

A Proposal for Engineering Students to Model a Lever System and Design a Serious Game in Order to Promote their Mathematical Learning

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Abstract

This paper describes part of a proposal for college students to design and program Serious Games for the learning of certain concepts involved in some mechanical systems. The aim of this is to use the design and programming activity for promoting learning according to a constructionist view; therefore these activities are considered part of a learning microworld to help contextualize issues of mechanical systems and which will require mathematical modelling of those systems on the part of the student. We present some of the aspects that we consider that students must follow as part of the design and programming activities of a serious game. In this paper we focus on the specific case of the mathematical model of a class 1 lever and how this model can be embedded in a serious game for the learning of the concept of equilibrium in a system.

Keywords

serious games, constructionism, microworlds, learning trajectories, mathematical modelling

INTRODUCTION

Today many developers and researchers in education have turned to video games for use in the teaching and learning of science professions. According to what is stated in the study by Shaffer (2006), this is due to the fact that a game goes beyond simulating a physical phenomenon or emulation reality, by allowing the user (or student in this case) to engage in the "world" of the game and learn new skills that are the product of new forms of reasoning generated by this highly immersive activity. The pedagogical use of video games, has led to what is nowadays called Serious Games or SG. In our work, we take an unusual stance in the sense that we want students to design an SG in order to promote their learning: that is, instead of them simply engaging in a ready-made SG, we consider, using a constructionist approach, that their learning will be much more effective if they design and program the SG themselves.

THEORETICAL FRAMEWORK

To understand the study proposal it is necessary to define some of the concepts that we use, such as constructionism, learning microworlds, serious games, etc. We

also frame the proposal through a research literature review on the use of game engines as tools for building meaningful products.

Constructionism and microworlds as a basis for our proposal

The constructionist paradigm is based on Piaget's constructivism and was developed by Seymour Papert (see Papert & Harel, 1991); he defines it in the following way:

Constructionism – the N word as opposed to the V word – shares constructivism's connotation of learning as "building knowledge structures" irrespective of the circumstances of the learning. It then adds the idea that this happens especially felicitously in a context where the learner is consciously engaged in constructing a public entity, whether it's a sand castle on the beach or a theory of the universe. (Papert & Harel, 1991)

Thus the importance of providing learners with opportunities and a context to build hardware or software artefacts that are meaningful to him/her and engage with them. Kebritchi & Atsusi (2008, p. 1738) speak of the pedagogical foundation of educational video games today, and discuss a case of a game where constructionism was used to teach Electromagnetism by allowing the players to build their own game levels explaining that "new knowledge could be acquired more effectively if the learners were engaged in constructing products that were personally meaningful to them" such as their own game levels (Kebritchi & Atsusi, 2008; p. 1738). Our interest is similar in that we want to engage students in the building of the SG. We consider that engagement is a very important component when building something and students should be provided with the appropriate means so that this engagement is solid.

Following on the idea of providing students with a suitable context for engaging in the activity of "building a product", we also base our work on the concept of microworlds, which fits well with our proposal to engage students in the programming of a SG. Hoyles & Noss (1987) define a microworld as composed of four components: the student component (concerned with the existing understandings and partial conceptions that the learner brings to a learning situation); the technical component (constituted by the software or programming language and a set of tools which provides the representational system for understanding a mathematical structure or a conceptual field); the pedagogical component (the didactical materials and interventions that take place during the computer-based activity); and the contextual component (the social setting of the activities).

Thus, our proposal is based on a microworld with its different components in which students engage in the design of a SG for the learning of mechanical systems. The technical component is the programming environment where the SG will be built. The social component proposes collaborative work amongst the students. And for the pedagogical component we propose a didactic sequence to assist students in the construction of the SG.

Serious games

In a previous paper (Pretelín-Ricárdez & Mora, 2010), based on definitions provided by videogame designers (e.g. Juul, 2005; Prensky, 2001; Salen & Zimmerman, 2004; Salen & Zimmerman, 2006; Suits, 2005) and other authors (Klopfer, Osterweil & Salen, 2009; Michael & Sande, 2006; Raybourn & Bos, 2005; Zyda, 2005) we defined SG as a representation of an artificial conflict immersed within a story, delimited by previously defined rules where players seek to achieve a goal, through the optional and/or negotiable management of resources and decision-taking, whose consequences will lead to quantifiable results; and explained that the pedagogical aspect of the SG is embedded in, and subordinated to the story, and

can help develop, for the learning of sciences, skills and competences within a particular context.

