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ORIGINAL RESEARCH

System Thinking in Gamification

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Abstract

People spend a lot of time and energy playing videogames (Kapp in The gamification of learning and instruction: game-based methods and strategies for training and education. Pfeiffer an imprint of Wiley, San Francisco, 2012), and as a result, gamification has grown from a buzzword into a discipline. Since 2012, the authors have experimented with system thinking as a methodology for developing gamification and will present examples in this article. The primary objectives are to study how system thinking can be used to understand, design, develop and document gamifications, and how psychology and pedagogics can be integrated in the process to enhance the learning. This is an observational case study that gives examples of how students (i) use system thinking to understand and clarify the gamification case using system analysis and (ii) use system dynamics to simulate cases and predict user responses. Students begin system analysis once the gamification idea is developed and their goals and the case parameters are established, and it includes making casual loop diagrams, flow charts, and reference behavior patterns. Students then find and experiment with numerical data for the case and use system dynamics to simulate the gamification and predict the user results. The pedagogy is problem based and grounded in traditional problem-based learning and situated learning. This article shows how system thinking allows students and professionals to develop a deeper and more tangible understanding of the research materials and presumptions they have when engaging in any given gamification scenario. System thinking also provides tools to test research material and hypotheses in a more structured, manageable, and palpable way. Although we have discovered several ways system thinking can benefit gamification design, the research has also revealed new areas where system thinking could be explored further.

Keywords Gamification · Serious games · Game development · Games and learning · Pedagogy · System thinking

Introduction

Gamification stems from the idea that game mechanics and game thinking can be utilized for goals other than creating entertainment and fun. Games employ structures, tasks, and rewards that can be used outside games to change human behavior and motivation and to help reach non-trivial goals. Gamification can create new ways to engage users, target new user groups, and motivate them to achieve goals they have or did not know they had [2]. The goal of gamification is to promote learning, engagement, motivation, and change behavior in a positive way [1]. The idea of gamification has been fueled by the proliferation of smartphones, social media, the internet of things, and the popularity of videogames.

The culture of the gamer has now permeated every age group; people spend a lot of time playing videogames, on many different devices [1] and the vocabulary of videogames is familiar to a big portion of the population. Yet, gamification is a relatively new field of study and as a discipline can be strengthened with scientific methods that can help design and test the development of different gamifications applications.

Designers must be able to predict how the user will react to and is motivated by the different components of the gamification. As gamification uses game-based mechanics, thinking, and esthetics, the user must engage with a system that is going to provoke extrinsic rewards and lasting intrinsic motivation that will result in some kind of quantifiable outcome [1].

System thinking can help predict and simulate the multitude of outcomes and reactions the gamification can create.

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It can give more insights into individual cases, and to some extent it can even estimate how motivation and learning will develop when someone is using the gamification. It can also help target the type of motivation that needs to be stimulated to reach an application's goals.

Gamification

Using different engagement models and reward systems to create learning, motivation, and behavior changes is nothing new—it has been done for decades in schools, sports, businesses, the military, and the advertising industry [3]. However, unlike these earlier applications, gamification fuses game thinking, game culture, and digital technology, and new ways of learning, engagement, and motivation emerge. This fusion ushers in new ways of fostering learning, engagement, and motivation, leading to a transformation in how individuals interact with tasks, challenges, and goals. The word "gamification" is often considered to have been coined by Nick Pelling in 2002 [2]. But it was Jane McGonigal's 2011 book, "Reality is Broken," that popularized the idea of gamification as a tool [4]. So, what defines gamification? One short definition is that gamification is the use of game design elements in non-game contexts [3]. Another more elaborate definition asserts that "Gamification is using game-based mechanics, esthetics, and game thinking to engage people, motivate action, promote learning, and solve problems" [1]. The overarching goal of gamification is to make activities fun and engaging by introducing game mechanics but also to harness the inherent engagement people experience when playing games in areas other than entertainment.

In gamification, one can motivate not only through rewards (extrinsic motivation), but also through fostering inner motivation that can change the user's behavior permanently (intrinsic motivation) and enable the user to reach goals she could not reach on her own [1]. In the realm of gamification, motivation takes on various forms. It can stem from extrinsic rewards, where individuals are motivated by external incentives [5, 6]. However, gamification also has the potential to nurture intrinsic motivation, which prompts lasting behavior change within users. This intrinsic motivation not only influences behavior but also empowers individuals to achieve goals they might have deemed unattainable on their own [1]. As a growing discipline, gamification uses knowledge and research from other fields, including game design, pedagogy and didactics, psychology, and interaction design [7]. This multidisciplinary approach fuels the evolution of gamification by infusing it with insights from a variety of domains. But as a new discipline, it also needs to develop methods to design gamification applications.

One promising avenue for developing foundational knowledge about gamification design is through system thinking. By comprehending the various components of a game and delving into the formal theories and definitions of games, this approach facilitates the creation of gamified experiences that align with desired player experiences. System thinking can be a useful tool for developing the basic knowledge of game design—understanding the different components of a game as well as the formal theories and definitions of games—that underpins successful gamification design, and thus facilitates the creation of gamification applications that give the users and producers the desired experience and outcome.

State of the Art in Gamification Design

Gamification design often builds on a traditional game design development process, and although gamification development has moved beyond the days of simply adding rewards to induce player motivation, the design process is often linear (Fig. 1. below). Normally, a video game production consists of specific phases that have become reasonably standardized, although the names used may vary somewhat [8–10]. Game development is often divided into three phases, which are also found in many other types of media productions: pre-production, production, and post-production [11–14]. During pre-production, developers established the foundation for the game's creation. This phase includes conceptualizing the game, defining core mechanics, establishing artistic direction, and planning the project's scope. Creative teams brainstorm ideas for the game's story, mechanics, gameplay features, and visual style to define its unique selling points [15]. Market research is conducted to analyze trends, understand target audience preferences, and assess competitor games to identify opportunities and ensure the game's viability. Prototypes are created to validate core gameplay mechanics and concepts, gathering feedback early in the process [16]. The production phase is where the actual game development occurs. Teams work on coding, art creation, sound design, and level design to bring the game to life. Programmers write code to implement game mechanics, user interfaces, artificial intelligence, and other technical aspects [12]. Artists produce character models, environment assets, textures, animations, and other visual elements defining the game's esthetic [9]. Sound designers and composers enhance the immersive experience with background music, sound effects, and voiceovers [17]. In the post-production phase, the focus shifts to refining the game, rigorous testing, and preparing for release. Quality assurance (QA) testing is crucial, where testers playtest the game thoroughly to identify bugs, glitches, and gameplay issues for resolution. Developers refine gameplay, graphics, and other aspects based on QA feedback and user testing [16]. The game is translated into different languages, and the final version is prepared for distribution across various platforms [3].

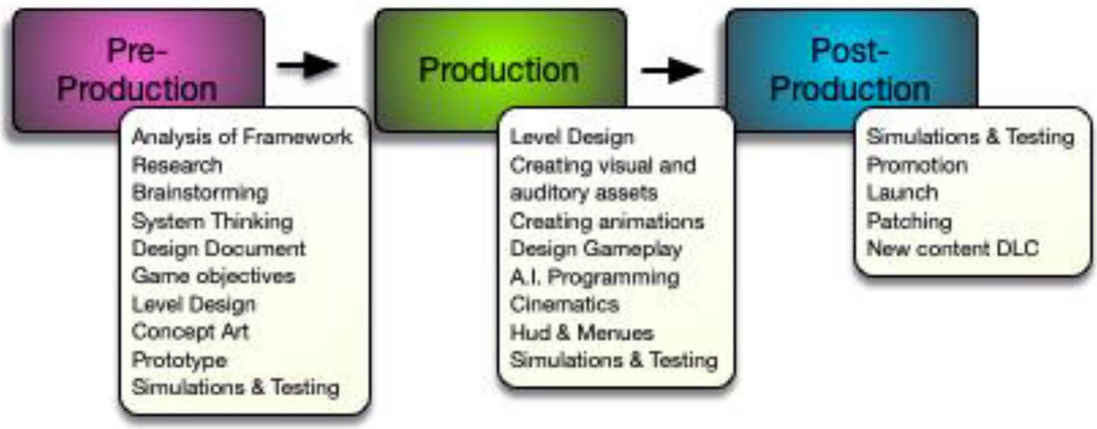


Fig. 1 Traditional game design

While gamification design shares similarities with traditional game development, it distinguishes itself by focusing on enhancing services or products to achieve specific objectives. A gamification project typically begins with the owners' desire to reach specific objectives. Achieving these goals often involves analyzing user behavior and preferences, which then informs the translation of these objectives into actionable game-design elements that constitute the final gamification product or service [18]. Notably, while pedagogics and psychology may be considered during the design process, they are rarely integrated into gamification design with scientifically proven methodologies. This is where our project comes into play. We employ system thinking to integrate game design, psychology, pedagogics, and technology through system analysis and simulation. This approach underscores the significance of feedback loops as an integral part of the design process.

