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Design Science Research: Balancing Science and Art in Building a Game Applied to Health

Luma Wanderley de Oliveira [**Universidade Federal de Goiás** | ***luma.lwo@gmail.com***]
Saulo Soares de Oliveira [**Universidade Federal de Goiás** | ***saulosoares150498@gmail.com***]
Marcos Alves Vieira [**Universidade Federal de Goiás** | ***marcos.vieira@ifgoiano.edu.br***]
Silvana de Lima Vieira dos Santos [**Universidade Federal de Goiás** | ***silvanalvsantos@ufg.br***]
Sérgio Teixeira de Carvalho [**Universidade Federal de Goiás** | ***sergiocarvalho@ufg.br***]

In the field of applied computing, such as in the development of games applied to health, there is a growing interweaving of two distinct fields: ”Science” and ”Art”. The methodology of Design Science Research (DSR) can contribute by directing with greater scientific rigor the development of technology-oriented research. The objective of this paper is to present and discuss the use of the DSR methodology in applied computing research, in which the developed artifact is a game applied to health. Three development cycles were defined. The first cycle prioritizes the understanding of the problem, the second defines the development of the main artifact, and the third, in turn, deals with the evaluation of the artifact. In this way, it was possible to instantiate a DSR model and generate artifacts that contribute to the understanding and the practical development of the solution. We also present a discussion about the conduct of the research and adaptations that this model could receive for research focused on game design for applied game development. The conclusion is that a balance between ”Science” and ”Art” results in innovative work that is in demand for production.

Keywords: *Design Science Research, DSR, Applied Game, Serious Game, Arterial Hypertension*

1 Introduction

A recurring discussion in the field of computer science originates from the conjecture about whether computer science is really a science (Denning (2005)). When it comes to science, some criteria delimit it: principles, fundamental recurrences, explanation, discovery, analysis, and dissection. On the other hand, there is “Art” that refers to the useful practices of a field and is more connected with practice, performance, specialization, action, invention, synthesis, and construction.

Therefore, computer science brings together both characteristics, sometimes closer to science, mainly in mathematical areas, as in fundamentals and theory of computation, sometimes closer to art, mainly in areas such as applied computing, where there is a concern in the use of knowledge. Formally:

> Applied Computing is a branch of Computer Science that uses the methodologies, methods, and techniques of Computer Science as a means to solve problems, theoretical and/or practical, in other areas of knowledge (Gelain et al. (2014)).

Thus, to establish scientific rigor in research with applied computing features, the difficulty lies not only in developing a solution, but also in evaluating or validating the research hypothesis in another area.

If the computational solution to be developed is a game, one should still be concerned with all aspects of game design (Pakarinen and Salanterä (2020); Bayrak (2020)). Consequently, it can be seen that multidisciplinarity and transdisciplinarity are fundamental elements for the work to be developed (Gelain et al. (2014); Muñoz and Dautenhahn (2021)).

To contribute to the foundation of research related to computing and technology (close to the “Art”), the Design Science Research (DSR) methodology was developed so that the entire artifact development process generates not only the technological product itself but also that the crossing of knowledge contributes to computer science itself, and not only in the applied area.

This paper aims to present and discuss the use of DSR methodology in an applied computing research, where the developed artifact is a game that is applied to health to improve patient engagement with the treatment of arterial hypertension, relating gameplay and self-care. A DSR model was instantiated, and development cycles were defined to obtain the game, a web service and health goals.

This paper is an extended and revised version of a paper published in the Brazilian Symposium on Games and Digital Entertainment (SBGames) 2021 (Oliveira et al. (2021a)). Among the main extensions is a more detailed explanation about the generated artifacts in the stages of the DSR methodology and a discussion about the duality of science and art related to the research we present in this paper.

The paper is organized into six sections. Section II presents the DSR methodology as a way to do science through technology development. Section III provides a contextualization of the research and discusses the use of the methodology in the development of a game applied to health. Section IV, in turn, presents the results obtained to the present state of the research. Section V discusses the DSR methodology and the insights obtained through design thinking, and finally, Section VI covers the conclusions and future works.

2 Design Science Research

Scientific knowledge seeks to explain the world through observation and the use of methods to validate hypotheses. It can be categorized into formal sciences, which encompass the study of abstract and symbolic relationships; natural sciences, which comprise the study of natural phenomena; and social sciences, which cover the study of human and social phenomena (Rochadel (2016)).

Technological advances have caused so many transformations in society that have influenced the way science is done: traditional sciences have limitations because it is not enough to explore, describe, explain and predict phenomena, there is still the need to design and produce systems for the advancement of science (Dresch et al. (2015)). Therefore, mankind has been increasingly building artifacts for problem-solving. Observing this context, Simon (1980) highlights the concept of Design Science, translated by science of the artificial, aimed at research that is focused on problem-solving and consequently on the design of artifacts.

Design Science Research (DSR) was developed as a research method for advancing science and technology with the intent to legitimate the production of scientific knowledge from the construction of artifacts and using as an epistemological basis the science of the artificial (Dresch et al. (2015); Peffers et al. (2007); Rochadel (2016)). This epistemological-methodological approach has been applied in the fields of information systems, production engineering, and applied computing, and relies on seven fundamental criteria that help conduct the research: the creation of new artifact, specific problem, artifact evaluation, contribution in the market and the academy, artifact development strictness, research execution, and communication of the results (Dresch et al. (2015)).

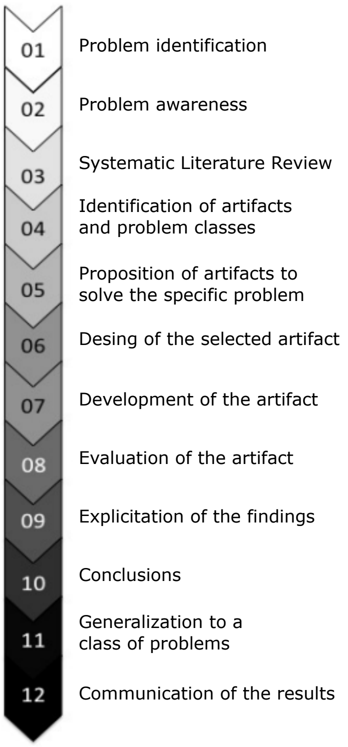

Figure 1. DSR Steps. Adapted from: Leitao et al. (2021).

A proposal for conducting this method was made by Dresch et al. (2015) which considers twelve main steps (Fig. 1): Problem identification; Problem awareness; Systematic Literature Review; Identification of artifacts and problem classes; Proposition of artifacts to solve the specific problem; Design of the selected artifact; Development of the artifact; Evaluation of the artifact; Explicitation of the findings; Conclusions; Generalization to a class of problems; Communication of the results.

Table 1. Types of artifacts. Source: Reis (2019).

