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APPROACHES ON METRICS AND TAXONOMY IN SERIOUS GAMES

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Abstract: *Serious Games, along with the various definitions they entangled and the multifaceted approaches they benefitted from in relation to their applicability, are and still gain ground in becoming a resourceful educational material provided they are used as a means to an end, the educational objectives per se. What research still has to cover is a rethinking of all the elements in terms of educational effectiveness, given this landmark has got new dimensions with the 21st century.*
In this context, SGs offer new ways of learning which are highly consistent with the competence-based approaches that are also reflected in modern theories of effective learning. Subsequently, in deploying Serious Games on the realm of education and training, special tools will be claimed as mandatory in order to both know what games to use, when and where, for what reasons, but also how to measure the gain and the usefulness of playing a game. This stresses the need for an accurate work on taxonomy and metrics, a topic that is currently under complex development within GaLA (Game and Learning Alliance) NoE (Network of Excellence) funded by the EU under the 7FP.
This paper documents new perspectives on Evaluation metrics and taxonomy in Serious Games , considering state of the art taxonomies and repositories, such as the Serious.GameClassification[7], Imagine[8],Engage learning[9] databases; in this respect, a new knowledge space is being developed, based on the following dimensions: description/classification of SG, analysis of SG components, application domains, pedagogy, deployment and technologies, with the pedagogical dimension divided into two parts- theoretical frameworks and pedagogical outcomes. Such tools for a multi-faceted end-user from educator to student and labour market stakeholder, from corporate to industria will eventually contribute to a standardized vision over what educational effectiveness represents in the context of Serious Games.

Keywords: *serious games, metrics, taxonomy, educational effectiveness.*

I. SERIOUS GAMES TAXONOMY

There has been a plethora of literature within the Serious Games topic, trying to develop on assessment and strategies of evaluating both the game as such and the effectiveness of its use. What is important yet when we focus on the benefits of using games inside the educational process, as a means to transfer knowledge or improve skills, is to have a set of criteria that would help the instructor , the learner and all the other stakeholders involved measure to what extent the objectives have been met. In order to be able to provide a set of metrics that would thoroughly assess SG's **educational**

[7] serious.gameclassification.com
[8] www.imaginegames.eu
[9] www.engagelearning.eu

effectiveness, their usability and ability to shape user's cognition and skills , a taxonomic approach would help in covering perspectives from which a game could be evaluated to state its power to shift attitudes, build knowledge or give hands-on training, to see "when a game is appropriate for learning as well as what aspects of the game benefit learning outcomes"- [1]

1.1. State-of-the-art

A comprehensive , multi-purposed taxonomic approach of Serious Games can only be rendered by a concerted effort of pooling in expertise coming both from pedagogy, game design and mechanics, psychology on the one hand, and application fields on the other. A well built comprehensive taxonomy will best help revealing descriptors of games, users, and environment that lend themselves to metrics so that measuring criteria can be defined and from here- measurable elements.

A lot of work has been done about SG categorization and literature has some important papers on this topic. Taxonomies have been proposed classifying SG according to different criteria, such as application domains [[2] markets[3], skills ,[4]; [5], learning outcomes [6].These categorizations show the educational (some put it also more simply, speaking of concreteness or closeness to the real-world) added value of SGs with respect to games, for which a meaningful categorization can still be considered the one by Herz, [7], that involves the following categories: action games, adventure games, fighting games, puzzle games, role-playing games, simulations, sport games, strategy games. A more recent taxonomy is slightly more simple: action games, strategy games, adventure games, simulation games, puzzle game educational games.

A very comprehensive and transversal approach to SG classification has been proposed by Sawyer B. & Smith, [8], which rapidly became a reference, proposing a matrix of two major criteria: market (the application domain) and purpose (initial purpose of the designer). Items in the first dimension include: government, defense, marketing,education, corporate, etc. Items in the second include: advergames, games for health, games at work, etc.