The innovation in our project lies not in inventing new tools but in leveraging existing ones in novel ways. By adopting this holistic and systems thinking-based approach, we aim to bridge the gap between traditional game development and the ever-evolving field of gamification. This approach ensures that gamification products are not just superficial add-ons but are thoughtfully designed to meet specific objectives and engage users effectively.

By integrating diverse disciplines and leveraging system thinking, we pave the way for more sophisticated and impactful gamification experiences that can drive meaningful user engagement and behavior change in various contexts.

System Definitions and Knowledge Gaps

Our definition of system science and system thinking is based on definitions from our book, “System Thinking, System Analysis, and System Dynamics” [19]. System science is defined as the science of system thinking, system analysis, and system dynamics. System thinking is about understanding causal relationships and how a cause results in an effect and how the effect may have feedback on the cause [19–24] define system thinking as a set of synergetic analytical skills used to improve the capability of identifying and understanding systems, predicting their behaviors, and devising modifications to them to produce desired effects. These skills work together as a system. System analysis is a conceptualization from which a qualitative understanding of the logic of the systems is built, while system dynamics is about building a quantitative model of the system that is used to simulate the system.

We believe there are several knowledge gaps in the field of gamification development. First, we believe that the design of gamification can be strengthened scientifically by introducing well-known and proven scientific methodologies into the pre-production phase. Second, connecting gamification to motivational psychology can strengthen the credibility of the design and its goals in this phase [1]. Third, we believe that being able to simulate the use and interaction of the gamification before starting the production phase can save development time and money. This must be verified by further research (see Fig. 2).

Scope and Objectives

This article discusses how we use system thinking in several ways in connection with gamification. Two student projects from a course that focuses on the pre-production phase of gamification development will be given as examples. In this course, students do not create a finished gamification application but rather a prototype based on

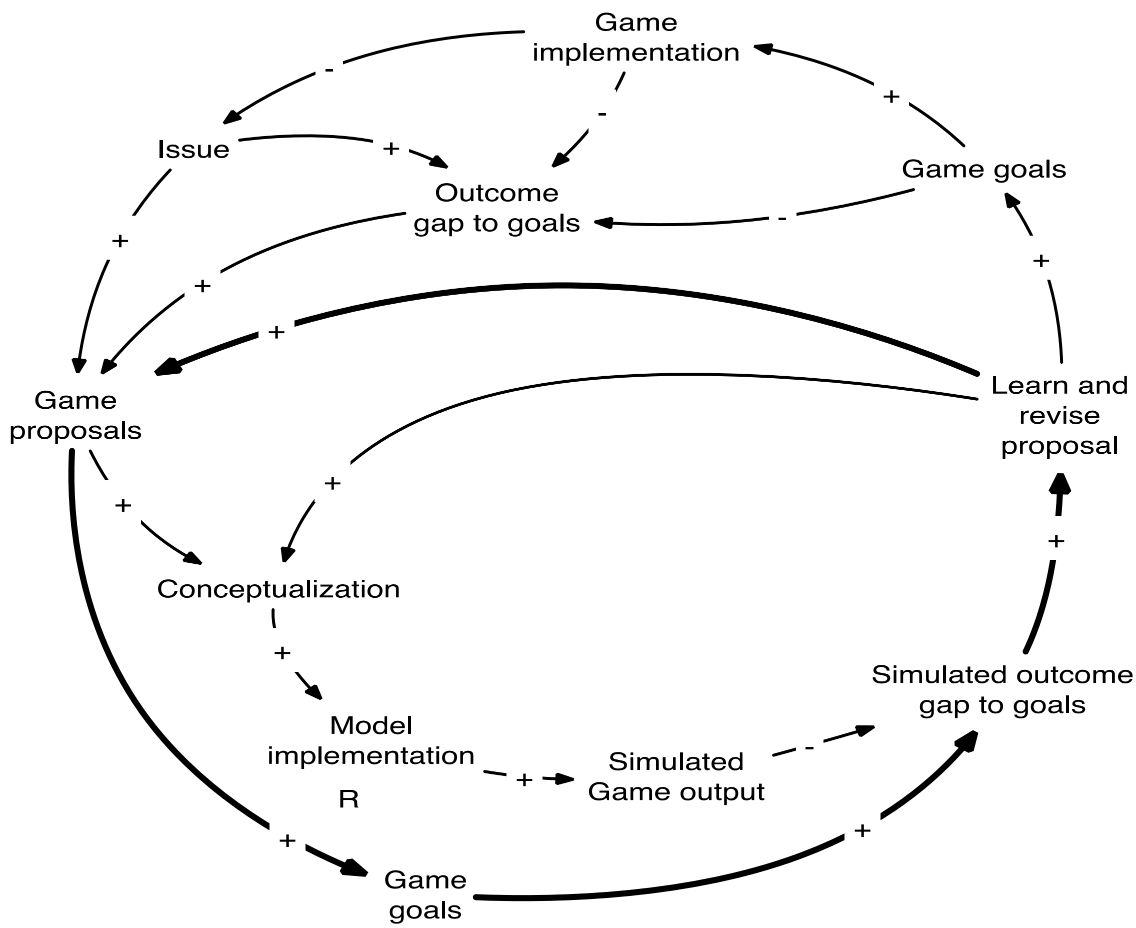


Fig. 2 Illustration of how the gamification is simulated and tested before they are implemented. It all starts with the Game proposal. In Simulated outcome gap to goals, the simulated design is checked against the Game goals to verify if our design works. If it does not, we go back to Conceptualization or the Game proposal to revise and simulate again. This can be done many times. When the result is satisfactory, we move to the top of the CLD and implement the game. There we compare the implemented version to the goals and, if necessary, go back to the Game proposal and modify it

psychology, system thinking, analysis and dynamics, and specific design choices. The article will not discuss the production and post-production phases of the gamification app in any depth.

Research Questions

The article discusses how system thinking can be used to understand, design, develop, and document the process of gamification, and how psychology and pedagogy can be used to enhance the learning process. The research question is: "How can system thinking be used to understand, design, develop, and document the process of gamification, and how can psychology and pedagogy be integrated into the process to enhance learning?".

Data Collection and Analysis

The research methodology used in student projects is Action Research. Both the research and the data collection are situational, practical, systematic, and cyclical, and the result of each cycle is constructivist in its implementation [25]. The collected data include student assignments and reports, meeting summaries, teacher notes from student presentations, and so on. These data are analyzed and discussed both during the course and afterward and form the basis for immediate changes or justifications of the course design and implementation. Whenever possible, system analysis is used to clarify and make sense of the results. The use of system thinking and action research has, over the years, spread into several courses and topics/disciplines in the game school, such as gamification, game design, programming, and others, and today is a form of collaborative action research.

Theory

System Thinking

System thinking is a concept and language that helps substantiate and explore how causal relationships and feedback work within a system. It has two components: system analyses and system dynamics simulations. System analysis is a qualitative way of describing connections, causalities, and feedback in a system, while system dynamics is a numerical simulation of the system. System analysis includes group modeling—stakeholders' interests and connections are mapped by finding shared questions for the problem, drawing flowcharts, and making a causal loop diagram (CLD). The CLD is the most important tool and shows causes, effects, and feedback in the system and how they are interconnected. An example of a CLD is shown in Fig. 3.

This drawing shows a simple CLD in which a cause produces an effect. An arrow links the cause to the effect. The plus sign (+) indicates that the cause increases the effect. The effect provides feedback on the cause, which is illustrated with an arrow leading from the effect back to the cause. The minus sign (–) here indicates that more of the effect will weaken the cause. The system has two loops: balancing (B) and reinforcing (R).

