible into four separate groups, so that every group had an as representative background as possible. The categories of players were chosen in accordance with the roles identified in the background research. These groups were; policy makers, researchers/scientists, developers, leadership/management. 2) *One control person in each group.* For each group there was one person who had actively participated in developing the design of the game and who was familiar with how to play the game. This was done to ensure that a) the players would be able to resolve confusions within the gameplay without having to pause the whole game, and b) so the control person could take notes during and assess how the players were experiencing the game. 3) *Plenary information session.* Everyone was given the same introduction, in the same room, at the same time. They all received the exact same information about the case and how to play the game. This means they all started at the same entrance level of knowledge. 4) *All games hosted simultaneously in the*

*same room.* All four groups were hosted in the same room. They were placed in four separate corners of the room and did not interact with the other groups. This way they all worked in the same environment and received the same stimuli and input from it. 5) *Collective time.* The game sessions relied on one large shared timer, that was shown on a large screen on the wall where all players could see it and keep track of how much time they had left for each level. This also means they all progressed at the same pace, and everyone had the exact same amount of time to finish the tasks.

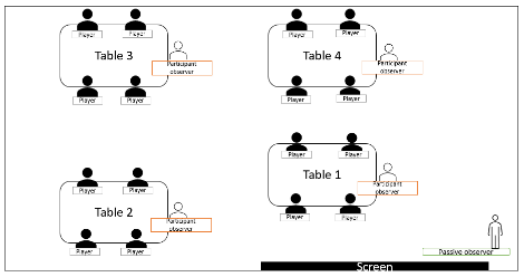


**Figure 4**. Game session layout

The practical layout of the game session can be seen on Figure 4 above. Each of the table only communicated within the table, and all five participants were free to participate equally in the game. The passive observer only interacted with the tables and players in the event they had clarifying questions about the rules of the game. The passive observer did not participate in any of the game play.

## 5. Findings

It was the expectation of this study, that the impact of the game can be measured across the three goals, namely, awareness, comprehension, and collaboration. The impact of the game across these goals is measured according to the self-assessment provided by the players in their intake and outtake surveys. The results will be presented in the following order: awareness, comprehension, and collaboration. This structure is followed as the game must first target awareness of the quantum transition and its challenges, before the game then can begin to foster comprehension amongst the players. After this, the game surmises the players should be able to extend the in-game comprehension into real-life application and identify important steps, such as, potential collaborators. Accomplishing impact across these goals is a significant advancement for the transition to quantum-resilient PKI in the Netherlands.

Firstly, looking at the results related to awareness, in the intake survey, the players generally considered themselves to be at a high level of readiness. When asked to place themselves between a one and five in terms of readiness, with one being the lowest and five being the highest, they all ranked themselves as a three or a four. On the aggregate, this meant that even if they did not consider themselves entirely ready they also did not consider themselves unprepared. However, after having played the game, the trend spread out more evenly. While a few players identify as a five after playing the game, meaning they consider themselves entirely prepared, one fourth of the players now had re-estimated themselves as a two, clearly indicating that post-game they felt a lot less ready.

This study does not necessarily consider a regression of self-estimated readiness amongst the players to be a negative result. On the contrary it shows that a group of players which all trended towards feeling prepared became aware of the immense complexity of the situation and the wide range of knowledge required to accomplish this collective transition, and re-estimated their readiness level accordingly. As such, it is a positive response for the games ability to affect awareness amongst the players.

Secondly, looking to the results related to comprehension in the intake survey it is evident that the players already consider themselves as comprehending the complexities of the transition. This is to be expected as the players all are part of the Post Quantum Transition group in the Dutch government. This responsibility requires a fairly specialized skill set and at least a working understanding of quantum technologies and quantum innovation. What this game then sought to challenge them on was less their knowledge of technical elements and quantum application challenges, but more so their abilities to comprehend the complexities of performing the transition and not just governing it. This challenge seemed to have been successful by the measurement of the outtake survey, where the players generally seemed to have improved their understanding of varied elements of the transition, like what their own contribution would be and assessing preparedness inside of their organization. This showed in the outtake survey, where all players considered themselves at a three or above in the topics related to comprehension. Thus these metrics were successful in only impacting the players in a way that was perceived as positive, and generally the players estimated their comprehension of the transition had improved.

Lastly, collaboration was measured across elements like whether the players felt they could identify relevant collaborators in the transition and if they knew what their practical next steps would look like. For these data points we saw a small change from the intake to the outtake survey, but primarily the answers remain the same. The players do not appear to have been largely impacted by the game, in terms of collaboration. Most of the players trend neutral in their answers by ranking at a three. For some of the survey points, we saw some slight deviation were some went down to a two out of five and a single person identified as a five. Thus the results showed that impact on this topic was sporadic and more of a deviation than are foregone conclusion. Most of the players seem to not been impacted at all by the game in terms of identifying collaborators and carrying out the transition in reality.

Over all, the game seem to have been successful in its goals of targeting awareness and comprehension, and less so in terms of targeting collaboration. That the game failed in its third goal is not necessarily negative for the goals of awareness and comprehension. Simulation games can be highly realistic and extend beyond the boundary of game-play and into real life if it manages the foster the right circumstances and flow [19], [22]. The failure to achieve this suggests a lack in the third design principle *learning content*, and future research should be focused on improving the content of the game to overcome this problem. Nonetheless, the game managed to impact both awareness and comprehension which are two important goals for the Dutch transition to quantum-resilience. Moreover, it suggests that the game is capable of preparing Dutch citizen registry actors for the transition to quantum-resilience, and thereby also assisting in a large-scale socio-technical transition.

## 6. Conclusions and Recommendations

The paper set out to ascertain to what extend a serious game can target awareness, comprehension, and collaboration amongst BRP stakeholders in the quantum transition. In that vein, this game was developed according to three design principles, namely, learning perspective, learning approach, and learning content. The design principles were developed through the lens of hermeneutics, which allowed us to target learning as a core element for all parts of the game. This game was successful on two counts, namely, awareness and collaboration, and therefore the principles of learning perspective and learning approach were also successful. However, learning content was not as impactful a principle in its current form. For further research, the learning content principle needs to be restructured to allow for better immersion and flow, which in turn should improve upon the likelihood of extending the game-play into reality. Nonetheless, the game was successful in impacting the players which signifies that it is possible for a serious game to prepare actors connected to the Dutch citizen registry for the quantum transition, and thereby impact large-scale socio-technical transition. This is significant as currently, to the best of our knowledge, no other game has attempted this is relation to the transition to quantum-resilience. If you follow and apply these design principles, you can expect to find a framework centered on learning on each level of the game development process that is particularly suited for a complex socio-technical transition, like the quantum transition. However, we recommend making the game as specific as possible. When using a specific case it is allows for more flexibility in the perspective, like alternating between governance and organizational perspectives, which results in a more granular experience for the players.

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