Cabinet – Strategy Board Game for Network and System Management Learning

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Abstract

Gamification may be a new term, and recently it has been receiving a considerable attention in several areas and fields. This neologism, however, describe an idea that is not exactly new: using game-thinking and game mechanics to solve problems and to engage audiences.

This paper describes the approach to applying gamification to a higher education subject in the course of computer science. We focus mainly in the design, development and assessment of a strategy board game of the worker placement type. It is used with the purpose of providing an environment for reflection and concept learning regarding the overall operation of data centers.

The game is called "Cabinet" and contains a game board, two data center boards and four extensions. It also contains 80 pieces, representing the resources and components associated to the operation of computers stored in racks integrated in organizations' data centers. The gameplay is evaluated through a specific Game Engagement Observation Protocol, assessing the interaction between players, the dynamics of the game and the overall satisfaction of players.

Keywords: Gamification, Strategy Board Game, Computer Science, Higher Education

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1 Introduction

Higher Education Institutions (HEI) have three primary missions: education, research and cooperation [Kyvik and Lepori 2010]. While in different weights and strategic importance, most institutions try to cope with these missions to contribute for population education at high level, scientific and technological advances and economic and social development.

Regarding education, HEI must create an appropriate environment for learning. However, adequate student learning disposition is fundamental to achieve high-level academic performance [Pintrich and de Groot 1990]. The way they plan, monitor and modify their learning, how they manage and control their effort on academic tasks and the cognitive strategies used to learn, remember, and understand materials all contribute to the overall education process within the student.

Students must be motivated to use the strategies as well as regulate their cognition and effort [Pintrich et al. 1993]. A motivated student is energized and available to pursue activities and tasks that appeal to him. Delivering content alone has virtually no effect on students' beliefs about the world. They can memorize data, but without active engagement and hands-on application, they do not really confront the implications of the new content.

There are several factors that determines motivation, and usually they also depend on the person characteristics. To foster motivation it is important that students understand what they can and can't do and have accurate and realistic feedback that can help them acquire the expertise needed to learn. It is also fundamental to provide tasks that should be neither too easy nor too difficult, but challenge students in appropriate ways [Pintrich 2003]. High-degree of motivation is usually achieved when the expectations are high [Weber and Chapman 2005]. Low stakes and high expectations are precisely the typical conditions of a good game.

With this in mind, we designed a higher education subject, of the computer science course, around game concepts and mechanics. This gamification approach allowed us to define adaptive challenges, a reward system, curiosity and chance to increase the time students spend working, experiencing and learning in a HEI. The sections in the subject curriculum were transformed into levels, awarding stars for increasingly complex achievements. There is also the concept of soft currency, which is used to increase the student autonomy and incentive the work load. Some games are also used as learning experiences, allowing collective knowledge building in the preparation and also playing the games.

This paper describes the design and evaluation of an education game, of the strategy, worker-placement, type, based on the popular board game Argicola, by Uwe Rosenberg. It is structured in five sections, starting with this introduction. The next section describes related work as well the overall gamification approach, including the award mechanism, grading and some learning experiences. It proceeds by describing the design and evaluation of Cabinet and, we finish with some conclusions.

2 Related work

Playing games is something that has been with humans since the dawn of civilization. Recent research has been demonstrating that game play contributes to faster reactions as well as to increasing the brain activity, allowing people to live longer and delaying dementia.

The use of games for learning in higher education aims to make complex theoretical knowledge more accessible, providing the means for students to repeat and simulate situations that may lead to a more in-depth learning. Based on the possibility of fantasy, challenge and curiosity that characterizes games, the online game Internal Force Master (IFM) is an educational game software specifically designed and developed for the study of Civil Engineering [Ebner and Holzinger 2007]. It was developed in Macromedia Flash and made available to master level students. The authors concluded that the learning result of the playing group is at least equivalent to the group who learned using the traditional method. Moreover, they also state that gambling can be a new, modern and also useful learning method.

Effective learning and learner autonomy promotion is a recommended by several governments and education institutions. In this context, learning by doing is instantiated in the development of games by the students, allowing them to acquire a diverse set of skills. The Adventure Author used this approach, showing that game making provides a range of opportunities for successful learning [Robertson and Howells 2008]. Children were motivated and enthusiastic, showing determination to achieve and ability to learn collaboratively and alone. They also showed evidence of being able to link and apply their learning to new situations.