System dynamics is a numeric simulation of the system analysis results. In our project, we use STELLA Architect for the system dynamics simulation. Figure 4 shows the simulation of the CLD in Fig. 3.

The effect influences the inflow through the feedback loop to the cause. The cause also influences the value of the effect through the outflow. More about system thinking can be found in Senge [22], Sterman [23], Haraldsson and Sverdrup [24], and Sverdrup and Svensson [26].

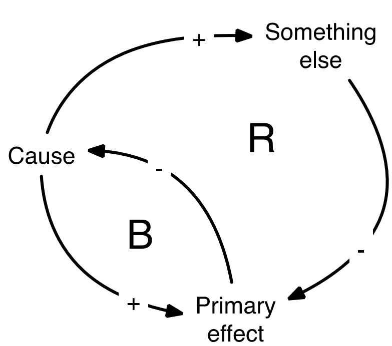


Fig. 3 An example of a causal loop diagram (CLD)

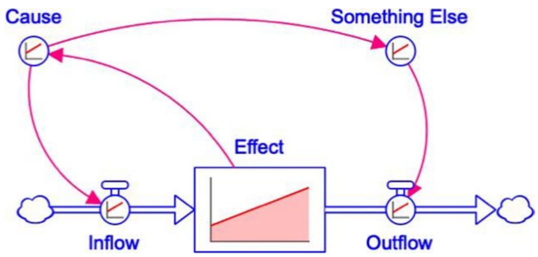


Fig. 4 Realization of the causal loop diagram

Gamification Psychology

Gamification is about creating motivation. It normally begins with extrinsic motivation, with the goal of creating permanent intrinsic motivation. Proven and tested psychological models exist that can be used to better understand how extrinsic and intrinsic motivation are created—the student examples discussed here not only focus on the ARCS model and the self-determination theory (SDT) [1], but also occasionally use other theories such as Malone [27] and Lepper [1]. As the ARCS and SDT models are the most widely used in the student examples, we will briefly introduce them below, building on Kapp's explanation of the model [1].

The ARCS model is a four-factor model developed by John Keller [28]. ARCS stands for *attention*, *relevance*, *confidence*, and *satisfaction*. Many of these elements have applications for gamification and motivation and can be applied to various aspects of gamification and game-based learning. Attention addresses gaining a learner's interest in the content through various means. Perceptual arousal draws learner attention through specific, relatable examples. Inquiry arousal stimulates curiosity through questions or challenges posed to the learner. Roleplay or hands-on experience also falls under this rubric. Relevance can be established by using goal orientation that describes how the goal will help the learner by illustrating the importance of reaching the goal [1]. Similarly, the learner gains confidence when they achieve success. Satisfaction is about learning having value and being worth continued effort. That is, the learners should be given the opportunity to successfully apply their new knowledge and skills in a real or simulated setting so they can see what they have learned being applied. Additionally, variability is about varying the delivery method periodically to maintain the learner's attention [1]. Positive encouragement and reinforcement keep them motivated throughout the learning process—it is important to try to tap into the intrinsic and not only the extrinsic motivation of the learners.

According to the self-determination theory (SDT), human motivation to perform a task or activity is internally driven as opposed to externally driven. SDT can be used to describe how and why motivation is facilitated or undermined in diverse human activities such as sports, education, healthcare, work, and religion. The theory also proposes that events and conditions that enhance a person's sense of autonomy and competence support intrinsic motivation and, on the other hand, factors that diminish perceived autonomy or competence undermine intrinsic motivation. SDT focuses on three elements: autonomy, competence, and relatedness.

Case Methodology

In our classes, students construct their gamification projects within one of three categories: Learning, Health, and Sustainability. The project assignment is divided into three parts: (1) project analyses through system thinking, (2) design of the gamification prototype, and (3) writing the project report. Continued progress on the projects is fostered by requiring students to present their work to the class at regular intervals and by receiving comments and feedback from peers and teachers. The students also regularly write blogs detailing their progress and seek out feedback and advice in online forums and from peers.

Teaching methodology in the gamification course is loosely based on problem-based learning (PBL). PBL originates from the novel instruction model implemented in medical education in the late 1960s by Howard Barrows and his colleagues [29]. PBL was originally conceived as a student-centered learning model in which students solved real-world problems in groups. This approach is also our focus; we want our students to learn to solve real-world problems and practice the methodology they are taught. During this phase, they also find and study the theory they need to solve the problem. Working in groups ensures that individual students do not get stuck. However, to ease the challenges a bit and to help students who need more guidance, our course also includes lectures and workshops on psychological concepts relevant to gamification studies [1].

The gamification development process in the class and the groups is also situated learning. That is, learning is integral to participation in a community of practice that has the common goal of learning to create gamification [30, 31]. According to Lave and Wenger, as instructors, we can expect that participation and mutual engagement in the class will also trigger interest in related school topics. This interest can then trigger intrinsic motivation.

We also encourage online communication in relevant forums. This allows students to bring their outside-of-university activities and identities into their work, whether this is as bloggers, gamers, or participants in online communities. We think this adds important and relevant informal learning into the classroom.

Finally, our gamification class lets the students experience learning—they are not simply being told what to learn because their gamification development is learning by doing [32]. Students are also motivated to study related theory when they need to solve a practical gamification or system thinking challenge, which connects theoretical learning with solving practical tasks. This is learning just in time [33].

The Case Study

Below, we will provide two examples of the design of a gamification application that student groups created during our course. The first example focuses largely on the overall situation the gamification aims to improve, while the second example addresses the motivation the gamification seeks to create. Each example uses system thinking differently: the first has a broader focus and a less detailed perspective on motivation, while the second delves deeply into various psychological motivation theories.

Project Analyses Through System Thinking

The first thing students do after brainstorming a good idea is to undertake system analysis. System analysis starts with establishing a clear and precise question about what their application will do. They, then define the project's parameters and objectives. Making CLDs and flow charts helps them define the systems, feedback loops, and flows in their gamification. Finally, they draw reference behavior patterns (RBP), which give them an idea of how the system develops over time.

The next step is to create a simulation of their gamification in a simulation tool, such as STELLA, and collect numerical data for all the variables. This can be a challenging task, and quite often the students will not find precise data and must make qualified guesses based on their research. This requires them to dig deep into their model to develop a thorough understanding of how it all fits together.

The students then design scenarios that simulate system behavior over time, and from that, they predict as closely as possible how the gamification will perform given different variables and inputs. This is usually done by simulating the motivation of their users through extrinsic rewards and intrinsic motivation. It is often hard to find quantified data on motivation or learning. In a commercial context, this would be solved by sending questionnaires to users, but the students rarely have the time or resources to do this in our educational setting. Instead, they have to make qualified guesses by searching online. While these predictions are less reliable, the guiding principles and the methodology for gathering feedback remain valid.

After the system analyses and system dynamics sessions are completed, the students present their findings in the class to get feedback from classmates and teachers.

Design the Gamification Application

The next step is to design the gamification application. The design should closely build upon the findings from the system analyses and system dynamics exploration. The app should use relevant game mechanisms, esthetics, and rewards to influence the users in the desired way. Students should also aim to use different technology platforms, such as wearables, sensors, and tracking devices in their design. They must also produce a gamification design document, which should describe the gamification concept in meticulous detail. The project necessitates a user experience-centric focus, with the design being player-centric. This means the user's goals and motivations need to be mapped and designed so that gameplay motivates the players to achieve their desired outcomes [2]. Students must detail the goals and outcomes that users are expected to achieve, along with the changes in behavior, attitudes, or knowledge they hope to elicit from the user. The document also needs to delve into details about the target group and their motivations for change, extrinsic and intrinsic rewards, game mechanics and tasks, reward systems, descriptions of technology, esthetics, game environment, and budgets. Students create a prototype of the app using tools like Invision or Adobe XD, but they are also permitted to use game engines such as Unity or Unreal for prototyping. Once everything is completed, they present their results in the class to gather feedback.

