Serious Games Design
A tutorial

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Goals of the tutorial

Introduce learners to the design of educational serious games

Allow learners to be able to prepare a proper document design for an educational serious game, given a set of specifications

Subgoals (and structure of this presentation)

- Have an idea about collection of requirements from stakeholders
- Have an overview of pedagogical approaches that are mostly relevant for SGs
- Understand how they can be mapped to game mechanics
  - Particular focus on items such as: assessment, feedback, collaboration, plot/story
This tutorial is strongly related to the SG Analysis Framework that we used for SG studies.

- We exploit is a reference tool

We propose a Top-Down approach, but it is an iterative process.

- Not all the points should be addressed in sequence
- Some points may be skipped
- Some *(all, in principle)* points could be updated later
Designing a serious game

A multidisciplinary challenge

Theory
- Pedagogy
- Cognition
- Learning
- Psychology
- Flow/presence
- Perception
- Behaviour
- Learning

Contents
- Museum
- History
- Mathematics
- Science

Game design
- HCI
- Storytelling
- AI

Goals
- Rules
- Levels

A/V
- 2D/3D graphics
- Programming
Putting it all together in a meaningful whole

Different (if not conflicting) goals

- Pedagogy
  - Rigorous provision and verification of knowledge
  - Determinism
  - Efficiency
  - Avoid misconceptions, guidance
  - Distinguish reality from fiction

- Games
  - Fuzziness
  - Chance
  - Repetitiveness
  - Trial and error, free exploration
  - Suspension of disbelief

Common aspects

- Feedback (formative and summative)
- Hyphen on motivation
- Problem solving
- Inquiry-based learning
Putting it all together in a meaningful whole

 neuropedagogical perspective

This the challenge of SG design

All the topics/concerns related to pedagogy/contents and entertainment must be addressed together since the beginning of the design since:

- superimposing a posteriori game mechanics over an exercise only seldom creates a fun/entertaining SG
- inserting a posteriori cultural/curricular contents inside a game only seldom creates valid educational tools
Requirements (I)

Collection and elicitation of the requirements
- Interviews, questionnaires, domain analysis, field studies, literature review

Who are the end-users?
- Demographic aspects
- Any relevant feature
- Different categories? (may imply personalization or different versions)

Who are the buyers?
- (What is the business model?)

Who are the stakeholders?
- E.g., parents, educators, museum/exhibition curators, etc.

What do they need from the game?
- Stress in particular the learning/educational objectives
- Collaborative?

What do they expect from the game?
- Consider also the entertainment goals/constraints
What is the context of use of the game?

- Usability aspects
  - Constraints, expectation
- Constraints on costs, technologies, etc.?

- What is the novelty of the game?
  - Study the state of the art and state your main innovation
  - Be focused on particular strengths

- Merging and reconciliation of the requirements
Prepare one or more requirement tables
  ➤ Write in bullets to be synthetic

Write text use cases of your game
  ➤ If you have time…

Your game will need to support/comply with all these requirements

You will then need to derive the features of your SG on the basis of these requirements

And you will need to check that your SG meets these requirements
  ➤ Expert and user focus groups
  ➤ Expert evaluation
  ➤ (Field) user tests
Pedagogical requirements in detail

What should the players learn?

- Focus on the contents
- Define «learning units» (for knowledge and/or skills)
  - Specify difficulty levels
  - Specify dependencies among units
    - Overall oriented graph structure (Game knowledge/skill Graph - GKSG)
    - Loops may be possible
  - Specify (additional) pre-requisites for every unit
  - Specify the expected learning outcomes
  - Specify success conditions (the unit may be repeated?)
  - Specify how knowledge/skill acquisition could be verified
  - Time constraints?

(Write in bullets)
Learning theories/approaches/strategies

Learning happens is different ways

Let’s have a look at some established learning theories (in the SG and technology enhanced learning literature) to get inspiration

You do not need to follow all of them
You may consider just one of them

Our selection:

Revised Bloom taxonomy
Kolb’s Learning stages
Cognitive Load Theory
ARCS model
Personalism
A taxonomy of Learning goals

**Remember**
- Recall information
  - Recognize, list, describe, retrieve, name, find

**Understand**
- Explain ideas or concepts
  - Interpret, summarise, paraphrase, classify, explain

**Apply**
- Use information in another familiar situation
  - Implement, carry out, use, execute
Revised Bloom taxonomy

▲ Analyse
- Breake info into parts to explore understanding and relationships
  - Compare, organize, deconstruct, interrogate, find

▲ Evaluate
- Justify a decision or course of action
  - Check, hypothesize, critique, experiment, judge

▲ Create
- Generate new ideas, products or ways of viewing things
  - Design, construct, plan, produce, invent

More detailed info:
How to use the Revised Bloom taxonomy?