Artifact	Description
Constructs	Consist of the conceptualization used to describe the problems within the domain and to specify their respective solutions.
Models	Set of propositions that express the relationships between constructs, *i.e.*, describe or represent the context, the structure of reality to be a useful representation.
Principles	Guidelines to serve as a support or guide for structuring systems – facts, principles, and concepts to guide design.
Methods	Set of sequenced steps for executing a task, based on a collection of constructs (language) and a representation (model) in a solution space.
Instantiations	It is the materialization of an artifact in its environment, that is, it is the operationalization of the constructs, models and methods, demonstrating the viability and effectiveness of the models and methods that they encompass.
Theories	Speculative, methodical, and organized knowledge – a set of instructions perspective (of a hypothetical and synthetic nature) on how to do something to achieve a certain goal. A theory includes other artifacts, such as constructs, models, design principles, and methods.

The artifacts mentioned in this approach correspond to human creations, such as instantiations, frameworks, architectures, design principles, methods and models (Table 1). Therefore, it is said that DSR is based on two different types of research that complement each other: design research and behavioral science research (Dresch et al. (2015)).

3 Instantiation of the DSR Model for the hypertension problem

The context of this research emerged through the interactions between researchers and health professionals and applied computing researchers at the Laboratory of Health Informatics (LabIS), forming a partnership between the Institute of Informatics (INF), the Faculty of Nursing (FE), and the League of Arterial Hypertension (LHA), all belonging to the Universidade Federal de Goiás - UFG.

The interest in addressing chronic non-communicable diseases was highlighted by the impact factor of these diseases on society. Due to the characteristics of chronic diseases, the patient must commit to medical treatment for his entire life and, in most cases, must change lifestyle. Health professionals pointed out that there is a challenge for the patient's adherence to the medical treatment of chronic diseases, being a major issue for both the patient and the entire health system.

The meetings were held remotely with a discussion about the low adherence to health treatment and the care plan of patients with chronic non-communicable diseases. It was emphasized that in the capital city of Goiânia there is a larger number of individuals with hypertension and type 2 diabetes, and that these groups exhibit greater difficulty in the Lifestyle Change stage.

Originally, the research was inclined to focus on people with type 2 diabetes, due to the amount of accessible material and the number of health professionals who work directly with this public. However, the LHA's support was crucial to the final decision, as it helped to delimit the problem the research would focus on and facilitate the evaluation process and other health sector formalities.

Therefore, the group started to search for references and concepts involving the care of arterial hypertension, such as: Brazilian Guidelines, Basic Care Manuals, Criteria and Parameters of Care, and Recommendation Reports. As a consequence, the interest in approaching self-care and remote monitoring of arterial hypertension in a continuous care context was delimited.

Simultaneously, while the problem and the context were being delimited, there was in the group a growing research around the use of ludic, in such a way that through systematic reviews (Oliveira and Carvalho (2017); Souza et al. (2021)) it was found that a game can be a tool that adds a layer of fun to routine activities, impacting the person's experience and producing emotional responses that can engage them in these activities. Thus, the research question arose: can a game support a person's engagement in self-care for hypertension?

This research question relates several theoretical and technical aspects that range from the construction of the game (artifact) and its acceptance in usability aspects, to the factors that relate adherence, engagement, and self-care in the context of hypertension, thus framing the research in Design Science.

Consequently, the proposal is to evaluate the relationship of engagement provided by an intervention through a game applied to self-care, adherence to treatment, and blood pressure control of hypertensive patients of LHA, who are followed up in a specialized service in a Brazilian capital.

The model adopted for conducting the research is based on the DSR model adapted by Pimentel and collaborators (Pimentel et al. (2020)) and it enforces the construction of a theoretical framework for the research to make explicit the behavioral conjectures that influence the design of artifacts.

The twelve steps proposed by Dresch et al. (2015) are contemplated in this model, that is, by this stage, the problem has been identified, there has been aware of it, and the literature review was conducted.

Based on the references and with the cooperation of the healthcare professionals, criteria for acceptance of the artifact were established. The artifact must:

- enable welcoming and motivating the person;
- present simple and frequent tasks;
- follow a change plan;
- reinforce desired behavior;
- prevent relapses;
- enable easy interaction when recording data.

With this, it was possible to establish the knowledge information about the problem and context, problem in context, and acceptance criteria, as shown in Fig. 2.

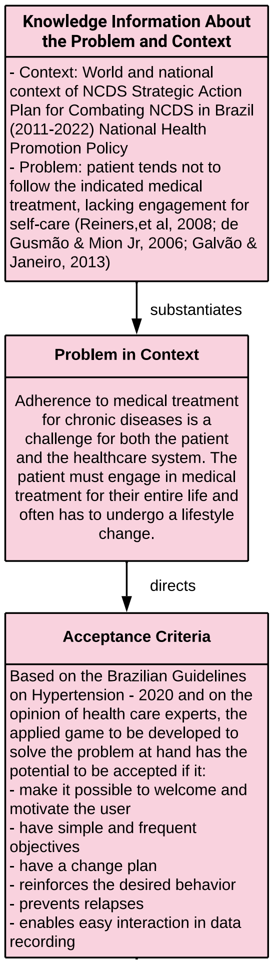

Figure 2. Framework regarding the problem and context.

The next step was to define the target audience. In a macro view of the LHA population, it is mostly composed of women over 55, polypharmacy, 30% diabetics, with cases of depression and anxiety.

The audience profile resulted in some requirements for the construction of the artifact:

- Usability question - How to simplify data entry?
- Acceptability question - Which games appeal to the audience profile?

To answer these two questions it was necessary to perform searches in research databases (Souza and Trevisan (2014), Cota et al. (2014), de Oliveira Santos et al. (2013)). It was defined that the use of smart devices (IoT, Internet of Things) could be adopted as the most natural way (pervasive) of data collection, and that games of the casual genre, such as Candy Crush, are popular among the adult/elderly audience, as they present characteristics of having adjustable difficulty, easy controls, clear objectives, and reduced daily playing time.

Thus, the artifact's scope was better delimited. The name *Salus Ciber Ludens* (SCL), adopted for the project, derives from a few terms: "Salus", from Latin, refers to the health, and life; "Ciber", the element that makes up the English word cybernetics (or *cibernética*, in Portuguese) and relates to technology and connectivity; finally, "Ludens", from Latin, represents the ludic and the game. Thus, by uniting these concepts, we have the SCL platform, which is a ludic system for the integration of a game applied to health with patient monitoring at home. Its goal is to improve the patient's engagement in the treatment of non-communicable chronic diseases, such as hypertension.

Once the context, the problem, the research question, and the artifact were established, the process of developing the artifact started. It can be noted that in these stages there was a lot of research around the problem and the proposal, which were important to extract criteria to assess the research. To facilitate the description of the process, three main cycles were defined: the first cycle, which covers the initial development and the artifact concept; the second cycle, encompassing the coding and creation of assets; and the third cycle, comprehending the artifact's evaluation.