Writing the Project Report

The final assignment of the gamification project is to write a research report. In this report, the group discusses the implementation, challenges, and how they overcame them. Students must anchor their report in theory discussed in the syllabus literature or other books or articles they deemed necessary for developing the gamification. The report must discuss and reflect upon system thinking, their own research, the simulations they conducted, and the pedagogy and psychology they employed. They are expected to discuss and explain why their gamification should work as intended, and why the game design and game tools they chose will be effective. Lastly, the report must detail how the group collaborated to achieve its objectives, outline individual responsibilities for the various components of the project development, simulation, and implementation, and specify who authored each section of the report.

Student Examples

Student Example 1: Galapágos

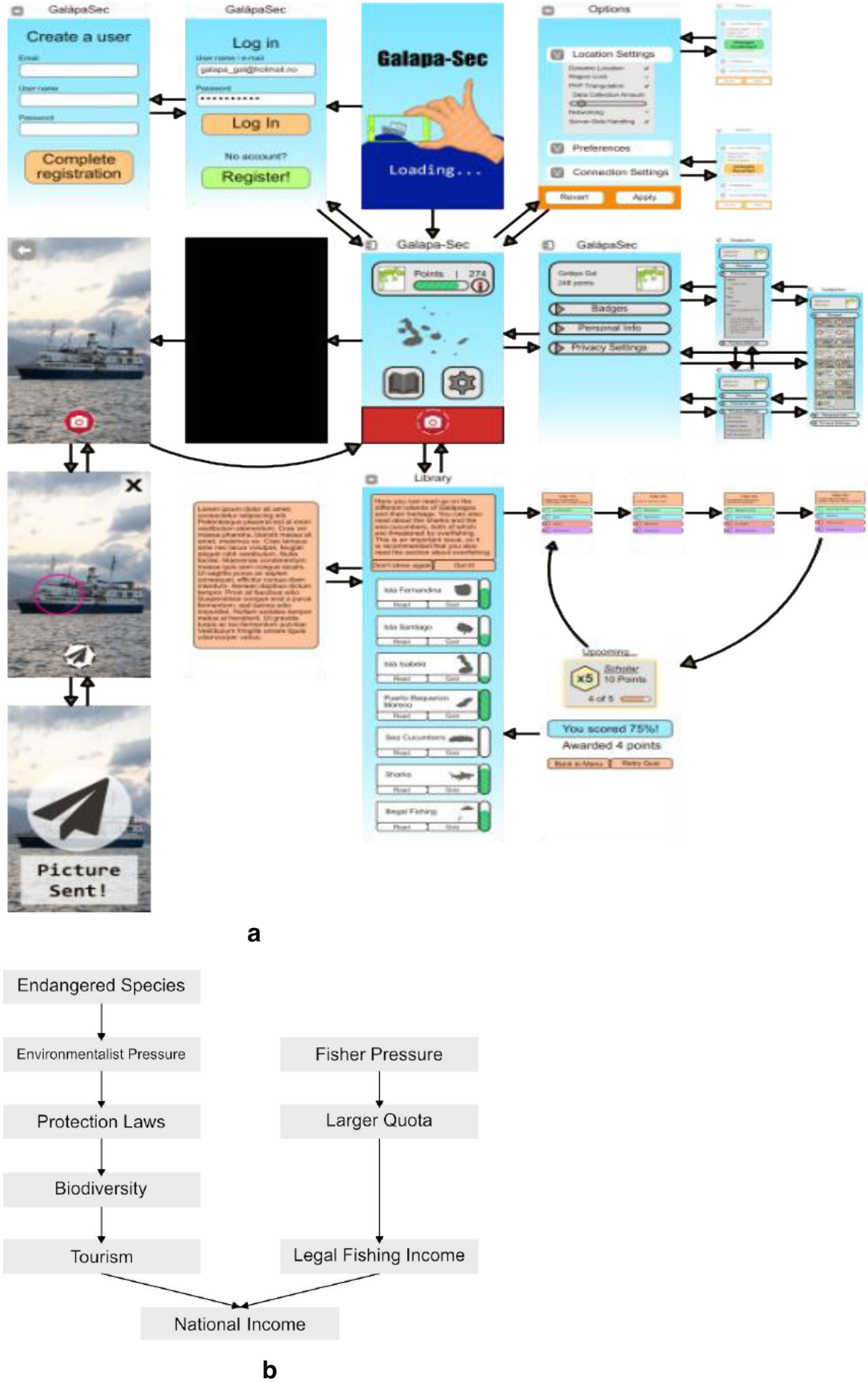
This first example pertains to the Galápagos Islands in Ecuador, where economic growth and tourism pose a threat to indigenous wildlife. This example is derived from the systems thinking textbook by Sverdrup et al., [19]. In the Galápagos, the primary economic resource is the natural environment, the health of which is intrinsically linked to the local economy. Consequently, the preservation of nature and native species through ecotourism and wildlife conservation is paramount. All diagrams below are from the student submissions and are meant as an illustration and not all details are readable.

Certain species on the Galápagos Islands have been overfished to near endangerment, jeopardizing the islands' tourism industry. The students were tasked with devising a solution that could safeguard both the environmental and economic interests of the Galápagos Islands through a gamified app. They crafted a game supporting law enforcement's endeavor to monitor and apprehend illegal fishers around the Galápagos, an effort both costly and challenging. Players are encouraged to photograph suspicious fishing activities and upload these snapshots, accompanied by their GPS coordinates.

Figure 5a illustrates the application's interfaces and flow. The left-hand side of the flowchart in Fig. 5b embodies the conventional harvest model. For instance, when fish populations are endangered, fishing quotas typically see reductions. These diminished quotas, coupled with protective measures, contribute to species conservation and biodiversity preservation, bolstering tourism. However, as depicted on the right side of Fig. 5b, these reduced quotas simultaneously induce stress among fishers.

The CLD presented in Fig. 6 utilizes red lines to symbolize a decreasing effect (–) and green lines to indicate an augmenting effect (+). The students emphasize that the situation is an amalgamation of ecosystem and economy: In the Galápagos, tourism and fishing are the predominant income sources. Both are depicted in the CLD. The chart underscores the dependency of tourism on biodiversity, with fishing resources segmented into four categories: sea cucumbers, sea cucumber predators, medium-sized fish, and sharks. The CLD illustrates the interplay between economic growth and biological biodiversity, leading to environmentalist pressures, ensuing legislation, fishing restrictions, and enforcement. Given the bulk of the harvested marine resources are earmarked for export, the fishers' livelihood hinges on external demand. In the CLD, the students positioned foreign economy as the primary determinant of fish demand. This demand subsequently influences both the official and black-market prices, thereby determining the volume of legal and illicit fishing. As a result, most fishing activities are indirectly governed by overseas demand.

Originally, the students made a simulation that covered the whole ecosystem, with links to the dynamics of fishing and to biodiversity and tourism. Unfortunately, it proved impossible to find enough data to run this bigger model, so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Connection Settings
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274
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Badges
Personal Info
Privacy Settings
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Picture Sent!
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x5
Scholar
10 Points
4 of 5
You scored 75%!
Awarded 4 points
a
Endangered Species
Environmentalist Pressure
Protection Laws
Biodiversity
Tourism
Fisher Pressure
Larger Quota
Legal Fishing Income
National Income
b

◂**Fig. 5** **a** Phone application flow and screens. Event flow chart for the modeling process. **b** Phone application flow and screens. Event flow chart for the modeling process

they made a simpler model that addressed only the economy. In this model, the categories 'industry' and 'activist pressure' are merged as they are only concerned with the strongest influence on legislation at any time. Foreign demand is the motivation for industry, and biodiversity is the motivation for activists. Legislation then influences fishing and tourists and, finally, economy. This simplified economic model is shown in Fig. 7 and the output diagrams from the same model are shown in Fig. 8.

The students simulated four scenarios:

1. Situation continues as usual.
2. Fishing is banned.
3. Foreign demand decreases.
4. Tourism declines.

Although the simulation overall is largely a simplification due to the lack of data, the scenarios show how the Galápagos economy could react to drastic changes in ecology. The students said that working on the models and simulations provided them with insight into the dynamics, and thus a better understanding, of the Galápagos economy. The students also explained that although the search for data and the material available did not provide enough data to run a fully fledged model, the data set they obtained included descriptions of the dynamics and cases that helped them understand how the key factors in the economy work together. They concluded that the most beneficial alternative path for Galápagos is to disband the legal fishing industry and focus entirely on tourism and other minimally harmful activities.