SG were mainly conceived in order to take advantage of the advances of technology, and in this case of videogames, for professional training and development. Thus, SG have the characteristics of a game, but also have well defined pedagogical aims (usually related to the development of skills and competences) within a highly immersive context.

Game design for learning

Since the early days of computers in education, game design and programming has been proposed as a methodology for engaging learners (see, for example, Harel, 1990). The works by Yasmin B. Kafai and colleagues (e.g. Kafai & Resnick, 1996; Kafai, Franke, Ching & Shih, 1998; Kafai, 2006) present some of the foundations and structure of this methodology, and their relationship with the constructionist paradigm, even though those works are with younger learners than the ones in our study. One of the key ideas is that “game design provide[s] a situation that naturally combine[s] issues of practice and theory, and reflection on those relationships and game design provided opportunities for discussion, reflection, and collaboration within a meaningful context” (Kafai et al., 1998; p. 180). Other recent works in this area are those by Baytak and Land (2010), as well as that of Holbert, Penney and Wilensky (2010) which presents some considerations for implementing constructionism in the design of action games.

METHODOLOGICAL CONSIDERATIONS

It is common for engineering lecturers at undergraduate level to face questions by students on how mathematical concepts and tools relate to the real world in which they will work. These questions arise often when the mathematics that is being taught is not placed in the context in which it will be used. That is why there are calls for mathematics to be taught in the real life contexts in which they will be used (e.g Packer; 2003) so that they are truly meaningful.

We thus wanted to relate and contextualize the mathematics used in modelling in engineering. Generally (at least in our country – Mexico), in order to link the mathematical model the corresponding physical system, simulation software such as Matlab or LabVIEW, is used; however, even though this helps create a link between the two, a true contextualization of the simulated model of an engineering problem is not carried out.

That is why we are carrying out a study with a group of undergraduate engineering students on how to create a learning situation that both contextualizes the mathematical concepts as well as facilitates their learning; it is thus that we conceived to create a constructionist microworld for the programming –by the students— of a serious game (that would help contextualize the concepts). In order to build the SG, students would also need to mathematically model certain ideas, as well as construct simulations. For all of that, it is important to identify and establish a relationship between each of the components of the microworld, in order to establish a proper didactical sequence.

The main objective is that each student (or team of students) designs and programs (builds) a SG that is both effective and meaningful in the context of the engineering concepts that are being studied. Each student, or team of students, chooses a problem that is linked to a story that he/she will develop in the SG.

In this paper we present some of the considerations that students will need to take into account when designing and building a SG for the learning of the concept of equilibrium using a model of a first class lever system (where the fulcrum is located between the effort and the resistance).

A SG FOR THE LEARNING OF THE CONCEPT OF EQUILIBRIUM BASED ON A MATHEMATICAL MODEL OF A FIRST CLASS LEVER

The aim of this example is to describe and help understand the functioning of our proposed microworld, and how a learner and the technology in it would interact with the other components of the microworld. The SG will be constructed in the technological environment, but its foundation will be the story (which should involve in an adequate manner an engineering situation); the building blocks will be the theoretical mathematical concepts (abstracted within the programming code) that create the modelling of the system.

In relation to the latter, we recognise two levels leading to the abstraction of the theoretical concepts used by the student in what he/she will build:

1. In the programming code: through the description derived from the understanding of the mathematical relationships involved in the situation (equations and models).
2. In the actual contextualization of the SG into an engineering “story”.

Following is a description of the considerations that students will need to take into account in the construction process of the SG, and it is divided in three stages of design and one stage of implementation.

Description of the mathematical model embedded in the SG

For this section we consider the information given by Cejarosu (2005):

From a theoretical viewpoint, the lever is a rigid bar that oscillates on a fulcrum due to the action of two opposing forces (effort and resistance). In technological projects the lever, can be used for two purposes: to overcome forces or obtain displacement. From technological viewpoint, when we use the lever to overcome forces, we can consider four important elements shown in Figure 1.