[Kickmeier-Rust et al., [9] introduces the following categories based on the psycho-pedagogical and technical level of games:

- Mini Games for Young Children. Often the game genre is based on trivia, puzzle, memory, or drill and practice (in a positive sense) styles.
- Simulation Games, that basically pursue a drill and practice approach to certain procedural, strategic, or tactic skills.
- Off-the-Shelf Games / Moddings. This approach uses commercial off-the-shelf games for educational purposes
- Game-like Enhancements for Learning Material. Such approach incorporates small games as training for a specific limited set of skills.
- Competitive Educational Games. This term indicates games with a primarily educational purpose that – at the same time – can compete with commercial entertainment games as well as with conventional learning environments. These may be considered the real SGs.

An original hypercube taxonomy yet has been developed by Kickmeier-Rust in the context of the 80Days EU project[10], which involves 4 dimensions:

- Purpose – ranging from fun/enjoyment to training/learning
- Reality – ranging from imitation of real and fictitious contexts to proving abstract visualizations such as in games like Tetris.
- Social Involvement – ranging from single player games to massively multiplayer games.
- Activity - ranging from active game types (e.g., action games or – even with a physical dimension – the Nintendo Wii game play) to passive game types (where at the end of this continuum the passive perception of a movie is situated).

Along the years, an ever huger number of SGs have been developed, and now some repositories are available online, with related taxonomies for cataloguing and search. Djaouti, Alvarez, Jessel – of the University of Toulouse, partners of GaLA - have created

serious.gameclassification.com (2336 featured games, as of november 2011), a collaborative classification of SGs, which is a reference at world level [11]. The selected classification dimensions (that are a clear extension of the [Sawyer B. & Smith, 2008] [8] model are:

- *Gameplay* (game-based vs. play-based – games have fixed goals to achieve; core rules represented by bricks constituting a game)

- *Purpose* (Education, information, marketing, subjective message broadcast, training, goods trading, storytelling)
- *Market*(Entertainment, State&Government, Military &Defence, Healthcare, Education, Corporate, Religion, Culture&Art, Ecology, Politics, Humanitarian &Caritative, Media, Advert, Scientific Research)
- *Audience* (Type: General Public, Professionals, Students; age groups)

Additional user-contributed keywords are also possible.

This description of games is simple, but has allowed a good, and ever growing and improving classification of a variety of SGs.

Related to this,[11], the same authors have refined their approach in a recent academical paper, defining the "Gameplay /Purpose /Sector" (GPS) taxonomy, which involves:

- Gameplay: rules, objectives, conflicts, etc.
- Purpose: create awareness, teach, train, broadcast a message, etc.
- Sector: health care, military, government, business, etc.

Conversely, Imagine[10] is a Lifelong Learning Programme EU project aimed at building a substantial community of policy makers with a high level of commitment to pursue the implementation of game based learning across a large number of countries and all three levels of education covered. The project also includes a game directory, where game descriptions can be searched by genre, subject category, target audience and learning objective. The database contains around 90 game descriptions, as of September 2011.Here we highlight the search categories of the Imagine database:

- Genre: action, puzzle, trivia, etc.
- Subject categories: agriculture, medicine, science, sports, etc.
- Target audience: primary, secondary, tertiary, vocational, lifelong learning
- Learning objective: memory, dexterity/precision, applying concepts and rules, decision making, social interaction, ability to learn

More than that, another EU LifeLong Learning Programme (LLP)- Engage learning[11] is a project that has built a portal for game-based learning. This includes a catalogue of descriptions of games used for learning (even if also non-educational games are listed, like BioShock).The catalogue of games for learning include localization and cultural issues as well as information about quality and rating. The reviews contain case studies of how these games may be used in a classroom environment and suggested implementation of the game. The experience of the reviewer is tabled and a walkthrough to reduce the learning curve is detailed. The per-game descriptions are available online and accessible through a search tool that allows finding game descriptions based on search dimensions such as: type of game, platform, target age, learning objectives, learning purpose, learning curve, etc. The game description records (each one downloadable as a .pdf file) are rich and well structured, also because of the focus on how to use the game in different (educational) contexts, which is of outmost importance for a proper educational use of games. The database contains around 35, popular game descriptions, as of September 2011. Here we highlight the search categories of the Engage database:

- Game platform: PC, Nintendo Wii, Sony PSP, Nintendo DS, etc.