The research is currently in its second cycle and the SCL is its main artifact, which is currently in the final stages of development. At each stage of the artifact development, there is a refinement of the techniques and of the theoretical framework until the acceptance criteria are validated. In each cycle, smaller artifacts are generated that support the construction of the main artifact, and these are validated to mitigate errors at the end of the process.

3.1 First Cycle

The first cycle of the DSR methodology began with meetings with health professionals from the Faculty of Nursing (FE) of the Universade Federal de Goiás - UFG.

Once the target audience was decided, key parameters were defined that indicate through data whether the person is managing to perform self-care actions related to hypertension, such as what value of systolic and/or diastolic blood pressure can trigger events that not only notify the person, but also intervene in some way (in the game or in the analogic world).

Currently, to measure these parameters, the patient goes to the LHA, takes the weekly measurements, and returns home with a device for Residential Blood Pressure Monitoring (RBPM). At home, many patients do not take the necessary measurements or forget to write down the data. Therefore, as part of the solution the use of smart devices was specified, *i.e.*, devices that when used, collect data and send it to a system (*e.g.*, scales, RBPM devices, *smartbands*, body measuring tapes).

Regarding the system, five main elements stand out: the smart devices, a microcontroller, a web service to perform the communication with the devices, a mobile application that presents the health data in a format more suitable for information consultation, and, finally, the game, the main interface of ludic engagement for the person. In this way, the scope of the main artifact was defined, as represented in Fig. 3.

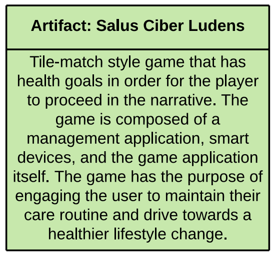

Figure 3. Artifact delimitation.

Concluding the first cycle, a simulation was created using Discrete Event Systems. The use of simulation is a way to predict the behavior of complex systems that could not be tested otherwise (Zeigler et al. (1997)). Thus, the DSR steps of identifying the artifacts and problem classes and designing the main artifact (the SCL) were performed.

3.2 Second Cycle

The second cycle of the DSR methodology started with the definition of the overall SCL architecture (starting from the interaction flow), which is composed of three main modules and a web service for communication (see Fig. 8, SCL overview).

In this cycle, the development of the application and the web service structure were started. The RESTful web service uses the HTTP communication protocol to transport data and distribute services. In this manner, any application that supports the HTTP protocol can request the available services. The JSON data formatting standard allows for a lightweight information exchange, *i.e.*, it does not require extensive network bandwidth consumption from both the client and the server.

At this point in the development, the artifact's verification criteria were stipulated so that the devices, the application, and the game must communicate with the web service, being able to both send and receive data. Also, in-game interactions should always generate some feedback being the narrative progression an immediate way of noticing weekly progression.

In addition to the development of the web service, health goals were also stipulated, which are the activities that the SCL should manage and support. In the game, these health goals represent the goals to be met, and as they are fulfilled, progress is made in the game's narrative.

Through the artifact's development process, more concepts were added to the instantiated DSR theoretical framework model, which became more complete with definitions such as health education and treatment adherence, use of IoT in health care, cyber-physical systems, multimodal games, player archetypes, interactive narratives, psychology and behavior, emotion map, and Kubler-Ross model (Kübler-Ross and Kessler (2005)).

These concepts helped to both ground and polish the behavioral conjectures, as shown in Fig. 4:

- People are more motivated to self-care when they know more about their disease;
- People are motivated by seeing progression in their activities and receiving immediate feedback;
- People interact better with technology if it is easy to use;
- People are motivated by ludic elements.

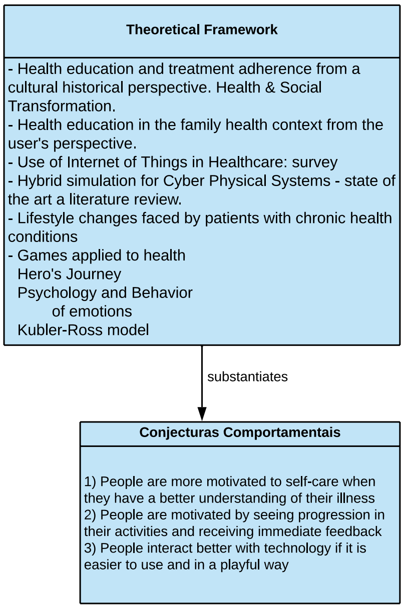

Figure 4. Theoretical framework and behavioral conjectures.

There was also an evolution in the State of the Technique framework by establishing the technologies used in the development such as IoT, pervasive computing and smart devices, RESTful communication protocols and microservices architecture, and game design techniques regarding design, coding, and illustration (Fig. 5).

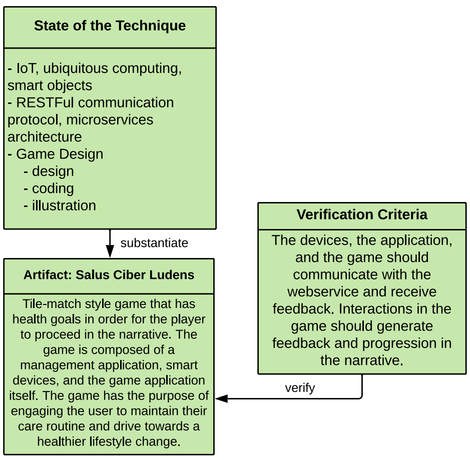

Figure 5. State of the Technique, artifact, and verification criteria.

The game design steps started to be discussed in the first cycle, and were further developed in the second cycle, whose results are presented in Section 4.

3.3 Third Cycle

The third cycle was initiated with further planning of the artifact evaluation, in which two forms of empirical evaluation were defined.

The first evaluation, using the Delphi Method (Wright and Giovinazzo (2000), Alexandre and Coluci (2011)) with judges from the computing and health fields, aims to validate the development aspects and observe if the artifact construction meets objective criteria from both fields.

In the second evaluation, through an intervention study, the target audience will have contact with the produced artifact aiming to evaluate usability issues and whether the objectives were achieved. To this end, questionnaires on Adherence to Systemic Arterial Hypertension Treatment (QATHAS) ((Rodrigues et al. (2014))) and the Hypertension Self-Care Scale will be applied.

Extending the Empirical Evaluation framework presented in the instantiation, the adopted intervention will last six weeks with LHA support. Fig. 6 presents the frameworks linked to the main artifact evaluation.

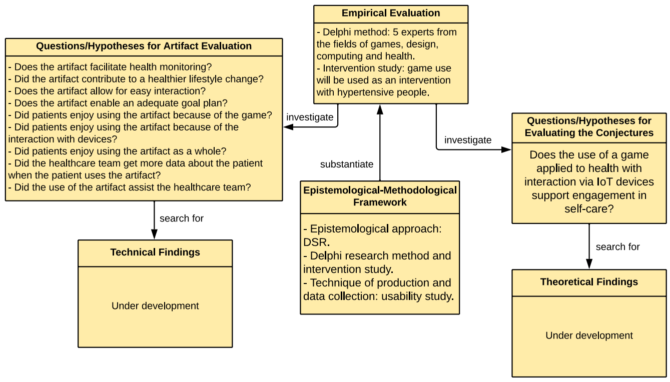

Figure 6. Artifact evaluation questions, empirical evaluation, hypotheses for conjecture evaluation, epistemological-methodological framework, and findings.