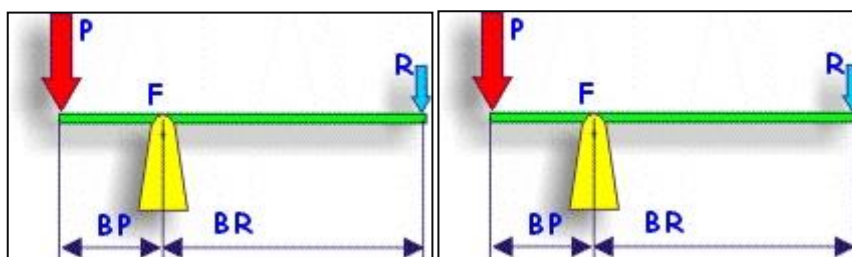


Figure 1: Lever elements

Figure 2: Law of the lever

- Effort (P): Force to apply.
- Resistance (R): Force to overcome.
- Effort arm (BP): Distance between the point at which we apply the effort (P) and the fulcrum.
- Resistance arm (BR): Distance between the point at which apply resistance (R) and the fulcrum.

The Law of the lever is formulated using these four elements as shown in Figure 2 and is mathematically represented as:

$$(P)(BP) = (R)(BR) \dots \text{Eq. 1}$$

Class 1 lever allows setting the resistance (R) on one side of the fulcrum and the effort (P) on the other, which can be very convenient for some applications. And according to the above, there can be three cases:

1. Fulcrum centred, implying that the effort and resistance arms are equal ($BP = BR$). Figure 3.
2. Resistance (R) close to the fulcrum, so that the effort arm (BP) would be greater than the resistance arm (BR). ($BP > BR$). Figure 4.

3. Fulcrum close to effort (P), so the effort arm (BP) would be smaller than the resistance arm (BR). ($BP < BR$). Figure 5.

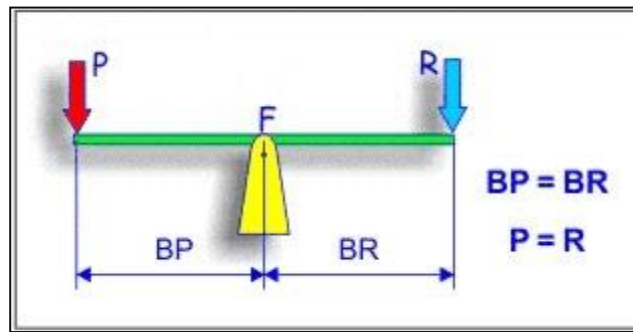


Figure 3: Case 1

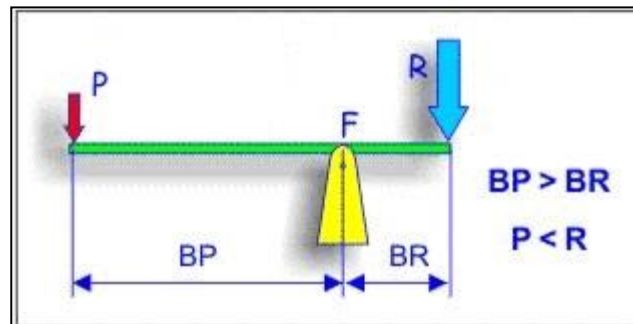


Figure 4: Case 2

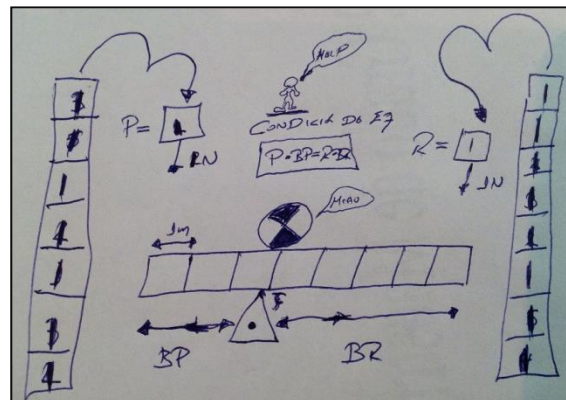


Figure 5: Outline of the interface SG

Having these theoretical concepts as a foundation, problems –or puzzles in videogame terms– can be devised.

Puzzle design

The design of the puzzle must be oriented to generate a "cognitive conflict" in the player (student), so that through interaction with the virtual world, he/she can acquire and build concepts that will allow him/her to solve the puzzle and advance to next level, having as consequence that knowledge will be gained.

With respect to the student who designs the puzzle, he/she must use the theoretical concepts given above and build a story where these concepts are embedded.

An example of a puzzle is shown in the sketch of Figure 5. It shows two columns of blocks with the number 1, which represent blocks weighing 1 Newton (1N); in the centre there is a graduated scale, whose fulcrum position may vary at each level or stage, making BP and BR dimensions vary and affect the equilibrium condition of the system, causing the character – which in the SG story is called Garagato – to

roll in a circle. The objective of the SG is to help another character –Garabato– to balance the system "placing blocks" of 1N in each end of the scale, to bring the system to equilibrium and thus prevent Garagato from falling by correcting the inclination of the balance. The user can activate a help button, found in the central part of the screen, that will tell the user whether or not the equilibrium condition, described by equation 1, has been reached.

