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CONSTRUCTION OF VIDEOGAMES BY ENGINEERING STUDENTS FOR UNDERSTANDING MODELLING PROCESSES

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Aim of this work

- Promote modelling learning through the use a constructionist approach of videogame design.

- Students understand mathematics and their relationships, constraints and concepts involved in the modeling processes.

THEORETICAL FRAMEWORK

Model-eliciting activities (MEAs)
(Hamilton, Lesh & Lester, 2008)

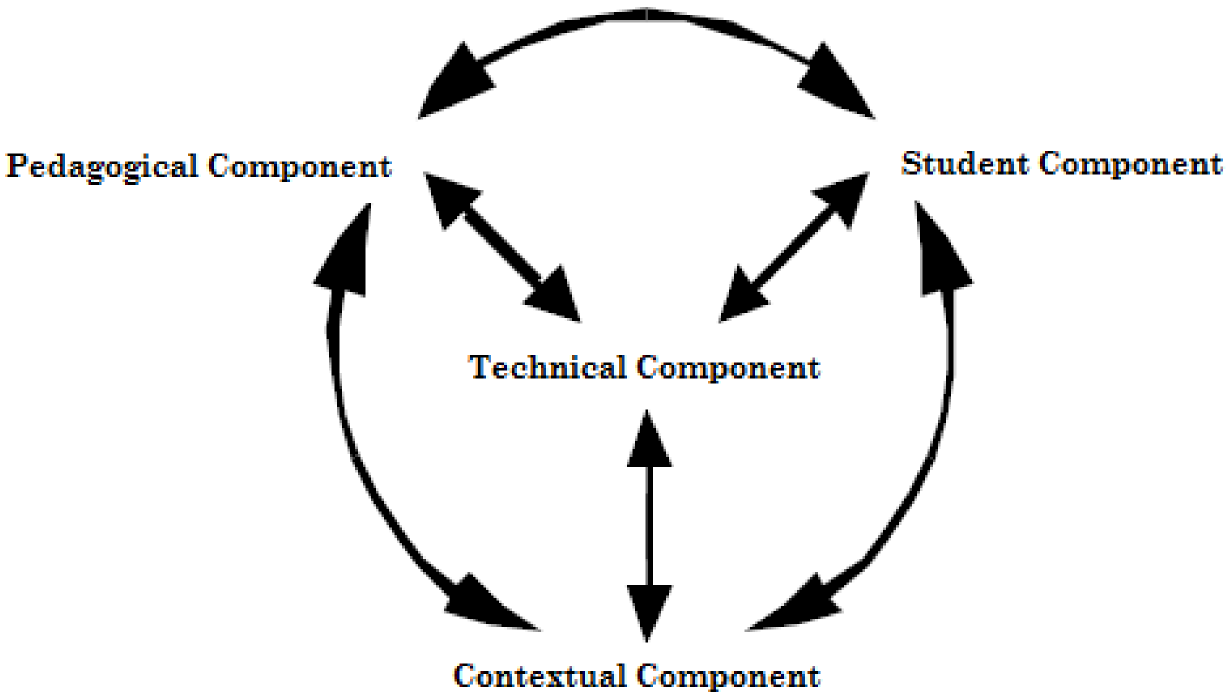
Constructionism
(Papert & Harel, 1991)

Building-videogames Based Learning (Kafay, 1995)

Computer-based Microworlds
(Hoyles & Noss, 1987)

METHODOLOGICAL CONSIDERATIONS

The components of the microworld



(Hoyles & Noss, 1987, p. 591)

The activities sequence

Initial questionnaire

- What step are needed to build a model?

Activity 1

- Collaborative
- Developing the videogames idea

Activity 2

- Individual
- Building a model of water behaviour
- Non traditional problem
- Previous knowledge needed: Algebra, vector calculus, differential calculus, fluid mechanics

Activity 3

- Collaborative
- Simplifying the model
- Building Simulation
- Building videogames

Post questionnaire

- What step are needed to build a model?
- Draw a block diagram of steps above

Activity 1

- Each team of two students had to develop an idea for their videogame.
- They designed a brief story-board of up to 4 images, and adding a brief description of the gameplay.
- We required that the gameplay used water as the main element to solve puzzles and complete levels.

Activity 2

- The task is presented, not as a traditional problem statement, but as an open problem, as it happens in real life.
- Students had to construct a mathematical model of the water behaviour, that included realistic physics, for implementing it in the previously designed game.

ACTIVITY 2 (CONT.)

- Some models of Water.