You should select one knowledge item/skill and an associated learning goal type from the taxonomy.

Examples:

- Retrieve from a list all the cities in Africa
- Use your knowledge on the typical African tissues to select an African cloth within a set of clothes
- Compare a set of possible decisions and choose the most suited to achieve a goal
- Interrogate several witnesses and identify the lier
- Make hypothesis about the next step of a process
- Plan the next steps to defeat the enemy or to overcome your market competitor
Kolb’s learning stages

- This cycle is particularly relevant for simulation games

- Think – The player studies a context (situation, environment, e.g., a company)
- Plan - Takes some decisions (e.g., sets parameters such as the prices of his products and the amount of production)
- Do - The simulation runs (e.g., one month of market) and the player sees the outcomes (e.g., how many products have been sold, what the revenues are, how customers are satisfied)
- Observe – The player reviews the results (e.g., graphics, historical trends, etc.) and reflects about the outcomes of his choices
How to use the Kolb’s learning stages?

- A proper educational tool (a SG, in our case) should well support all the steps of the Kolb’s experiential learning stages

- Think of SG situations, scenarios and mechanics that would trigger/support/stimulate all the steps

  - Particular attention to:
    - Allow the player to experience as well as possible all the aspects of the game scenario/situation/simulation
    - Support the player in reviewing and reflecting about his performance and what is happening
    - Stimulate conceptualization and conclusion making and experience
    - Allow the player to control parameters in a fair and appropriate and effective way

- Think of graduality

- Particularly suited in simulation SGs
Cognitive Load Theory

- Relies on the hypothesis that **short term memory** is limited in the number of elements it can contain simultaneously and must not be overloaded.

- Sweller builds a theory that treats **schemas**, or combinations of elements, as the cognitive structures that make up an individual's knowledge base.

- The contents of **long term memory** are "sophisticated structures that permit us to perceive, think, and solve problems,". These cognitive structures make up the knowledge base. **Schemas are acquired over a lifetime of learning**, and may have other schemas contained within themselves.

- From an instructional perspective, information contained in **instructional material must first be processed by working memory**. For **schema acquisition** to occur, instruction should be designed to **reduce working memory load**.

- Cognitive load theory is concerned with techniques for **reducing working memory load in order to facilitate the changes in long term memory associated with schema acquisition.**
Cognitive Load Theory

**Intrinsic cognitive load**: Is the intrinsic mental effort needed to learn a certain unit of knowledge.

**Germane load**: Is the load that helps building new complex schema in a successive manner helping the learner to move from novice to expert. It is a self effort to learn, and memorize information learned.

**Extraneous cognitive load**: Results from the techniques in which the to-be-learned information is presented. Extraneous cognitive load does not contribute to learning.

**The total cognitive load** is the sum of the three above.

Modifying the instructional material to engineer a lower level of extraneous cognitive load will facilitate learning.

Good instructional design
Eliminate the working memory load associated with having to mentally integrate several sources of information by physically integrating those sources of information.

Eliminate the working memory load associated with unnecessarily processing repetitive information by reducing redundancy.

Increase working memory capacity by using auditory as well as visual information under conditions where both sources of information are essential (i.e. non-redundant) to understanding.
Possible supporting SG elements

- Tutorials
- Maps for better exploring the space
  - Possibly, with status information
- Objectives’ list
  - Possibly, with status information
- Landmarks in 3D worlds
- Contextualized helps
  - Non-virtual characters
  - Triggered on particular conditions (when the player is in difficulty – see also the slides on «Assessment»)
- Bookmarks
- Animated worked examples (cut scenese)
- Graduality of levels
- User profiling to avoid useless repetitions
ARCS model

A model based on a synthesis of existing research on psychological motivation

- Focus on learner’s motivation

ARCS is an acronym that represents these four classes: Attention, Relevance, Confidence/Challenge, and Satisfaction/Success

Attention

- Goal: gain and keep the learner’s attention
- Means: sensory stimuli (alerts, use different media), inquiry arousal (raise questions, suggest missions and tasks), variability (introduce variability elements)
ARCS model

Relevance
- Goal: learners need to know how the activity relates to their current situation, and/or to them personally
- Means: goal orientation (know and meet the user needs), motive matching (allow choices and responsibilities), familiarity (tie instruction with the learner’s experience)

Confidence/Challenge
- Goal: the activity cannot be perceived as either too hard or too easy
- Means: adaptivity, keep the flow, build a positive expectation for success, success opportunities (enhance the students’ belief in their competence), personal control (awareness that success is related to personal effort and abilities)

Satisfaction/success
- Goal: Learners must attain some type of satisfaction or reward from the learning experience (internal or external to the learning experience)
- Means: awareness of the achievements, awareness of the positive consequences of the newly acquired knowledge, internal/external rewards, badges, charts, standings, earning analytics, etc.
For ARCS, like for other educational strategies, it is key to profile the user in order to estimate the attention status (see also the «Assessment» slides)
Education as a human relationship between a child (learner) and adult (teacher) who introduces to reality (free) questions and answers

Focus on supporting the relationship

Real-world hooks and references

Augmented reality

Mobile games

Territorial gaming

References to other media
Mapping to SG mechanics

- The game designer should select the above seen learning goals/activities that best match the pre-defined requirements.