Off the shelf, commercial games can also provide valuable learning experiences for students. The choice and evaluation of games allows better adaptation of requirements and learning goals [Bellotti et al. 2012; Tannahill et al. 2012].

On the other hand, specific, custom developed games, can provide a uniform and specific learning environment. Digital forensics, for example, is complex and requires a diverse set of skills through expensive specialized tools. Digital Forensics Interactive is developed in Unity to build a virtual environment to students. The game-play consists of the challenges and actions the game offers players and the sequence of the game is the progression of activities that consists of the game [Yerby et al. 2014].

The inherent complexity of such games requires large efforts for their development. Specific frameworks can be followed to maintain the process within controlled complexity without losing sight of the main goals, either in game-play and on learning goals [Westera et al. 2008; Jassem and Piskado 2014].

3 Gamification in Higher Education

Gamification describe the use of game design elements in non-game contexts [Deterding et al. 2011]. This includes the creation of learning experiences that make use of challenges, rewards, points, levels and others, according to the goals of the game. Moreover, using games as learning experiences allows taking advantage of the motivational and entertainment the characterizes them to increasing the student knowledge [Linehan et al. 2011].

The game described in this paper was developed and used in the subject Network and System Management of the Computer Science course of the Polytechnic Institute of Bragana, Portugal. It was used as a learning experience to help students deal with several concepts related to the operation of enterprise wide data centers.

3.1 Educational Games

Educational games try to harness the motivational qualities of games in order to create powerful, engaging educational tools [Linehan et al. 2011]. There are two approaches to using games in education. The first seek the engagement that commercial and wide available games (COTS – Commercial and Off-The-Shelf) have to foster learning outside the school environment. Games such as Sid Meier's Civilization or World of Warcraft can provide a challenging and motivating world that require analyzing, planing, communication skills and others, contributing to improving the problem solving abilities of players. On the other hand, games can be specifically designed to convey traditional content in a different, nontraditional, form.

COTS games clearly provide opportunities for learning. Although typically associated to the development of soft-skills, such as language, analytical or communication, they also promote planning, collaboration, problem solving and even concepts learning. Games such as Monopoly grasp basic economy concepts and real estate value. Other simulation games, for example, are used by the military to train soldiers on combat missions that could not be completely replicated in the physical world [Annetta 2010]. Virtual worlds, such as Second Life, provide three-dimensional environments used more for social interaction, disregarding specific skills or content.

The weakness of the previous type is that there is some difficulty in covering mandated content areas. This requires the design and development of specific, custom made, games. Traditional teaching methods are essentially based on the transmission of content and this approach is frequently used to design educational games. As a consequence, many games lack in either fun or on educational benefit [Bruckman 1999].

It seems obvious that an educational game is simply not a collection of content organized in a nontraditional way. Educational games should follow the same principles that makes entertainment games intrinsically motivating [Whitton 2007]. As mentioned above, some of these principles include the existence of medium and long term goals organized as increasingly complex levels, they should require the player to make decisions and take actions, provide immediate feedback, include a reward system for achievements, gradually teach the player new skills necessary to overcome more challenging obstacles [Klopfer et al. 2009].

We decided to design and develop a custom educational board game, trying to both convey specific content knowledge and be fun to play. The process should not start by simply connecting the content. Content should be an inner part of the game, integrally linked with the game-play. This require the definition of the learning objectives and the identification of specific parts that can be made part of the story or a set of challenges.

We created the game for the Network and System Management subject of the Computer Science course, focusing concepts of networked systems.

3.2 Network and System Management

Network and System Management is a third year, second semester, subject of the Computer Science course of the Polytechnic Institute of Bragança. At the end of the subject, it is expected that the learner be able to:

- use a basic set of virtualization tools;
- install and configure both disconnected and networked computer systems;
- manage secondary storage medium, user accounts and system startup and shutdown procedures;
- install and configure basic network services; install and configure network file servers and authentication domains;
- identify and describe the role of integrated network management in modern organizations, and use some related tools.