[10]www.imaginegames.eu
[11]www.engagelearning.eu

- Genre/Type of game: action, racing, puzzle, etc. and a list of specific SG types: SG-business, SG-exergaming, SG-healthcare, SG-military, etc.
- Learning objectives: memory, dexterity/repetition, applying concepts/rules, decision making, social interaction, ability to learn
- Schooling level: primary, secondary, adult
- Learning purpose: motivational, cognitive skills, spatial awareness, motor skills, social interactions, and a set of curricular topics: history, maths, physics, sports, etc.
- Rating descriptors: bad language, discrimination, drugs, sex, violence, etc.
- Learning curve: less than 5 min.s, 5-30 min.s, 30-60 min.s, more than 60 min.s

1.2. GaLA Virtual Research Environment

This analysis conducted in the Taxonomy and Metrics task inside the GaLA NoE EU project has inspired and informed the task devoted to the design and implementation of the Virtual Research Environment (VRE), one of the long-term targets of the project. According to the elicited VRE requirements, in fact, it was of outmost importance to support the SG field definition, in order to favour research, in particular keeping into account the typically multidisciplinary nature of the field.

The GaLA VRE idea is to build a system involving a network of entities, that are organized in hierarchical taxonomies with descriptions and examples. Descriptions involve texts, keywords and other multimedia assets deemed as useful. The entities are linked among each other, representing meaningful relationships.

At present, the following six main knowledge areas have been identified (we can also see them as access channels, or views, to SGs), that will contain entities possibly structured in hierarchies. The areas are independent of each other, but their items are cross-linked to represent correlations:

- Description/classification of games, where a taxonomy similar to serious.gameclassification.com or the Engage project could be incrementally build to a larger extent.
- Analysis of game components (UI, rules, goals, entity manipulation, assessment), for a detailed specification of the game mechanisms.
- Application domains, such as business & finance, cultural heritage, health, manufacturing, etc., that are the topics of the GaLA WP3's Special Interest Groups (SIGs)
- Pedagogy. The GaLAtaxonomy from this perspective may be organized in two major sectors:
  - Theoretical frameworks
    - Constructivism, Situated learning, Experiential learning, etc
  - Outcomes:
    - Cognitive (related to mental skills; this point refers to knowledge building and to the development of intellectual skills)
- Remembering, understanding, applying, analysing, evaluating, creating][12]
    - Psycho-motorial (i.e., skills related to physical movement, coordination, and use of the motor-skill areas)
- Perception, set, guided response, mechanism, complex overt response, adaptation, origination [13]
    - Affective (related to attitudes; this point includes the manner in which we deal with things emotionally, such as feelings, values, appreciation, enthusiasms, motivations, and other attitudes)
- Receiving phenomena, responding to phenomena, valuing, organization, internalizing values [14]
    - Soft-skills (personal attributes not easy to quantify, and sometimes described as intangible, that enhance an individual's interactions, job performance and career prospects)
- Intra-personal: self-reflection, self-control, self-motivation, self-discipline, ability to learn, strategic thinking, creativity

- Inter-Personal: empathy, team working, conflict management, communication, negotiation, collaboration, decision making; cultural empathy
- Deployment ("Use of the game")
  - Target users (age, specific categories of persons, school level, etc.)
  - Prerequisites for use (if any) (cognitive, content-related, domain related, psychomotor, etc.)
  - Context of use (e.g., formal education, corporate training and other)
  - Play mode (single player, multiplayer, online multiplayer...)
- Technologies. Platforms, tools, algorithms