- Every learning goal/activity should be:
  - supported by proper content
  - mapped to concrete game situations (mechanics)

- This is a very critical point

- Every choice should be consistent and properly justified
SG mechanics/components

Main info sources: the Game Ontology Project (GOP) and T. Hussain, "Serious Game Design Tutorial," Gametech 2012

.interface
  - mapping between the actions of the player and the manipulation of game entities
  - Receiving the feedback from the game

.rules
  - Constrain what can and can’t be done in a game
  - Determine the basic interactions that can take place within the game

.goals
  - Objectives or conditions that define success in the game

.entities
  - Objects in the game that the player manages/modifies/interacts with

.entity manipulation
  - Alteration of the game made by player or in-game entity
  - Actions that can be performed by the player or in-game entity
SG mechanics/components

User Interface:
- scoreboard, screen, keyboard, charts/standings, physiological sensors, time indicator, performance meter, odometer, dashboard, cockpit, tactile output, touch-screen, stylus pen, point of view, point & click interface, cameras, bio-feedback, aural output, warning, alarm, notification, 3D, 2D, etc.

Rules:
- Bonus, checkpoint, difficulty levels, dynamic difficulty adjustment, mission, tasks, dialogues, segmentation, game ends, lives, level, narrative, spatiality, matching, social interaction, social networking, time, etc.

Goals:
- Score computation, performance record, performance metrics, rewards, gadget, learning experience etc.

Entity manipulation:
- collect, encounter, acquire, gain, etc.

Subdivision is somehow arbitrary, and we are interested also in some (transversal) SG-specific aspects such as:
- Assessment
- Feedback
- Plot/Story
- Guidance
- Graduality
- Cooperation/Collaboration
Before going in detail: game genres

You should choose a SG genre:

- Mixed solutions are also possible

Examples from the cultural heritage domain

- Adventure 3D
  - Battle of Themopylae, Revolution, TiE
- Adventure (point and click) 2D
  - TimeMesh, The Plague
- Strategy 2D
  - Expedition the game
- Simulation 2D
  - Building Detroit
- Documentary 2D
  - The cat and the coupe
- Trivia/puzzles
  - The great bible race
- Territorial (mobile) game
  - VeGame (can be a mix of the above – the definition criterion concerns the use, not the contents/interaction, differently from the above)

- Other?
Before: game models

- You may follow a game model
  - SG Sandbox model
    - 3D context environment to be explored
    - Tasks (minigames) assigned in relevant points
  - Treasure hunt
  - Snakes and ladders
  - Board game
  - Other
- You can also think of one or more specific games
Plot/Story

Typical story elements to be defined
- Characters (player avatars and non-player characters), settings, voice, plot, conflicts, events, themes

Structure:
- Introduction
- Breaking event
- Climax
- Solution

Typical elements
- Quest, race, competition, cooperation, surprise, affectivity, etc.

Could be schematic at high level
- E.g., treasure hunt

Think of graduality and levels (cfr the «Graduality» slides)

Think of interactive storytelling
Introductions and conclusions

- **Why?**
  - Create/strengthen the plot
  - Explain the value of the next/previous step in the game
  - Introduce/make clear the educational value of the next/previous step

- **When?**
  - At the beginning of the game
  - At the beginning of each level/task/mission

- **How?**
  - Cut-scenes
  - Texts

Dialogues with the NPCs

- **Closed dialogues**
  - The player chooses among a set of predefined questions

- **Open**
  - Natural language processing. The system answers with the best-matching answer from a database of possible answers

  - **Support for inquiry-based learning**

Narration/voice over

Sound effects/jingles/motives/soundtrack
Graduality is key for any pedagogical activity

Scale difficulty of contents and challenges

Graduality should be employed to pass from extrinsic motivation (at the beginning of an educational process, where the teacher) to intrinsic motivation (at the end)

See also next slide

Graduality may be reflected in games through game mechanics such as:

- Levels
  - Define the levels
  - Start and end conditions (time elapsed, achieved goals, etc.)

- Personalization/adaptation
  - Define the conditions and the personalized/adapted components/items (see also next slides)

Other?
Graduality: the continuum from game to simulation

Combine extrinsic and intrinsic motivation

More game-like
*(extrinsic motivation)*

More simulation-like
*(intrinsic motivation)*

Knowledge/skill is expected to increase as time elapses

Parameters to be tuned during the transition: structure, rules, targets, timing, assessment, feedback, virtual vs. real world rewards
Adaptation

- Keep the flow
- Adapt difficulty to the user level
- Provide motivation, in particular for the weaker users
- Support weaker users (also to increase competitiveness), also through score
Assessment

Assessment is key for any pedagogical activity.