The current curriculum is structured in four sections or chapters. Each section has several topics that should be mastered before advancing to the next section. The final assessment and the associated grade depends on the success on each of the section as well as the creativity and the knowledge level demonstrated in every topic. Students are graded from 0 to 20, which is translated to the ECTS grading scale, demonstrating how she performed relative to other students (the best 10% are awarded an A-grade, the next 25% a B-grade, the following 30% a C-grade, the following 25% a D-grade and the final 10% an E-grade). Success is only considered if the student has a grade equal or above 10 (0-20).

The assessment and grading follows a reward structure design pattern. All the students have to fulfil the minimum requirements to succeed, meaning that he has to overcome all the sections or "levels". This will grant him the 10 grade. Within each level, the increasing number of overcame obstacles will grant the student a higher grade.

Each level is marked by a castle. The student can additionally obtain up to 2 stars, associated to the complexity of obstacles he successfully faced. Whenever a learning experience is completed, BitPoints are awarded, which can be used to "buy" extra tools or help from the teacher. In other words, the reward system will have castles, stars and points (Table 1).

Table 1: *Reward system and structure.*

Element	Description	Grade
Castle	Awarded for each completed level. Student will need five castles to succeed in the course.	Up to 10
Star	Each level will award up to 2 stars.	Up to 10
BitPoint	Awarded when completing a level. Can be used to buy tools or information.	-

The student can, at any time, see the evolution within the awards system using a standard web browser. This will present the completed levels, the levels still to come, the number of stars awarded in each level and the total BitPoints (Figure 1).

The level map also gives access to the item store, where the student can buy information or tools to be used in other tasks. The shopping list includes several items that can be valuable to overcome obstacles (Table 2). The store provides information about five items, its price and the available BitPoints. It also provides the student with the number of items already bought (Figure 2).

Each time the student selects an item, the description in the figure will change, to further explain the meaning of the item. If the number of BitPoints is enough to buy the item, the "Buy" indication will also appear, allowing the student to perform the transaction.

Figure 1: *The gamified GSR level map.*

Table 2: *Shopping list.*

Price	Item
50	Command line string
250	Virtual machine file
350	Step-by-step configuration recipe
500	Configuration file
999	Service configured

3.3 Learning Experiences

The term learning experiences is typically used to describe that the learner is experiencing something that, hopefully, contributes to a change in thinking, understanding, or behavior afterward.

For this to happen, learning experiences should be active, meaningful, with social meaning, integrative, and diversified. We consider active learning experiences when the student has the main learning role. They should provide knowledge and skills that directly contribute to the learners ability to perform more effectively in the context of workplace learning.

The diversity of ways in which students can learn from and interact with teachers, in addition to the level of independence they may have when learning, is considerable. In the subject of Network and System Management, these include not only traditional transmissive approaches and practical work assignments but also designing as well as playing games.

Cabinet was developed in this context, providing the students with an educational strategy board game, including concepts and content from the third level (Networked Systems).

4 Cabinet

Cabinet is a learning experience belonging to the third level, Networked Systems. It is a turn-based strategy game, of the worker placement type. Players will have to collect resources, which allows the workers to earn money or build things, and to perform other activities, such as:

- extend their data-center by building additional rack space;
- hire more system administrators;
- build environmental control;
- purchase servers;
- install network services.

Resources include:

- money, necessary to pay the personal and the power consumption;
- operating systems, to support network services;
- virtual machines, for expanding the data-center;
- wiring and ducts;
- network services, such as DNS, network file-systems, and others;
- web servers, that can be used as additional source of income resulting from hosting external managed services.

The general learning objective for this game is for students to operate an enterprise wide data center, with the most common services available to personnel. This translates into the following learning objectives:

- identify all the parts of a networked system;
- recognize the dependency between network services and operating systems;
- produce a simulation of an enterprise wide data center;
- assess the efficiency of the whole system.

In this game, students are system administrators in an enterprise data center. On each turn, they'll get to take a single action from all the possibilities of a data center management: increasing rack space, installing a network service, collecting resources, and so on. As the data center grows, more resources are necessary, which will require careful decisions and actions (Figure 3).