This leads us to the next example, which is more about the motivation models presented earlier in the article.

Student Example 2: Family Manager This app is aimed at families and focuses on teaching children the importance of positive habits and how to maintain structure in their lives by doing chores. Parents create assignments for the kids to complete which then earn points. Points can be used on rewards, and the family decides together what the tasks and rewards will be. For children, typical tasks are cleaning their room or doing their homework, while a typical reward might be an ice cream or an allowance. In addition, the family can establish collective goals, like a family trip. The app can also teach children about personal finance. Although the students are well aware their app is not a game, they compare the game mechanics in the app with a role-playing game, where the RPG quests are replaced with the individual and family tasks. Again, all diagrams are from the student submissions and are meant as an illustration and not all details are readable (see Fig. 9).

The students' system thinking in this example primarily focuses on motivation. They split the motivation into intrinsic and extrinsic motivation, and the app tries as much as possible to trigger intrinsic motivation. These students use not only the psychological ARCS and the SDT models [1], but also occasionally other theories such as Malone's theory of intrinsically motivating instruction [27] and Lepper's instructional design principles for intrinsic motivation [1].

The CLD from the system analysis below gives an overview of the system. Nearly, all loops address motivation directly, and there are more reinforcing loops than balancing ones. The students see this as a good sign; it points to an increase in motivation over time. Second, they point out that intrinsic motivation increases the more the users engage with the app. They also highlight the importance of making the results visible for users to feel accomplishment and mastery. The CLD also indicates that incomplete tasks and excessive extrinsic motivation can decrease motivation and must be monitored. We can also see that too many rewards will have a negative effect on intrinsic motivation [1] (see Fig. 10).

Flow charts are essential for understanding how a gamification system works and are an integral part of a system analysis. Below are a few examples of the students' flow charts.

The students first present a few examples of how tasks flow through the system. We then examine the flow of motivation (Figs. 11, 12 and 13).

The CLD and flow charts form the foundation for the system dynamics simulations. The simulations were crafted in ISEE Systems Stella Architect and encompassed various scenarios (Fig. 14).

The simulation in Fig. 14 is best interpreted by referencing the CLD in Fig. 10 and the flow charts in Figs. 11, 12 and 13. To the left is the task manager that manages tasks from their inception until their approval. It is important to note that every element in the simulation is arrayed so that each family member has their own simulation. The psychological parameters related to intrinsic motivation are displayed on the top right, while the parameters associated with extrinsic motivation are on the lower right. The combined intrinsic and extrinsic motivation points for each family member are situated in the center of the screen.

Table 1 displays the initial values for the simulation. In this example, we observe that the parents possess higher skills compared to the children, and the skill level ascends with age. The subsequent line showcases the initial values for both intrinsic and extrinsic motivation. The base constructive feedback percentage designates when to offer constructive feedback. Additionally, there is a random variance of + -10% added to the initial value—for instance, completing 60–80% of the tasks provides the kids with constructive feedback.

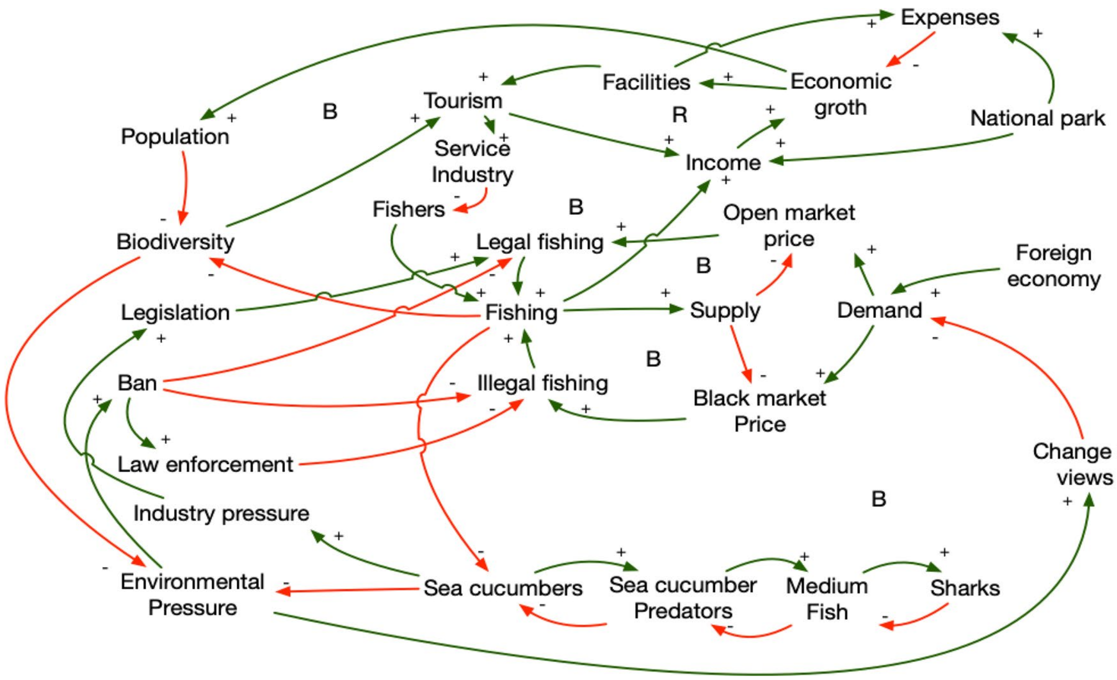

Fig. 6 Casual loop diagram (CLD). The dynamics of fishing, demand, biodiversity, legislation, and tourism

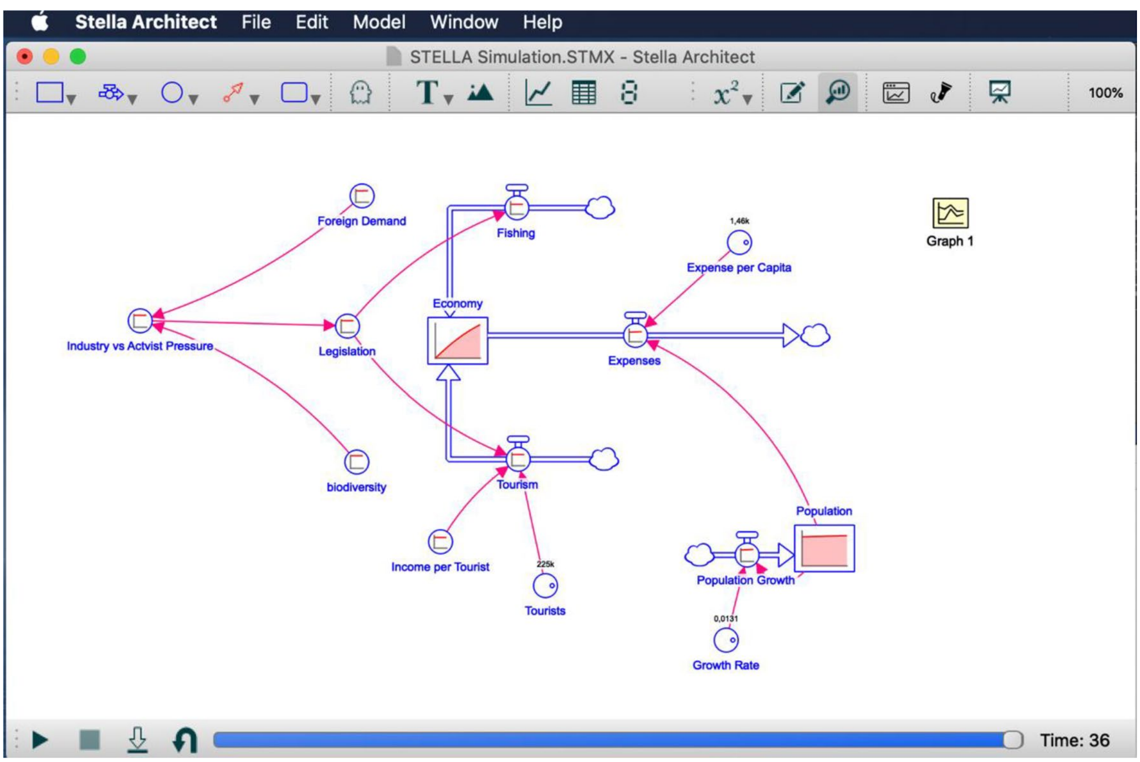

Fig. 7 Stella simulation interface as interpreted by the students

The students simulated three scenarios. Each scenario runs for a whole year. The scenario in Fig. 15 uses the initial values in Table 1. Here the intrinsic motivation increases steadily for all members of the family, which is exactly what the students hoped to achieve. We can see that extrinsic motivation moves toward the same constant