Through these evaluations it is possible to extract questions to evaluate the artifact, such as:

- Did the artifact facilitate monitoring the person's health?
- Did the artifact contribute to a healthier lifestyle change?
- Did the artifact enable an adequate goal plan?
- Did patients enjoy using the artifact through smart devices?
- Did the patients enjoy using the artifact as a whole?
- Did the healthcare team obtain more data about the patient when they were using the artifact?
- Did the artifact contribute to treatment adherence?
- Did the artifact support the self-care of the person with hypertension?

Fig. 7 presents the instantiated DSR model, resulting from the composition of the discussed frameworks: problem and context, artifact delimitation, theoretical framework and behavioral conjectures, state of the technique, artifact, and artifact verification and evaluation criteria.

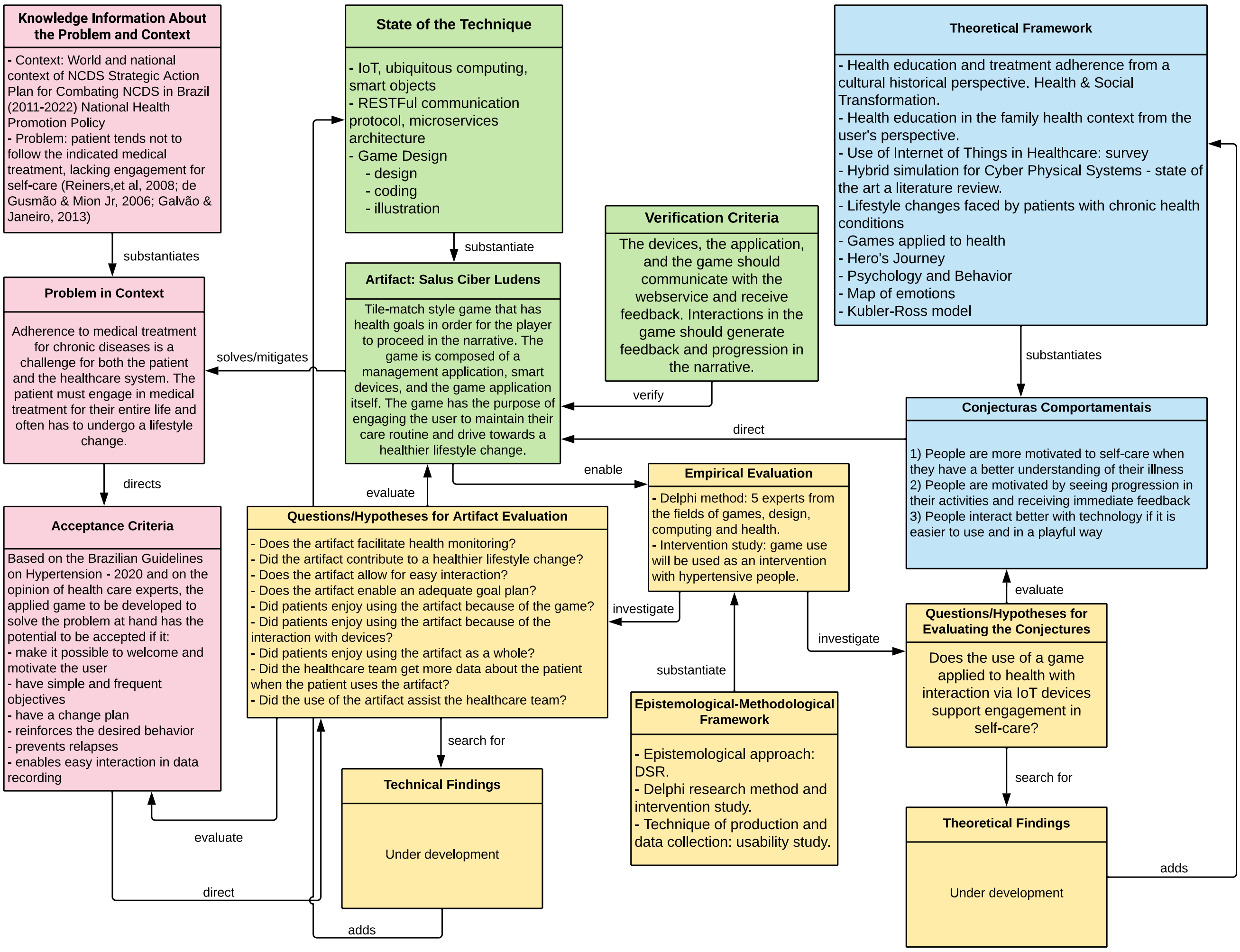

Figure 7. Instantiated DSR Model.

4 Results

This section presents the main artifacts generated using the DSR methodology. Table 2 lists the artifact generated and its type. Following this, each one is detailed.

Table 2. Generated artifacts

Artifact	Artifact Type
SCL Overview	Model
Architecture	Instantiation
Concept of key hypertension parameters by device	Construct
Interaction Flow	Method
Data flow simulation	Instantiation
Game	Instantiation
Goals	Model
LHA patient evaluation	Method

4.1 SCL Overview

Fig. 8 presents the SCL overview, which is composed of three modules: Visualization and Management, Ludic and Motivational, Sensing and Actuators.

The visualization and management module is composed of an application where it is possible to configure the system, as well as make manual records, access statistics, and manage the health goals used in the game.

The ludic and motivational module contains the game itself. This game has its play mechanics to motivate the user. In this case, it is a casual tile-matching game with the use of game narratives that are unlocked as the user achieves their health goals.

The game has as its target audience people newly diagnosed with hypertension and who have been indicated by the medical team to use it. The presented thematic is to reach the storm and get it under control, analogously to the life of a hypertensive person who needs to live with this condition, and having the need to adapt and manage to reduce their blood pressure level.

The game is structured for a six-week duration, in which each week, a set of activities (goals) is presented to the player. For example, in the first week the topic is about the definition of hypertension: through the smart devices, the player will perform weight monitoring, check his blood pressure, and continuously monitor his activities and heart rate. This data changes the character's trajectory within the game, helping the player to engage in hypertension care.