Felipe's model (molecular model)	Javier's model (continuous model):
Felipe built a, mathematical model, based on, intermolecular interaction force. $\overrightarrow{F_{12}} = -\frac{\partial e_{12}(d)}{\partial \overrightarrow{r_1}} = 6\frac{e_0}{d_0}\left[2\left(\frac{d_0}{d}\right)^{13} - \left(\frac{d_0}{d}\right)^{7}\right]\frac{\overrightarrow{r_1}-\overrightarrow{r_2}}{d}$ Where: e_0 **,Finite distance at which the inter-particle potential is zero (potential well)** $d_0 \approx 3\times10^{-10}m$**, Critical distance** $e_{12} = e_0\left[\left(\frac{d_0}{d}\right)^{12} - \left(\frac{d_0}{d}\right)^{6}\right]$**, Potential energy of interaction between molecules (Lennard-Jones Potential)** $d = \lvert\overrightarrow{r_1}-\overrightarrow{r_2}\rvert$**, Intermolecular distance between two molecules**	Javier built a, mathematical model, based on, water macroscopic behavior. $\rho(\vec{r},t) = \lim_{\Delta V\to0}\frac{\sum_{i=1}^{N(\Delta V)} m_i}{\Delta V}$ **, Local density** $\vec{v}(\vec{r},t) = \lim_{\Delta V\to0}\frac{\sum_{i=1}^{N(\Delta V)} m_i\vec{v_i}}{\sum_{i=1}^{N(\Delta V)} m_i}$**, Local speed** $E(\vec{r},t) = \lim_{\Delta V\to0}\frac{\sum_{i=1}^{N(\Delta V)}\frac{1}{2}m_i\lvert\vec{v_i}\rvert^2 + \frac{1}{2}\sum_{i=1}^{N(\Delta V)}\sum_{j=1(j\neq i)}^{N\Delta V} e_{ij}}{\sum_{i=1}^{N(\Delta V)} m_i}$ **, Local energy** $\frac{E(\vec{r},t)}{\sum_{i=1}^{N(\Delta V)} m_i} = \frac{1}{2}\lvert\vec{v}(\vec{r},t)\rvert^2 + u(\vec{r},t)$ **, Specific energy** Where: $N(\Delta V)$**, The number of molecules contained in the volume** ΔV **at time "t"** $\vec{r}$**, It is the position vector of the point where you are considered local properties** m_i**, It is the mass of a given molecule** $\vec{v_i}$**, It is his molecular speed** e_{ij}**, It is his potential energy** u**, The internal energy contained in the volume element**

Activity 3

- The two students **shared** their mathematical models.
- In discussing them, noted that **it would not be possible** to simulate them for validation in the game engine (Game Maker Studio),
- Concluding that they must **simplify the model**

ACTIVITY 3 (CONT.)

- For constructing an appropriately simple model, students had to take into account certain **constraints and relationships** of the physical engine of GameMaker Studio:

  - The metric system,
  - Scales, and
  - Instead of the model being applied to a real 3D environment, it had to work in a virtual 2D world.

- This implied adapting the formulas.

Activity 3 (Cont.)

- Some constraints in physics engine (inside the game engine):
  - Uses as measuring system the metric one,
  - but limits objects to have a size equivalent to between 0.1 m and 50 m;
  - however it also sets that pixels should not be in a one-to-one (1:1) relationship with meters, and
  - radians are used as angles.
  - Thus, the scaling ratio used by students, inside the virtual physical world, was 10:1 (i.e. 10 pixels equal 1 m).

Activity 3 (Cont.)

- A important relationship in the simulation was to establish the value of the constant of **gravity acceleration (g)**.

- For this, the students decided that the constant, which is equal to **9.8 m/s^2** , should be rounded to **10 m/s^2**, due to the scaling factor that they needed to use;

- **this meant that the acceleration would be of 100 pixels per second, every 30 steps, in the direction 270°.**

ACTIVITY 3 (CONT.)

- The value of **g** affects every object in the virtual world differently, depending on the properties of that object:
  - **Density**,
  - **Friction coefficient**.
  - **Linear damping**,
  - **Angular damping**,

ACTIVITY 3 (CONT.)

- To set the value of **density** for each water particle simulated in the virtual world, students had to take into account that the density used was not a **volumetric density one (3D)**, but a **surface density (2D)**:

- That is, $\boldsymbol{\rho=1000\ Kg/m^2}$ (with square meters, instead of cubed as in $\boldsymbol{\rho=1000\ Kg/m^3}$).

Activity 3 (Cont.)

- In GameMaker Studio, **friction is defined as the force that resists movement or slippage of a material over another, as can happen when two materials collide in the virtual physical world**.
- The friction value must be between zero and one.
- In this case, because the students were **modelling water** which is a fluid, they tried **to define this coefficient as a coefficient of viscosity** expressed in Kg/m*s, giving it a value of 0.01, considering that the viscosity value between water particles is very close to 0.

ACTIVITY 3 (CONT.)

- Another property, is the **restitution coefficient** that indicates **the amount of kinetic energy that remains after a collision between particles or objects**;
- That is, **this coeffcient refers to the level of "bounce" between particles**.
- The restitution value is between zero and one.

Activity 3 (Cont.)

- The students had to establish relationships for the **linear and angular damping**, which refers to **the forces that oppose the linear and rotational (angular) motion of a particle (like air friction)**. Air friction dampens water motion.

- A simplified representation of air friction is the formula **Af = -K*v**,
  - where K is the damping coefficient dependant on the shape of the body, and v is the velocity of each particle, dependent on its interactions in the virtual world.

- Damping forces are normally expressed with values between zero and infinity, but **the game engine uses a simpler method, giving shapes that have less air resistance (i.e. round ones) values close to zero and rectangular shapes that have more resistance, values near 1**.

Observations

- Through the MEAs, students engaged in producing a working model that was **meaningful** for them.
- The activities also led them to reflect on what is involved in a modeling process

Reflecting on the process

- Students gained a **deeper understanding** of all **elements involved** in the modeling process

Many students commented on how

- the teachings they had **previously** received had given them an **incorrect conception** of what is involved in a modeling process:
- they had a **traditional view of a "problem statement"** that requires a **fixed, final answer**.
- But now they understood **a modeling process, as an iterative and improvable activity**.

Future Work

- Experimentation with **other models of physical systems**
- Using more robust videogame engines, like **Unity 3D**.

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Thank you!

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STUDENTS' CONSTRUCTIONS (THE SIMULATION AND VIDEOGAME)