Figure 2: *The gamified GSR item store.*

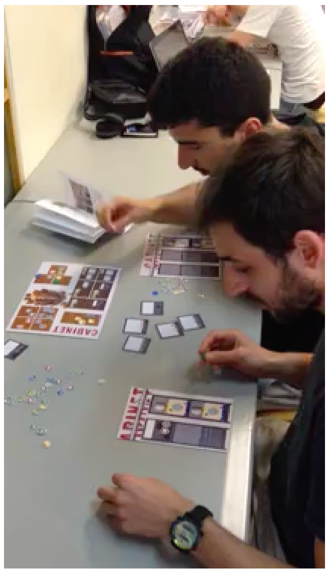


Figure 3: *Playing cabinet.*

4.1 Design

The design of a board game does not follow a specific, well defined recipe, although the process may use a set of heuristics that aim at providing an interesting experience [Malone 1982]. The early process for designing Cabinet included extensive study of game taxonomy and education, in order to identify the most adequate type of game for learning purposes [Apperley 2006]. This initial approach supported the creation of a strategy game type, since it requires dealing with resources, restrictions and keeping, at all times, the overall picture of the game.

The following step included the study of several strategy board games, such as Carcassonne[1], Agricola[2], Caylus[3], and Dominion[4].

Agricola, although in a totally different story and environment, used all the concepts we intended to use:

- Resource restriction: computational resources and data center space, as well as energy consumption, are limited. Growth is bound and depend on the resources that the player is able to acquire, also providing a competition and challenging environment.
- Limited playing time: since the game is to be played in classroom, we want to limit the amount of time. Agricola provide that in the form of a fixed number of rounds.
- Setting: Data centers are installed in buildings, demanding proper environmental and security control. They host racks to organize the network and computing infrastructure.
- Multiple resources: racks, servers, operating systems, hypervisors, Central Processing Units, Power Source Units, keyboards, applications and services all are used in modern data centers. Their operation require detailed knowledge of the role and importance each has.

We defined Cabinet as a turn-base strategy board game, of the worker placement type. It consists in 8 rounds with 3 turns each. In a turn, players are able to execute a single action, such as increasing the number of racks, collecting hardware or software, or installing network services. All the actions are taken on the game board. In each turn, the players place each of their three workers, immediately executing the corresponding action. The winner is the player with the largest number of network services and applications installed in his data center.

The game is designed for two players, in direct competition for resources, with the goal to install more network services and enterprise applications than the other player. Each network service and enterprise application require an operating system which, in turn, depend on a server (bare metal or virtualized). The total number of servers and operating systems is fixed, meaning that after a player acquiring one, the other has less possibilities to win. However, if rack space is kept unused, we face bad resource allocation, loosing points.

The game setting include the main game board, where resource and workers are placed (Figure 4). It is shared by both players, although they cannot place more than a single worker in the same place at the same time.

Each player has his own data center, where he places the servers, operating systems, network services and applications (Figure 5). He can increase rack space up to two more racks, as shown.

Each rack has space for two servers which host network services and enterprise applications. Servers are represented by squares, varying the design according to the computational and storage power (Figure 6). After placed, the server cannot be moved. However, services can be installed in a different server, if compatible.

4.2 Parts

The complete set of parts include cardboard and plastic pieces:

[1]By Klaus-Jürgen Wrede
[2]By Uwe Rosenberg
[3]By William Attia
[4]By Donald X. Vaccarino

Figure 4: *Main game board.*

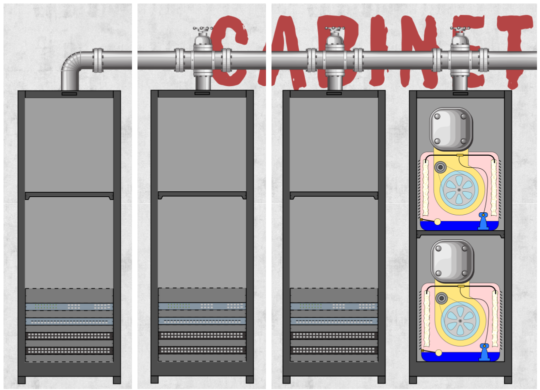


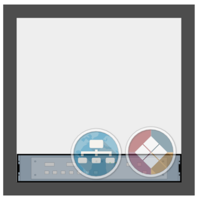
Figure 5: *Player board.*

Cardboard parts:

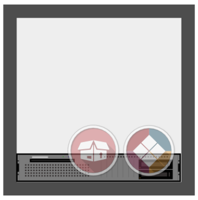
1	Board game
2	Data center boards
4	Additional rack space
2	Embedded rack server (1 operating system and 1 service)
2	Single core rack server (1 operating system and 1 service)
2	Dual core rack server (1 operating system and 1 enterprise application)
1	Bare metal rack server (2 operating systems and 2 services)
1	CPU bundle rack server (3 operating systems and 3 services)
1	Disk bundle rack server (3 operating systems and 3 services)
1	Single disk bundle rack server (1 operating system and 2 services)
7	Hardware pieces – user interface devices
15	Hardware pieces– components
10	Hardware pieces – power source unit
5	Software pieces – hypervisor
8	Software pieces – operating systems
7	Software pieces – network services
8	Software pieces – enterprise applications
1	Initial player sign

4.3 Playing Cabinet

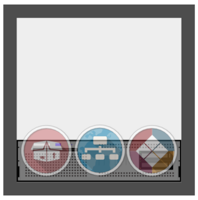
The game begins by deciding which player starts first. This can be decided by luck or by age, for example. The game has 8 rounds,



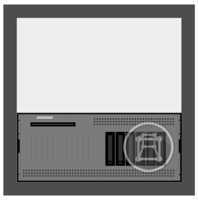
(a) *Embedded.*



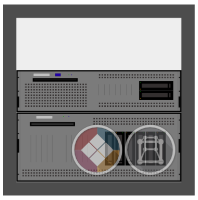
(b) *Single core.*



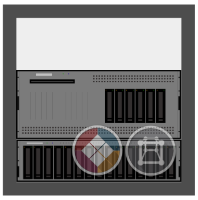
(c) *Dual core.*



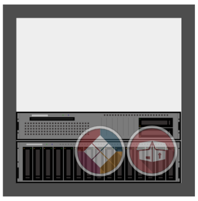
(d) *Bare metal.*



(e) *CPU bundle.*



(f) *Disk bundle.*



(g) *Single disk bundle.*

Figure 6: *Different rack servers.*

Plastic pieces:
3 Worker pieces – player 1
3 Worker pieces – player 2

Other:
1 Plastic bag
1 Book of rules

each with 3 phases.

Replenish phase

Each step starts by placing resources on the main board (light brown tables). Resources are placed regardless of the remaining from the previous step.

Workers phase

Starting with the first player, both place exactly one worker in the main game board, immediately executing the chosen action. At most one worker can be in a single table:

- Placing a worker in a table with resources allows collecting all of them;
- Resources are added to the data center reserve. Software can only be placed in the servers with operating system. Otherwise, they are returned to the general reserve. The exception is the operating system, which remain in the data center reserve even if no server is available to install it;
- It is important to have available servers to place ,  or ;
- Placing a worker in an assembly table, the player can change the hardware resources (, , ) by the corresponding server. The hardware resources are returned to the general reserve and the server is placed in an empty rack space.

The workers phase ends after placing the 6 workers.

Return phase

At the end of the workers phase, they return to the data center.

4.4 First player

The first player sign remains with the same player until a worker is placed in the table with the  mark.

4.5 End of the game

The game ends after completing 8 rounds. It is possible to count the rounds by the total number of operating systems in the general reserve.

Each network service and enterprise application adds 1 point.

- The player looses 3 points for each empty rack space.
- After the fifth enterprise application and the fourth network service, add an additional point.
- Add 2 points for each server placed in extensions to the data center.

5 Evaluation

The gamification of a higher education subject promotes the change of traditional learning approaches. This demands a careful and systematic evaluation in order to assess the learning process and to evaluate the gains. For the overall evaluation, we are using a qualitative research approach, with observation of classes, interviews, questionnaires and others.

In the context of this paper, a specific evaluation is performed regarding Cabinet. The educational game has the main goal of providing a pleasant learning experience to students and, as such, it is necessary to assess the way students learn, their motivation as well as the game dynamics and joyfulness.

To understand the impact of this learning experience in the motivation of students (a), the quality of the interactions (b) and the quality of students' knowledge (c), a Player Observation Record was created and used[5]. The details are registered in specific form, to better systematize data (Figure 7). However, the observation process is not a mere exercise in data collection but it also intends to create awareness of what is experienced in class, enhancing professional reflection about the learning opportunities.