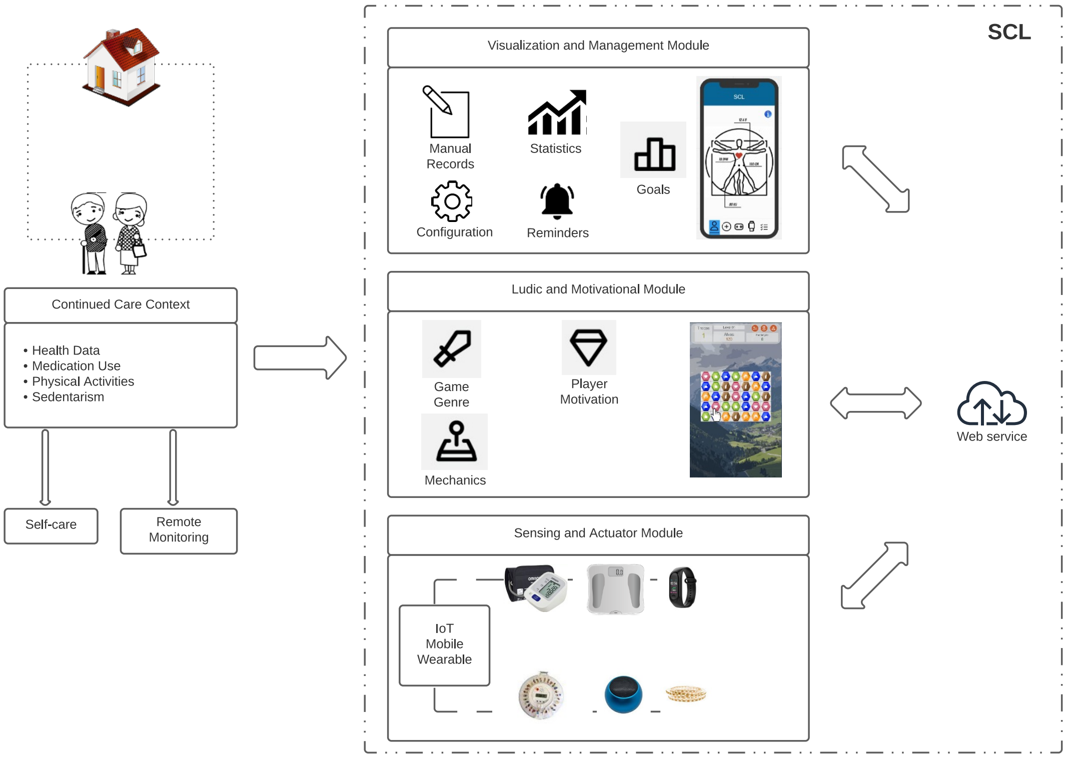

Figure 8. SCL overview.

The sensing and actuator module relies on the smart devices' communication method and their data processing so that they can be used by other modules.

4.2 System Architecture

SCL's Application Programming Interface (API) is based on RESTful Web Service patterns with standardization of the transported data in JSON format. The decision to implement an API aimed at allowing the distribution of data and services in an easy and scalable way, where client applications do not need to be aware of the complexity and processes performed on the server.

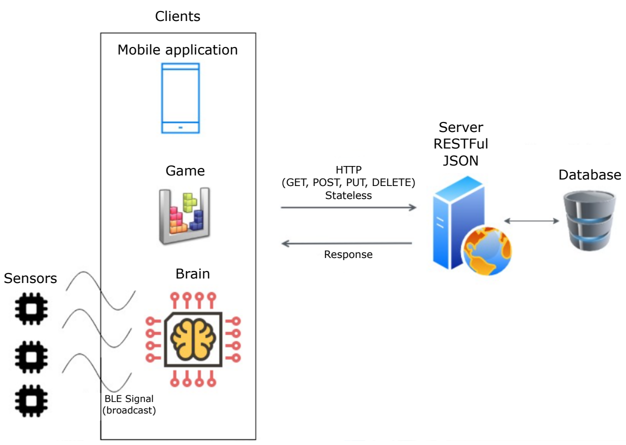

Figure 9. System architecture.

All communication starts with a request from the client side to the server, which can be an application on the smartphone, sensors installed in the patient's home, a browser query, third-party services, and so on. The formatting of the data sent must follow the JSON standards for text formatting in addition to obeying the parameter rules made available in the API documentation. When the server receives the requests it analyzes whether the data received is in accordance with what is expected for the requested service. If everything is in order, the server performs the internal processes of validations/consultations/changes in the database. Finally, a response is sent, in JSON format, to the requesting client, as shown in Fig. 9.

The current planning and development covers three possible types of client software: the mobile application, the microcontroller in the patient's home, and the game. These three client profiles are currently supported, but it is possible to easily adapt to support new profiles. With this in mind, the distributed services can be described as follows:

1. Microcontroller (Brain): To serve this client, only a single service was implemented. The microcontroller context was defined as Brain, since it will be the main point of control and analysis of the received data from the sensors distributed in the patient's home, which will be sent to the Web Service. The communication in this context always starts from some sensor, such as, for example, a Bluetooth Low Energy (BLE) scale, in which the weight measurement value is read and transmitted via Bluetooth. Brain receives the data sent, performs the necessary processing by identifying the type of sensor and how to format the respective message. After the analysis and validation process, the data is sent to the SCL Web Service via the HTTP POST method with the Brain/Value URL. Validations are performed to ensure data security and consistency

as well as performing the persistence processes.

2. Mobile Application: For this context, public and private services were distributed. The public services return public information from the server, such as the WebService version, token release for authentication, server status, among other data. The private services return private data that need authentication (through token) to be accessed, such as, for instance, data from the connected patient, patient's data update, reading performed by the registered devices, among others.

3. Database: Firebird, a relational database management system, was chosen as the management system for the SCL. Patient registration grants the patient access to the application, however without any record of sensors or readings. In order to start treatment and the use of sensors, a contract must be registered with the patient. Thus, it is possible to guarantee the use of sensors only for the patient during the treatment/testing period. Separately, each of the sensors has its own tables for data persistence.

To test the API, a Xiaomi Scale Body 2 that supports BLE communication was used. An ESP32 microcontroller (which supports Bluetooth and Wifi communication) plays the role of Brain. The test performed consisted of having the ESP32 communicate with the scale, receive the data from the device, connect to the server, transmit the data via HTTP POST, and receive the received message response. The server, in turn, makes the access checks to update the database. The API documentation can be accessed by following the link: `https://documenter.getpostman.com/view/7871307/TVCmQPkg`.

4.3 Concept of key hypertension parameters and devices

The key parameters of hypertension represent important data that reflect the patient's care regarding the progress of the disease. With the list of parameters, it was possible to define which types of devices are appropriate for collecting the data.

The devices for measuring parameters are considered to be frequently used by the patients of the League of Arterial Hypertension (LHA), so they should be kept in their homes during the intervention period. In addition, they need to support some communication protocol such as Bluetooth or Wi-Fi (except for the body measuring tape), referred to here as smart devices. Initially, in addition to the data collection devices, it is also planned to use actuators, such as a speakers to play game alerts, notifications, alarms, etc.

Table 3 presents the key parameters and maps the devices needed to collect those data.

4.4 Interaction Flow

Fig. 10 outlines the patient interaction flow. It starts with the patient positioning and connecting the devices at the appropriate location. Next, they access the application and configure the parameters according to their routine care. Then, through the application itself, they access the game and interact in both ways (mobile phone interface and device interface).