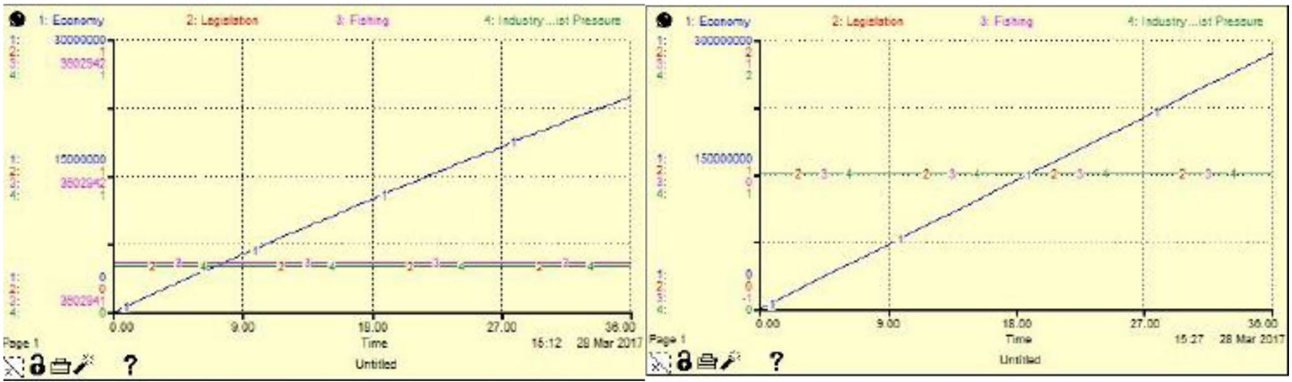

Fig. 8 Illustration of diagrams from the simulations data

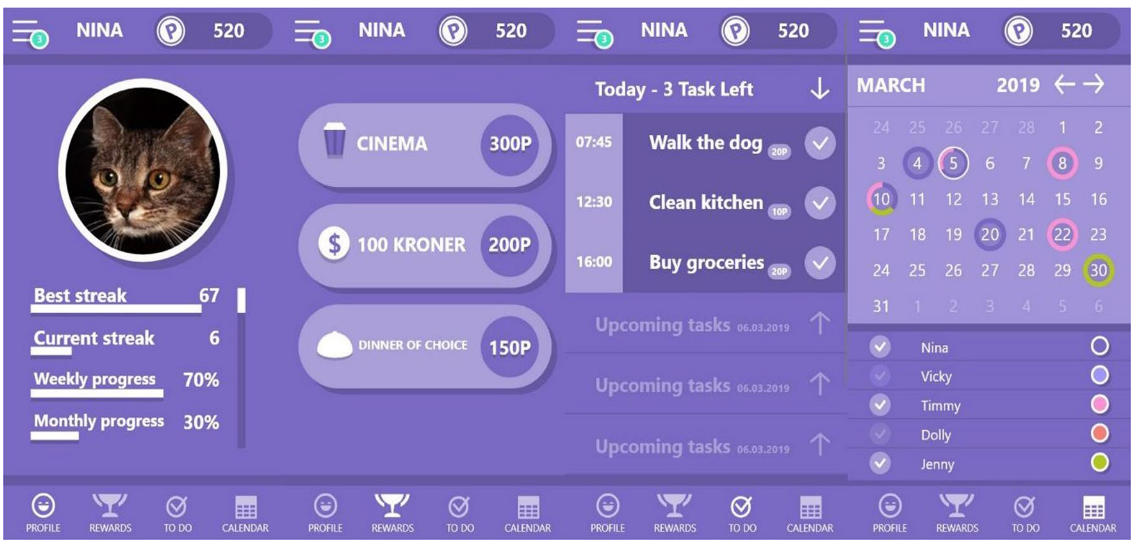

Fig. 9 App design—main page

value for all family members. The students point out that as this does not increase indefinitely, at some point, intrinsic motivation will take over for extrinsic motivation. They further assume that the app helps both kids and adults to "find a lasting motivation to keep a structured life."

In the two other scenarios (not shown), the students repeated the simulation, but with the constructive feedback set to a range of 0–100%. The scenarios show that children's intrinsic motivation increases to a noticeably lesser degree when little constructive feedback is given. Just as importantly, children's skills barely increase when nobody tells them how they can improve. The students point out that the message system in the application is very important. It gives children power to choose and a feeling of mastery; without this feature, the system was much less effective, which is precisely what self-determination theory finds [1]. The students articulated this observation in their report: "This proves that the usage of SDT in our app is the oil that keeps the gears turning".

Discussion

Building a gamification can be an intangible and complex process. First, the real-world system the gamification is built on must be understood thoroughly. Next, research must consider the gamification's users and how they will engage with it. Additionally, developers must ground their understanding of how the app motivates and teaches the users in a methodology such as psychology. A learning loop CLD must also be made so the learning process is clear, and goals must be set so user learning can be verified. The examples we discuss show that system thinking gives students tools to acquire a more tangible understanding of design principles

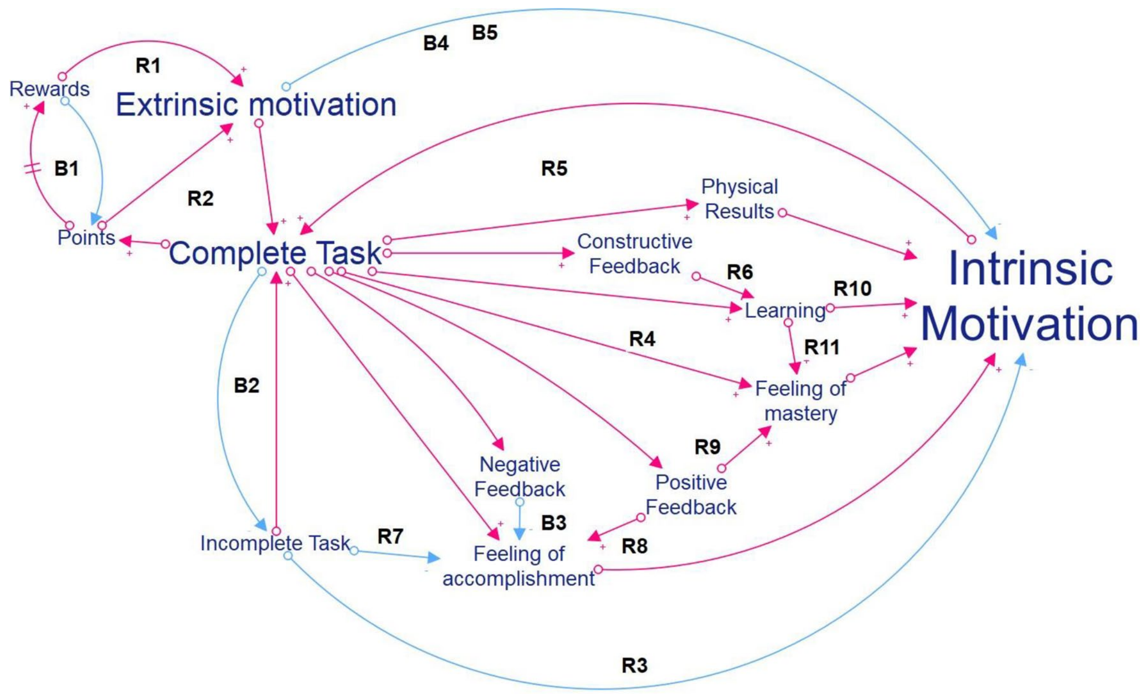

Fig. 10 CLD for the psychological motivation model applied in the app

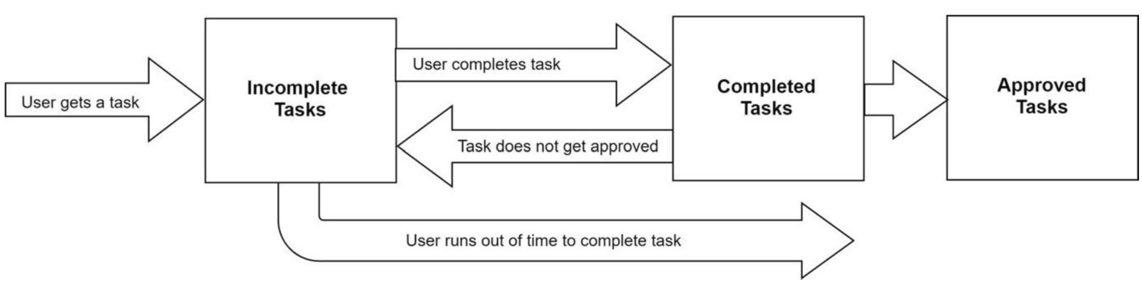

Fig. 11 Tasks. A task enters the system when it is assigned to a user. The user either completes it or runs out of time to do so. If time does not run out, the task is put in the queue to be approved