The form starts by identifying the date, time, and the student's name, sex and age. Considering the motivation, the Player Observation Record uses a list of signals that are recorded on a five-point scale. These range from level 1 to 5, corresponding to the following behaviors and attitudes:

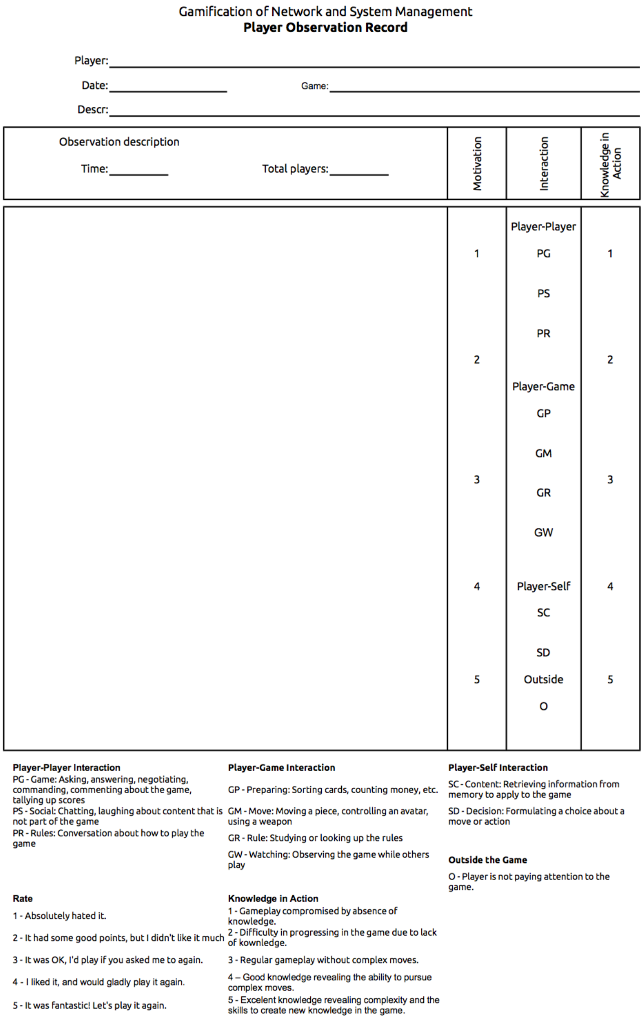
1. Absolutely hated it;
2. It had some good points, but I didn't like it much;
3. It was OK, I'd play if you asked me to again;
4. I liked it, and would gladly play it again;
5. It was fantastic! Let's play it again.

The quality of interactions was analyzed around four dimensions: Player-Player Interaction, Player-Game Interaction, Player-Self Interaction, Outside the Game. Each dimension includes summarizing actions player take.

Player-player interaction

- PG - Game: Asking, answering, negotiating, commanding, commenting about the game, tallying up scores

[5]Based on `http://edweb.sdsu.edu/courses/edtec670/assignments/GEOP.pdf`


Gamification of Network and System Management
Player Observation Record

Player:
Date: Game:
Descr:

Observation description Time: Total players:	Motivation	Interaction	Knowledge in Action
		Player-Player	
	1	PG	1
		PS	
		PR	
	2		2
		Player-Game	
		GP	
		GM	
	3	GR	3
		GW	
	4	Player-Self	4
		SC	
		SD	
	5	Outside	5
		O	

Player-Player Interaction
PG - Game: Asking, answering, negotiating, commanding, commenting about the game, tallying up scores
PS - Social: Chatting, laughing about content that is not part of the game
PR - Rules: Conversation about how to play the game

Player-Game Interaction
GP - Preparing: Sorting cards, counting money, etc.
GM - Move: Moving a piece, controlling an avatar, using a weapon
GR - Rule: Studying or looking up the rules
GW - Watching: Observing the game while others play

Player-Self Interaction
SC - Content: Retrieving information from memory to apply to the game
SD - Decision: Formulating a choice about a move or action

Outside the Game
O - Player is not paying attention to the game.

Rate
1 - Absolutely hated it.
2 - It had some good points, but I didn't like it much
3 - It was OK, I'd play if you asked me to again.
4 - I liked it, and would gladly play it again.
5 - It was fantastic! Let's play it again.