Table 3. Parameters and devices

Parameters	Devices	Controls
Blood Pressure	RBPM	Pressure
Body mass index (weight and height)	Scale	Body mass
Abdominal circumference	Tape measure	Body mass
Heart rate	Smartband	Sedentarism
Number of steps	Smartband	Sedentarism

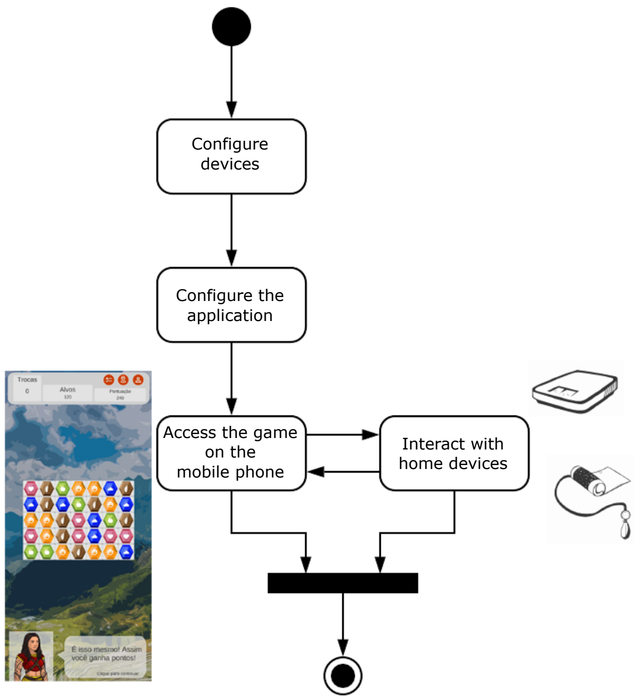

Figure 10. Interaction flow.

4.5 Data Flow Simulation

A simulation environment based on the discrete-event system modeling formalism (DEVS) (Zeigler et al. (2018)) uses events that represent both continuous and discrete processes. Since both the microcontroller and the web service were not yet defined, it was decided to experiment with a Publisher/Subscriber architecture (Schmidt and O'Ryan (2003)).

This simulation focused on monitoring the data mapping collected from the patient, the trajectory of that data, and the game's feedback action. The modeled scenario in the simulator describes the situation where a patient is using, at first, only a weekly scale and beacons[1] that return his indoors location, in real-time. These sensors access the cloud, using the publisher/subscriber architecture, where each sensor is a publisher of content in the cloud (which stores its last measurement), and the other elements of the system are the subscribers who register their interest in the corresponding topic,

[1] Beacon is a type of device that periodically transmits Bluetooth (Bluetooth Low Energy (BLE)) packages with data identification that contains information used by the receivers.

receiving notifications when there is an update on the topic. The system (which represents the mobile app) is responsible for the subscriptions in the cloud and uses this data to monitor the patient's data, as well as being responsible for configuring the patient's health care and sending commands to the actuators distributed around the house. The game is responsible for reading the information from the sensors through the application, configuring all the gameplay, and sending commands to the system so that it can communicate with the actuators.

In the simulation, the patient must stay in the weight range between 70Kg and 85Kg. If they leave this range, the game presents a message and adds a task related to reducing or increasing weight in a healthy way. As for the gameplay on the smartphone, a timer is presented in the game in order to make the game more difficult and convey the feeling of time pressure. As the patient completes the tasks, the speaker plays a voice that encourages the patient to continue their self-care through the narrative of their journey. When the patient manages to stabilize their weight for a certain period of time, a safe automatically opens, allowing the patient to pick up their reward (which they have previously placed in this safe).

4.6 Game

The game is the main artifact of the SCL platform, whose ludic module is essential to engage the patient in hypertension care. This section presents the game's overall concept. The narrative is what unifies all the other elements and delivers value to the patient's experience.

1. Premise: "The game tells a legend of the Dara people, who, blessed by nature, lived in abundance. On a certain day, the whole village noticed that very dark clouds appeared beyond the mountains. A terrible storm formed, bringing chaos to the small village. Thus begins the protagonist's journey to save their people. In this adventure, they go through challenges that include caring for the body, the mind, and nature. Only then will they have enough strength to be able to save their people."

2. Player motivation: Along the way, the patient encounters tile-matching style puzzles. The victory condition is to reach the storm and be able to control it (a metaphor that is closely related to self-care). Performing the self-care activities influences the game (by changing the difficulty, mandatory tasks, and alerts), as well as causing events in the actuators distributed throughout the house. For example, if the patient needs to take a blood pressure measurement, the speaker will play the voice of the protagonist that will indicate to the patient that it is time to use the RBPM and that by performing this activity, the character will feel more able to continue his journey. Then, when the person enters the game again, they will receive notification of their action.

3. Differential: It is a game applied to health that uses the home as a means to play. So, besides participating in the legend of the Dara people, the patient is also being engaged in taking care of their own health.

4. Target audience: People with hypertension.

5. Game genre: Casual, tile-matching puzzle style with narrative.

6. Target platform: Game intended for mobile devices for accessibility and availability reasons. An internet connection is required to communicate with the server.

It is worth pointing out that the mechanics of the tile-matching game was chosen after studies about casual games and the adult audience, and, mainly, for the ease of learning the mechanics. Moreover, the success of other games in the same genre, such as Candy Crush, may attract the audience by the gameplay similarity.

Another point to note is the game progression. While one can have fun in tile-matching, combining the elements, multiplying the score, unlocking new animations, and having a more aesthetic experience, the real progress of the game happens through the narrative. If the patient meets their weekly goals, then each week parts of the narrative will be revealed, for a total of six weeks of intervention, six phases and six narrative snippets, as shown in Fig. 11.

Figure 11. Game stages.

Fig. 12 shows some screenshots of the game. The first and last images show a dialog, the second one shows the tile-matching and the third one shows an opening game cutscene.

In the tile-matching interface, the player must select (by dragging his finger) the runes (colored elements) on the screen, so that the combination of three or more identical runes accumulate points. The runes symbolize the possible combinations of Levi's (the protagonist) strengths, so that she earns points and unlocks different animations. The yellow rune represents care about to the mental state; the green rune, care with food; the blue rune, the importance of sleep; the brown rune represents the importance of contact with nature; and the red rune, health as a whole.

To validate this conception before the game coding stage, a questionnaire was applied to five specialists in the fields of

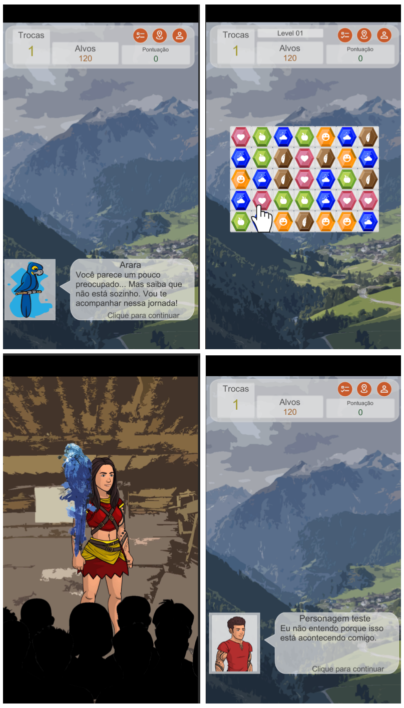

Figure 12. Some game screenshots, representing the tile-matching, dialogs and narrative video.

communication, game design, and computing. The objective of this questionnaire was to verify the ease of understanding of the game's storyline and its suitability for the target audience.