The game should continuously (or at some check points) assess the player activities according.

It is necessary to define a user profile able to capture the skill/knowledge dimensions.

- For instance, the user should be able to successfully complete the whole game knowledge/skill graph (GKSG) defined in the pedagogical requirements. This may be a data structure that could be employed.

The system should be able to update the player profile in real-time.

How is the score computed?

- Are there different (weighted) dimensions?

Are performance metrics defined?
Assessment

How does the game implement all the assessment/verification items defined in the pedagogical requirements? (in order to fill the user profile)

- Through questions? Assessment tasks (quizzes, minigames) at checkpoints? Evaluating the player actions?

Stealth/embedded assessment should not interrupt the user experience/flow

- Assessment by processing data from the game play
- Possible user moves and interactions should be carefully designed to support assessment
- You should define all the in-game actions/events/data that should be recorded and how they should be processed in order to update the user profile

Assessment is a key enabler for feedback provision and assessment/personalization
Feedback

Relying on proper assessment, it is necessary to provide feedback to the player

- Precision, accuracy, tutoring

Formative (real-time, push or on demand)

- Consider efficacy, efficiency, intrusiveness with respect to the flow, cognitive load

Summative

- (detailed) performance summary at the end

What mechanics?

- Learning analytics, charts and standings, (segmented) player rankings, bonuses, performance meter, performance dashboards/displays, multimedia alerts, suggestion signs on the screen, «virtual teacher» interventions, passage of level, lives, end of game, timer display, summary of state with regard to the best/ideal, others

Consider the various pedag. strategies/theories (in particular the ARCS motivation model)
Learning analytics

- Graphics showing:
  - Historical trends, (quantitative) relationship among different measured dimensions/parameters (score, precision/accuracy, time spent in a level, number of level passed, number of wrong attempts, age, sex, estimated competence in some topics, etc.)

- Supporting learners’ self-assessment to take decisions and improve learning

- Supporting teachers’ assessment to take decisions and improve teaching
Guidance mechanics

Guidance is very important, in particular in the light of the Cognitive Load Theory

Introductions and conclusions, dialogues with an NPC, already presented in the «Plot/Story – possible mechanics» slide
  ➢ Explicit/implicit instructions

Educational briefing
  ➢ Explain the educational goals
  ➢ Provide hints/clues that will orient/guide the player experience/quest

Map
  ➢ With some status information, landmarks

Objectives’ list
  ➢ With achievements reported

Cues and hints
  ➢ Visual, in dialogues

Bookmarks

Mouse-over information

Explicit references to more in depth info, typically on other media
Cooperation and collaboration

Cooperation

- Team mates cooperate when they do different tasks (without a significant interaction) to achieve a shared goal

Collaboration

- Team mates collaborate when they do some tasks (with a significant interaction and proper negotiation and agreement) to achieve a shared goal

How can this be supported through game mechanics?

Possible examples:

- Micro-blogging
- Chat
- Sharing of information (through verbal, text communication) that is (or an be) available to only one of the participants but is necessary also to the others
- Sharing of energy/resources, under what condition?
- Bonus score for collaborative behaviour
- Joint rewards (score, badges, etc.)
Every SG mechanics/situation should have a relationship with at least one of the pedagogical elements, such as:

- Bloom: remember, understand, apply, etc.
- Kolb’s: do, observe, think, plan
- Etc.

Put all together in the graphic representation in the SG Analysis and Design Framework (SGAD)

Always explain and justify your choices
The SGDA includes:

- A dynamic timeline, where the learning activities/goals and mechanics are specified for every level
  - In order to avoid repetitions, in the next levels only the differences with respect to the previous one are specified (e.g., increased question difficulty, reduced available time, new/missing mechanics, different modalities/weights in computing the score), assuming the rest to be the same

- A static document (the SG description template) with a general overview of the game, also including the static elements (e.g., tutorial sections, help pages, score/performance/analytics pages, etc.)
Deployment

How will the game be deployed?
  At home, mobile, in a kiosk, rented device, etc.

Context

Role of the teacher/guide/educator/attendee
Miscellaneous suggestions

- Consider using metaphores
- Be consistent in the choices
- Make the mechanics/implementation consistent with the message/content
- Carefully consider the time factor
The Game Ontology Project (GOP), [www.gameontology.com/](http://www.gameontology.com/)
T. Hussain, "Serious Game Design Tutorial," Gametech 2012
The end

Thank you for your attention!

Questions?

www.galanoe.eu
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