Knowledge in Action
1 - Gameplay compromised by absence of knowledge.
2 - Difficulty in progressing in the game due to lack of kownledge.
3 - Regular gameplay without complex moves.
4 – Good knowledge revealing the ability to pursue complex moves.
5 - Excelent knowledge revealing complexity and the skills to create new knowledge in the game.

Figure 7: *Game observation form.*

- PS - Social: Chatting, laughing about content that is not part of the game
- PR - Rules: Conversation about how to play the game

Player-game interaction

- GP - Preparing: Sorting cards, counting money, etc.
- GM - Move: Moving a piece, controlling an avatar, using a weapon
- GR - Rule: Studying or looking up the rules
- GW - Watching: Observing the game while others play

Player-self interaction

- SC - Content: Retrieving information from memory to apply to the game
- SD - Decision: Formulating a choice about a move or action

Outside the game

- O - Player is not paying attention to the game.

To analyze the students knowledge in action some signals and levels (also a five point scale) were considered:

1. Gameplay compromised by absence of knowledge;
2. Difficulty in progressing in the game due to lack of knowledge;
3. Regular gameplay without complex moves;
4. Good knowledge revealing the ability to pursue complex moves;
5. Excellent knowledge revealing complexity and the skills to create new knowledge in the game.

The goal of the student is to successfully finish the game to complete the learning experience and thus advance in the levels. Remember that students have to complete all the levels to be able to approve in the subject. The learning experience is only successful if the student finishes with a victory. Otherwise, he has to try again (until a win) or choose another learning experience for the same level.

All the 23 students played Cabinet and remained playing it until achieving a victory, to complete the learning experience. Concerning the gameplay, initially the students were skeptical, unknowing of rules and best strategies. As the knowledge was building, they were surprised by the creativity and the strategies that allowed them to build stronger and cheaper data centers. Some of the students (50%) asked to play again, either because they hadn't win or because they were having fun. As expected, almost all of them finished the game within 3 games (Figure 8).

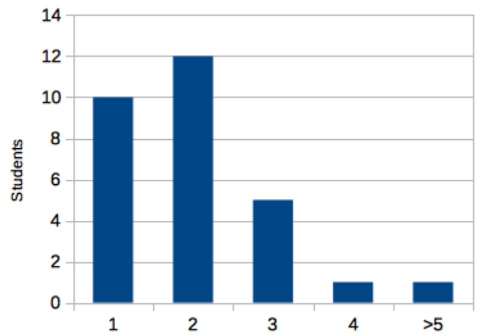


Figure 8: *Number of games until a victory.*

Other indicators required performing careful observations. In total, ten students were observed and filmed while playing Cabinet (43%), four observations per student, in a total of 40 observations (n = 40). The teacher and another observer registered and analyzed the collected data. The videos helped the team to understand the criteria for motivation, the interactions and the knowledge in action.

The data on the students' motivation show that levels 4 and 5 dominate 90% of observations. It is clear, from the overall evaluation work in course, that there is a substantial change in the motivation of students, comparing with their motivation in transmissive classes. This means that students felt drawn to the game, truly interested in and driven to engage in it. They have shown a high persistence in solving problems, higher levels of complexity and creativity, demonstrating they worked with confidence and perseverance for long periods of time.

The data also describe enhanced interactions of reciprocity between the students and their peers and the students and the teacher, well as a strong implication with the game. Teacher found ways to engage with the students, observing and supporting their motivation, getting involved to scaffold and extend learning and play.

The greatest difficulty was related to the number of operating systems. It didn't harm the gameplay, although with more available players would be able to install more network services and enterprise applications thus achieving more points.

6 Conclusion

Games can be used to foster learning, either by taking advantage of the motivation that characterizes Commercial Off The Shelf titles or by introducing custom designed and developed games, conveying the content required by the subject's curriculum.

In the context of Network and System Management, a subject of a Computer Science course, a gamification pedagogical approach was followed. Students grading was associated to an awards system, composed of Levels, Stars and BitPoints, a soft currency to buy tools and knowledge.

The learning experiences were also adapted to game mechanics and contexts, including the design and development of a strategy board game of the worker placement type. The Cabinet game provided students with learning goals related to networked systems, requiring them to build and manage an organization data center.

An two dimension evaluation was made, to assess the learning of students and the gameplay, to allow future improvements. Students were completely motivated, demonstrating high involvement with the game and reflecting upon the choices and concepts they faced within the building strategy.

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