The quantitative result of this questionnaire indicates that the game is suitable for the audience and that the storyline is contributing to the promotion of self-care and that is easy to understand. As for the characters, it would be interesting to use non-binary genders. The qualitative results also showed that the storyline needs to better specify the challenges faced by the protagonist and present more figures for interaction.

4.7 Health Goals

The health goals have been validated by the health professionals, who review the weekly activities and their progression. Based on the themes defined by an LHA researcher, the health goals come as a way to encourage the person to do certain tasks and get oriented to certain matters, as shown in Fig. 14.

In this validation, considering the target audience, the health professionals found: (a) the patient should have two blood pressure recordings per week for blood pressure control; and (b) the patient should have weight recording only in the first, third, and sixth week so that the patient has weight control, but without causing anxiety.

For example, on the first day, with a health professional at the LHA, the patient will log their medications, weight, and height into the application. At home, they will have help setting up the devices. These first records are already part of the goals of the first week. The theme this week is "What is high blood pressure?", so the patient will receive three mobile phone notifications explaining about high blood pressure. In addition, on two days of the week, the patient will be asked to take blood pressure measurements at home. In the second week, the theme is "Reducing sodium consumption". During this week the patient will be introduced to the alarms that indicate when to take their medication. Also, they will have to take two blood pressure measurements and will receive two notifications about this topic. And so on.

After the goals are validated, a positive reinforcement map will be structured to support the individual in accomplishing these activities. This reinforcement map characterizes the achievements through a hierarchy of medals (achievements), which bring a sense of progress and positive reinforcement.

4.8 Evaluation method by LHA patients

The evaluation by LHA patients was planned according to Fig. 13.

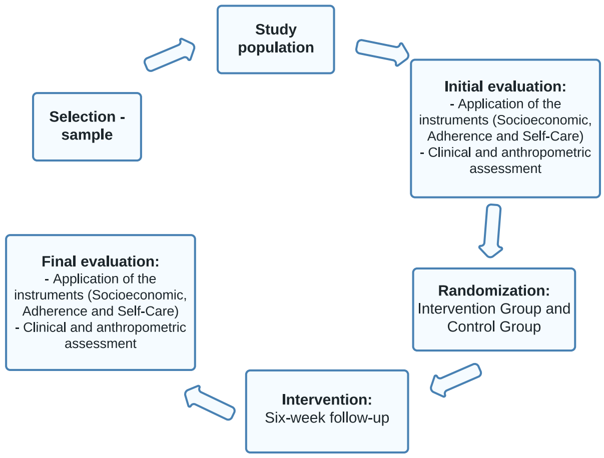

Figure 13. Evaluation scheme by LHA patients.

The sample size was calculated considering a two-sided significance level at 95%, power of the test at 80%, and inter-group ratio of 1:1 with estimated success of the intervention at 70%, and adding 10% on top of the calculated value for possible loss to follow-up. The final calculated number was 31 participants in each group. Results were calculated using OpenEpi, Version 3, open-source calculator – SSCohort.

The participants for the Intervention and Control Groups will be selected according to the eligibility criteria and prior consultation on the list of patients with weekly appointments at the LHA.

The selected participants will be randomized into the two groups (intervention and control).

The intervention will take place over six weeks, where the intervention group will use the SCL and the control group will maintain their normal hypertension care routines.

The final evaluation will occur with the application of the hypertension self-care scale, Systemic Arterial Hypertension treatment adherence questionnaire - QATHAS (Rodrigues et al. (2014)), socioeconomic questionnaire, and clinical and anthropometric evaluation.

5 Discussion

Conducting our research using DSR allowed us to consider that this methodology can be applied in research where there

Week 1	Week 2	Week 3
What is high blood pressure?	Sodium consumption reduction	Body weight reduction
Drugs registration	Use medication alert x1	Use medication alert x1
Blood pressure measurement x2	Blood pressure measurement x2	Blood pressure measurement x2
Guidance on blood pressure x3	Guidance on sodium consumption x2	Guidance on nutrition x3
Weight registration x1		AC registration x1
Height registration x1		Weight registration x1

Week 4	Week 5	Week 6
Sedentarism	Smoking	Stress
Use medication alert x3	Use medication alert x2	Use medication alert x3
Blood pressure measurement x2	Blood pressure measurement x2	Blood pressure measurement x2
Physical activity recording	Heartbeat recording x1	Heartbeat recording x1
Heartbeat recording x1	Guidance on nutrition x1	Guidance on nutrition x1
Guidance on nutrition x1	Guidance on sedentarism x2	Guidance on sedentarism x2
Guidance on sedentarism x2	Guidance on smoking x2	Guidance on blood pressure x2
		AC registration x1
		Weight registration x1

Figure 14. Health goals by week and theme.

is a focus on the development of an artifact to solve some problem, suiting applied computing research.

The use of the DSR methodology in the development of a game applied to health, such as the SCL, is meeting the requirements both for research and related to the development of the technology itself. However, it is noteworthy that for this purpose it would be more practical to incorporate some elements from the body of knowledge of the game design field.

As a suggestion to facilitate the use of the DSR methodology in game development, the researcher can choose a game design framework, such as the Elemental Tetrad (Schell (2015)), and add four rectangles that connect to that of the Artifact (see Fig. 7 of the instantiated DSR model): Aesthetics, Mechanics, Narrative, and Technology. Thereby, the researcher has a starting point from the game design perspective to anchor on.

As for the game being applied to a certain area, it is something well defined in the context of the DSR methodology, especially well detailed in the part of knowledge about the problem, context, and the acceptance criteria. What could be improved in this aspect is in relation to the target audience, that is, working with more specificity to who is the audience of this artifact and what are their characteristics within this context.

From a software engineering perspective, there is a symbiosis generated by the cycles and even a certain similarity of processes in the use of the DSR methodology and agile development techniques, which are applied to game development. However, caution should be exercised when instantiating the model in order to avoid neglecting the theoretical foundation.

The use of this methodology allowed some contributions regarding the architectural vision of the SCL platform and how to generalize it to understand and improve the communication of IoT devices. Hence, this work brought the opportunity for research focused on this theme. In addition, the research brought questions about the techniques of game development applied in the context of health. With this subject, there was a deeper investigation of the use of Schell's Tetrad framework and the SCL, published in SBGames 2021 (Oliveira et al. (2021b)).