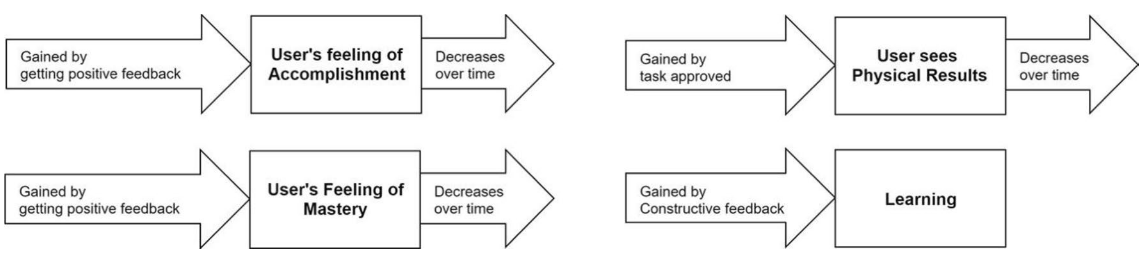

Fig. 12 Users are motivated by feeling accomplishment and mastery, learning and seeing results. Over time motivation decreases. The students assume that learning, unlike motivation, cannot decrease over time

and practices in their gamification scenarios. With system thinking, students also have the means to test their hypothesis in a more structured, manageable, and tangible way.

However, the student examples here are by no means complete or conclusive. There are many other ways system thinking can be used in gamification. For example, before

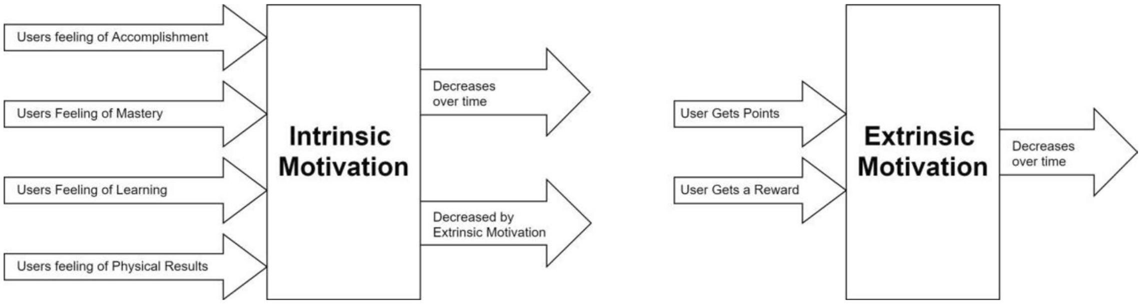

Fig. 13 Motivation. This flow chart shows how mastery, accomplishment, learning, and physical results will affect intrinsic motivation, while points and rewards influences extrinsic motivation

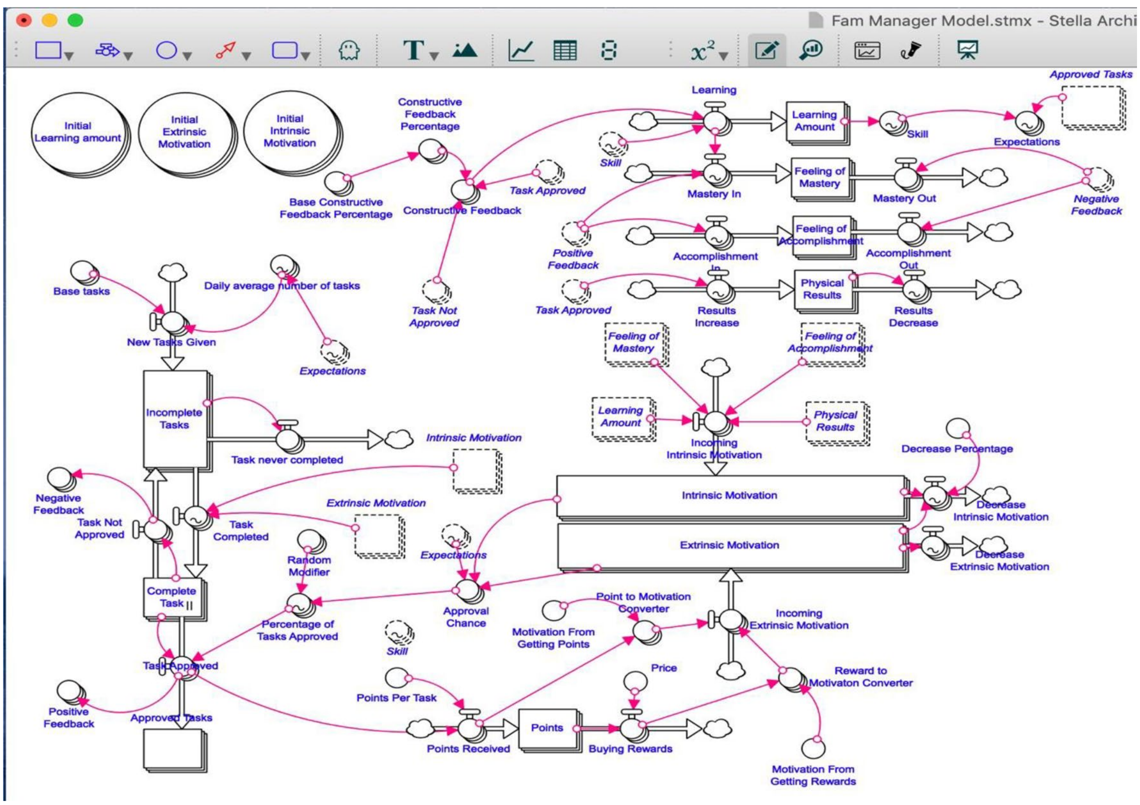

Fig. 14 The system dynamics STELLA Architect model interface

the gamification design process is even started, system analysis can provide a more thorough way to understand the real-world systems it builds on, or aspects of the real world that the gamification will affect. During the app design process, system thinking can enhance students' understanding of how players learn or reach their goals by making a learning loop for the design. Later in the process, system thinking can be used to experiment with game balances, testing and debugging, and of course aspects of marketing, distribution, and server loads.

There is also constant development in where and how system thinking is used in gamification design. We believe this is because system thinking forces us to dig deeper into the gamification. Our students have often pointed out that merely engaging system thinking around their gamification makes them dig deeper into the details and create more detailed solutions. The system analyses provide them with a deeper qualitative and logical understanding of how cause and effect function in gamification systems, and how the gamification app will perform and create user motivation.

Table 1 Overview of the parameter settings in the model

Initial values	Female (8)	Male (10)	Female (12)	Mom	Dad
Skill	2.1	4.19	5.06	8.92	8.53
Intrinsic motivation	10	20	2	50	50
Extrinsic motivation	50	30	10	10	10
Base amount of tasks	2	2	3	5	5
Base constructive feedback percentage	70%	70%	70%	0%	0%

In this regard, system analysis makes it easier to see, for example, where to insert game elements that create intrinsic motivation. Additionally, this mode of thinking leads students to pay more attention to how the game mechanics work logically in gamifications and to discover if there are hidden feedback loops. All in all, a system analysis forces students to think more closely about the details of the design, the feedback loops, and how the various gamification systems work together to achieve their goals.