Aesthetical aspect of the SG

This aspect is embedded in the story of the SG, and in the way in which the story will influence the user. The story is thus composed of elements of the user interface: characters, music and gameplay. The student-designer must be clear that his/her story will help define the play space where each element of SG coexists. The elements of the SG in the example are the following:

- **The SG story** occurs in the world of Garabato and Garagato; they are drawings that live in an engineer's notebook. In this case, Garabato has to balance the system's forces on the lever where Garabato likes to play so that he doesn't fall and get hurt.
- **The user interface** is the means by which the user interacts with the SG and vice versa, so it should be as simple and intuitive as possible, just as it should be designed according to the level of knowledge of the user. The flow of information also must be easy to access.
- **The characters drawings** ("blocks and characters") are very simple, but attempting to be charismatic to make the player identify with them. They are based on the design sketch shown in Figure 5, and are described in Table 1.

Table 1: Classification of blocks, characters and textures that make the SG interface.

Block	Description
	BLOCK END OF THE SCALE. It is the block that is in each of the two ends of the scale. It's a solid block.
	BLOCK OF THE SCALE 1. It is a block that constitutes the balance. It's a solid block.
	BALANCE BLOCK 2. It is a block that constitutes the balance. It's a solid block.
	FLAG. It is located in the upper part of the balance. It helps the player measure the extent of BP and BR.
	FULCRUM. Is the fulcrum of the scale, where GARAGATO is placed. It appears along the scale at the bottom.
	ONE BLOCK. It represents the inside blocks. These blocks having drawn a number 1. Represent a block of weight 1 Newton. They help the player move them to the ends of the scale and balance the system.
	TEXTURED CRUMPLED SHEET. It's the texture that appears in the scenes of the SG.
	GARABATO. It is a humanoid-shaped pattern. Is the main character of the SG. He can be moved from left to right. With the help of the player, this character can help his mascot Garagato.
	GARAGATO. It is Garabato's mascot. He is the representation of a point in a mechanical system. He rolls and loves to jump.

- **The music** of the game is very important, because it reinforces the level of immersion that can be obtained largely through the images that make up each of the acts.
- **The gameplay** should be simple and intuitive. With simple but powerful rules. The gameplay of this SG is limited to the user who can click on one of the "BLOCK ONE" that are stacked on the left and right of the scale; he can do this as often as deemed necessary to balance the system.

Educational model of SG (EMSG)

In order to establish the EMSG, we use the ideas proposed by Amory & Seagram (2003), such as the Game Achievement Model (GAM), that provide a useful way for developing and documenting educational games. "GAM is an efficient, well conceptualised and supportive model that can easily contribute to successful development and writing of stories for complex learning environments" (Amory & Seagram, 2003, p.207). In order to establish the GAM for the SG, "the first priority ... is to define the learning objectives and to outline the basic story" (Amory & Seagram, 2003, p. 213). This priority is shown schematically in Figure 6a, where the learning objectives' relationship to the story are represented when designing and implementing each of the acts of the SG.