In general, it was also possible to develop a mentality in Design, provoking several reflections not only in the practical, but also in the scientific domain. Based on the conduction of the research, these were the main reflections regarding the progress and next works to be carried out:

- creating a gaming platform for different types of players with different motivations;
- study on how to advance in usability of smart devices in games;
- study on how to add more characters participating in the system, adding value for health professionals and family members in the monitoring;
- study on how to expand the system for use in other diseases and the consequent modularization of the system.

Thus, bringing back the duality between "Science" and "Art", it was possible to observe that the scope of science portrayed *Why does it work?*, *What underpins it?*, *What impacts it?*, *How does it relate?* and *How is this validated?*, while the scope of art portrayed *How does it work?*, *How is it built?*, *Who is it built for?*.

6 Conclusion

This paper presented the DSR methodology by reporting on a research development of the SCL applied health game. Each step of the development process was addressed, from the instantiation of the DSR model to the conceptual process of the health part and the game in each development cycle.

Following this, there was a brief discussion about adaptations that the DSR model could have for research with a focus on game design for applied game development, taking into consideration the expertise in the field.

The many built artifacts together with the theoretical justifications used to support them in a systematic development flow and validated by professionals in the field, and by the target audience in order to test the hypothesis established by the research, makes it interesting to use the DSR methodology for research in the area of applied computing.

The work is at the end of the second cycle, which is focused on the development of the artifacts and their individual evaluation. The next cycle, the third, will start the process of evaluating the integration of these artifacts that make up the main artifact, the SCL.

It is worth noting that in a world that is increasingly connected and reflected in the digital one, such as the popularization of the metaverse, the science of the artificial is strong and growing. Thus, there must be an adaptation of the way of doing science that is useful and produce artifacts that add knowledge.

Therefore, we conclude that the balance between "Science" and "Art" results in innovative works that is in demand for production.

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References

Alexandre, N. M. C. and Coluci, M. Z. O. (2011). Validade de conteúdo nos processos de construção e adaptação de instrumentos de medidas. *Ciência & Saúde Coletiva*, 16(7):3061–3068.

Bayrak, A. T. (2020). Compassionate game design: A holistic perspective for a player-centric game design paradigm for games4health. *International Journal on Advances in Intelligent Systems*, 13(1):1–18.

Cota, T. T., Junior, N. V., and Ishitani, L. (2014). Impacto do gênero de jogo digital na motivação dos idosos para jogar. *Simpósio Brasileiro de Jogos e Entretenimento Digital*, 13(2014):361–368.

de Oliveira Santos, L. G. N., Ishitani, L., and Nobre, C. N. (2013). Uso de jogos casuais em celulares por idosos: um estudo de usabilidade. *Revista de informática aplicada*.

Denning, P. J. (2005). Is computer science science? *Communications of the ACM*, 48(4):27–31.

Dresch, A., Lacerda, D. P., and Júnior, J. A. V. A. (2015). *Design science research: método de pesquisa para avanço da ciência e tecnologia*. Bookman Editora.

Gelain, A., Watanabe, A. T. Y., Fouto, M. S., Bosse, R., and da Silva Hounsell, M. (2014). Uma breve história da computação aplicada no brasil. *Revista Brasileira de Computação Aplicada*, 6(2):123–135.

Kübler-Ross, E. and Kessler, D. (2005). *On grief and grieving: Finding the meaning of grief through the five stages of loss*. Simon and Schuster.

Leitao, T., Ferreira da Silva, F., and Xexéo, G. (2021). Análise de métodos de design de jogos sérios sob a ótica da design science research.

Muñoz, J. E. and Dautenhahn, K. (2021). Robo ludens: A game design taxonomy for multiplayer games using socially interactive robots. *ACM Transactions on Human-Robot Interaction (THRI)*, 10(4):1–28.

Oliveira, L. and Carvalho, S. (2017). Gamificação como estratégia para promover self-care e engajar pacientes: Uma revisão sistemática da literatura. In *SBGames 2017*.

Oliveira, L., Oliveira, S., de Lima Vieira dos Santos, S., and Carvalho, S. (2021a). Desenvolvimento de um jogo para hipertensão utilizando a metodologia design science research: equilibrando a ciência e a arte. In *SBGAMES 2021*.

Oliveira, S., Oliveira, L., Carvalho, S., and de Lima Vieira dos Santos, S. (2021b). Técnicas de design de jogos, saúde e iot - uma análise de um jogo autoral aplicado para o autocuidado da hipertensão. In *SBGAMES 2021*.

Pakarinen, A. and Salanterä, S. (2020). The use of gaming in healthcare. In *Developing and Utilizing Digital Technology in Healthcare for Assessment and Monitoring*, pages 115–125. Springer.

Peffers, K., Tuunanen, T., Rothenberger, M. A., and Chatterjee, S. (2007). A design science research methodology for information systems research. *Journal of management information systems*, 24(3):45–77.

Pimentel, M., Filippo, D., and Santos, T. M. (2020). Design science research: pesquisa científica atrelada ao design de artefatos. *RE@ D-Revista de Educação a Distância e eLearning*, 3(1):37–61.

Reis, P. (2019). Ciência do artificial e design science research.

Rochadel, W. (2016). As ciências do artificial em uma abordagem entre o conhecimento e a tecnologia. *Seminário de Pesquisa, Pós-Graduação e Inovação*.

Rodrigues, M., Moreira, T., and Andrade, D. (2014). Elaboração e validação de instrumento avaliador da adesão ao tratamento da hipertensão.

Schell, J. (2015). *The Art of Game Design: A Book of Lenses*. CRC Press, 2nd edition.

Schmidt, D. C. and O'Ryan, C. (2003). Patterns and performance of distributed real-time and embedded publisher/subscriber architectures. *Journal of Systems and Software*, 66(3):213–223.

Simon, H. A. (1980). Cognitive science: The newest science of the artificial. *Cognitive science*, 4(1):33–46.

Souza, C. H., Oliveira, D., Berreta, L., and Carvalho, S. (2021). Jogos digitais e engajamento na reabilitação de pacientes: Uma revisão sistemática da literatura. In *Anais do XXI Simpósio Brasileiro de Computação Aplicada à Saúde*, pages 25–36, Porto Alegre, RS, Brasil. SBC.

Souza, G. R. and Trevisan, D. G. (2014). Estudo investigativo sobre idosos, jogos e sua motivações. *Cadernos de Informática*, 8(3):35–40.

Wright, J. T. and Giovinazzo, R. A. (2000). Delphi: uma ferramenta de apoio ao planejamento prospectivo. *Caderno de pesquisas em administração*, 1(12):54–65.

Zeigler, B. P., Moon, Y., Kim, D., and Ball, G. (1997). The devs environment for high-performance modeling and simulation. *IEEE Computational Science and Engineering*, 4(3):61–71.

Zeigler, B. P., Muzy, A., and Kofman, E. (2018). *Theory of modeling and simulation: discrete event & iterative system computational foundations*. Academic press.