Gamifications will invariably include deploying psychology, pedagogics, and what the game designers consider common sense. The foremost issue here facing developers is grounding the gamification design, the motivation, and the in-game learning in psychological and pedagogical proven theories, rather than merely in so-called common sense. When students use psychological models like ARCS, Self

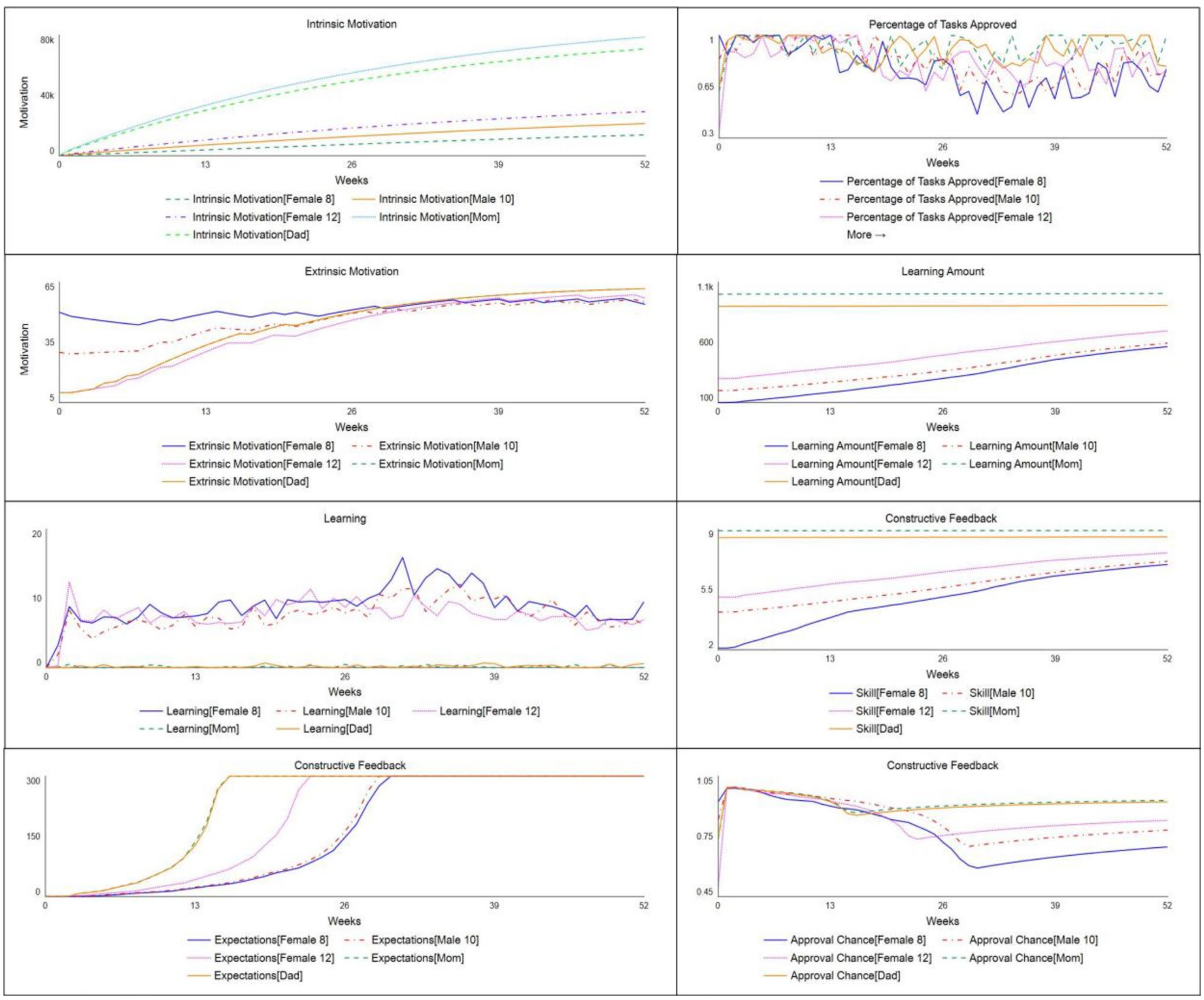

Fig. 15 These system dynamics simulation diagrams show how motivation, learning, tasks approved, and constructive feedback develop for 5 family members

Determination Theory, and similar psychological theories they have a more tangible base on which to ground their gamification design. Yet theories like these are often hard to understand and implement. Breaking them down into causes and effects in the CLDs that are an aspect of system analysis gives students a better understanding of the theories as well as providing solid and useful data and predictions about the design and behavior for the app's users. However, it is hard to find numbers or statistics on these theories that can be used in a system dynamics simulation of the gamification. These types of data would typically have to be found through user queries, interviews, and observations, as well as real-life user tests of the prototype gamification. Psychology and pedagogics are important not only in gamification but also in games; hopefully more research data and statistics in these areas will become in the next few years.

As the examples above show, it is necessary to supervise the students, so they engage in scientifically based reasoning rather than wishful thinking. For example, some student diagrams show that training and intrinsic motivation decrease over time. This is a certainly possible outcome, but the claim needs scientific foundation to be considered valid. In the same way, a statement that the need for extrinsic motivation will decrease because intrinsic motivation increases is based only on wishful thinking and would need to be backed up by scientific research in a real situation. However, students' simulation principles remain valid, and that is what counts in the classroom context. Since gamification is intangible and complex and involves a lot of lofty goals, it is easy for the systemic and straightforward nature of both system analysis and system dynamics to lead students to make claims that become self-fulfilling prophecies based on assumptions more than scientific facts and theories.

System dynamics simulation, the other component of system thinking, is quantitative by nature and offers a better understanding of the value ranges of the in-and-out data from the gamification. The system dynamic simulations in Stella are a valuable tool for students because they provide a real-time opportunity to numerically test different scenarios developed in system analysis. The quantitative output produced makes it easier for students to understand, theorize, and predict how the messy real-life usage of a gamification can behave. Even the simplified version of simulation in Example 1, where the students lacked data, gives a better view of the dynamics in the situation. System dynamics simulations are, additionally, helpful tools for predicting the application's behavior.

If designers simulate the gamification fully and include all input and output parameters available, the dynamic simulation can be used to design the actual programming code for the gamification application. Code from Stella can be exported as pseudo code, which can then be translated into any programming language. This is a very powerful feature—making a system dynamics simulation in Stella is easier than writing program code from scratch, and programmers can execute the simulation code directly in the game engine. A simulation in Stella can also save user testing time, and with repeated simulations students will better understand how the application will work with real users.

Developers can still write all simulation code from scratch based on the system analysis. This approach gives developers more flexibility and control but is also more difficult and requires more work, and in this scenario the system analysis remains very important as it serves as the complete logic design drawing for the programming design of the gamification.

Results and Conclusion

We believe the student examples discussed above answer our research question: "How can system thinking be used to design, develop, and document the process of gamification?" The examples show how students undertake system analysis by making CLDs for gamification designs (Fig. 6), and they illustrate the link between game elements and motivation (Fig. 10). The examples also provide flow charts of everything that flows through the gamification (Figs. 5 and 11, 12, 13). Lastly, they simulate the system analysis quantitatively through the use of system dynamics (Figs. 7 and 14).

However, as discussed above, this assignment has also revealed new perspectives on the ways that system analysis and system dynamics can be applied in developing gamifications. Using system dynamics can create a better understanding of the real-world system developers will gamify and building simplified models or "fish tanks" [33] of a case can improve understanding of how the system functions in general. Using system dynamics simulations to thoroughly test a gamification can reduce time and money spent on user testing. Undertaking different testing scenarios of the simulation will not only help iron out bugs and logical inconsistencies but also aid in balancing game elements such as challenges, bots, or tools to match different user responses. Trying out different parameters to test balancing is an area where the results can produce large amounts of data to measure and accommodate different users and user skill levels. Lastly, system thinking can offer meaningful insight into predicting shifts in markets, user numbers, server loads, update schedules, and other aspects of the gamification production phase.

In sum, through our classroom instruction, not only have we discovered several beneficial ways to implement system thinking into gamification design, but this process has also forced us to dig deeper into individual design projects in ways that yield new information about areas of gamification research that can benefit from the application of system thinking.

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Declarations

Conflict of Interest The authors declare that they have on conflict of interest.

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