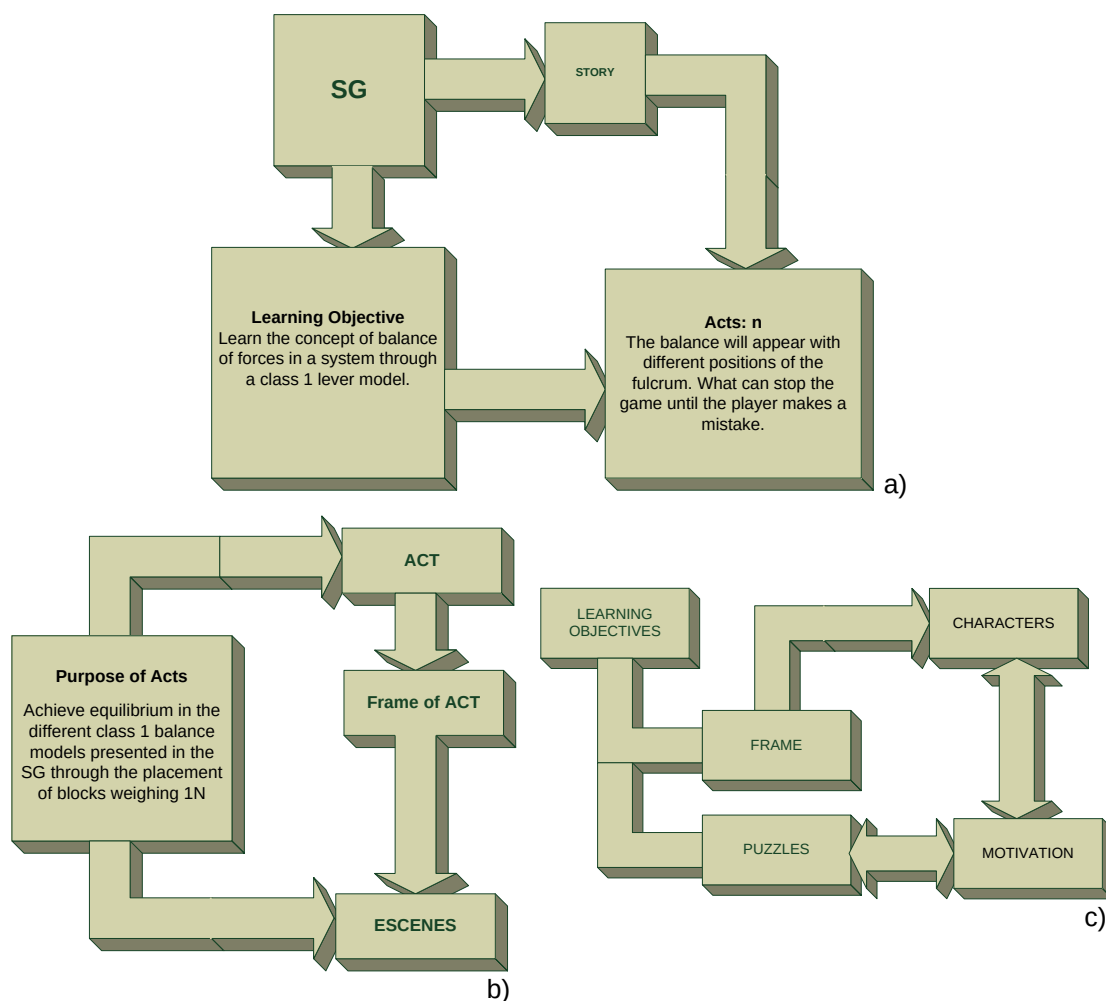


Figure 6: GAM for the SG

Figure 6b shows the purpose of each act and the "plot of the act" that feeds a scene. Figure 6c shows the relationship of the "learning objectives" and the plot with the puzzles and how these in turn are related to the motivation of the user (player)

who interacts with the elements of the SG through the character. Thus, the GAM describes how each of the design aspects relates to each other during the implementation; the GAM constitutes a powerful tool to understand the role of each of the elements present in the SG.

Software and Hardware Implementation.

The example presented here was built using a Windows-based PC. The software used for programming the SG was Game Maker Studio and for programming and editing some graphics and sound. Paint was used for creating and editing graphics. Figure 7 shows a screenshot of one of the scenes of the SG, implemented in the game engine Game Maker Studio.

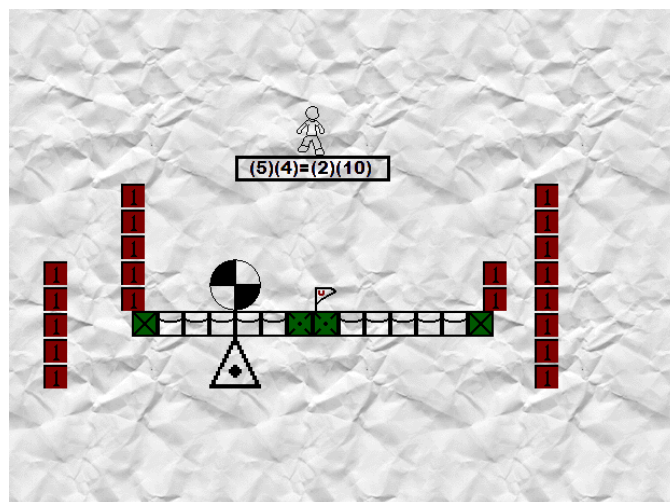


Figure 7: A screenshot of the SG implemented in Game Maker Studio

FINAL REMARK

In this paper we have presented a proposal for students to construct SG as a possibly significant activity that may help them relate and contextualize their learning about mathematical modelling with their engineering practice. We look forward in future papers to present results of our study.

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