The work inside this task intends to give rise to a complex Virtual Research Environment meant to:

- Allow an in-depth understanding of SGs through a detailed description of their mechanisms
- Apply existing games into learning and training contexts, considering appropriate pedagogies
- Desig new games and enhance existing games, identifying their weak points

1.3. Arguments for the validity and necessity of such a vision

1.The variety of users of SG with educational/training purposes and the growing scale of use per domains; thus, games are proving to be more effective than traditional teaching and improve learning and motivation which in turns enhance a better knowledge transfer for topics in school- math [15], physics (16], foreign languages (17], geography [18]- as well as various corporate training settings and fields-mechanical engineering [19], firefighting [20], healthy llifestyles [21]. Consequently: To enhance accessibility to a search engine within the SG field, a multifaceted taxonomy is called for, to provide information about the same game from different perspectives the user might try to tackle.

2. For a better understanding of what SG can provide as alternative training tools, a comprehensive view is needed as accessible , to render information over the topics they teach, learning objectives, context where the game is functional, so that the game can successfully be integrated into the lesson plan/ training program [22] Henceforward: Categories related to the outcome, learner and context, namely – what we get by using the game, variable features related to the user that have influence over the outcome of the training process, the context that also can vary and influence the outcome; a trainer needs to know all these aspects before taking up the game;

3. Since debates have gone deeply into whether effective teaching goes when using COTS compared to using games designed from scratch, our VRE offers also discreet information for designing new games or enhancing the existing ones into better deployment, for a better adjustement inside the educational process, inside the stage and type of the lesson, education level and type.

III. SERIOUS GAMES METRICS

The topic of metrics itself is a hot topic per se. Should we consider assessment as a form of metrics then literature in the field documents already existing SG metrics as evaluating corporate training by means of questionnaires, while education has tried to find the effectiveness of using SG in learning by tests , questionnaires and portfolios subsequent to the SG-training activities. Nonetheless, a set of definite indicators to test the effectiveness of using SG inside education or corporate training still lacks, despite the plethora of literature giving sets of directions on how to best evaluate games. A set of clear indicators, both qualitative and quantitative are yet to be mapped against clearly defined standards.The work on classification and taxonomies is propaedeutic to the one for metrics, since metrics needs to be established over a well defined and commonly shared ground.

Given the double nature of SGs (games with pedagogical purposes), we decided to consider two broad metrics families. One about pedagogical effectiveness, and another one about entertainment value.

3.1. Measuring the educational /training value

For the pedagogical effectiveness, our idea is to use the work on the VRE taxonomy about pedagogy as a starting basis. Thus, we would consider the following dimensions related to the learning outcomes (as we have already reported them in the previous sub-section):

- Cognitive (related to mental skills; this point refers to knowledge building and to the development of intellectual skills)
  - Remembering, understanding, applying, analysing, evaluating, creating [12]
- Psycho-motorial (i.e., skills related to physical movement, coordination, and use of the motor-skill areas)
  - Perception, set, guided response, mechanism, complex overt response, adaptation, origination [13]
- Affective (related to attitudes; this point includes the manner in which we deal with things emotionally, such as feelings, values, appreciation, enthusiasms, motivations, and other attitudes)
  - Receiving phenomena, responding to phenomena, valuing, organization, internalizing values [14]
- Soft-skills (personal attributes not easy to quantify, and sometimes described as intangible, that enhance an individual's interactions, job performance and career prospects)
  - Intra-personal: self-reflection, self-control, self-motivation, self-discipline, ability to learn, strategic thinking, creativity
  - Inter-Personal: empathy, team working, conflict management, communication, negotiation, collaboration, decision making; cultural empathy

By identifying what elements inside a game are able to render all the above mentioned learning outcomes and how can they be sustained inside the educational process, we will thus be able to define the performance indicators responsible for ensuring effectiveness of the educational process that uses serious games as complementary tools. This step will be achieved by mapping game mechanics to pedagogy in discreet analysis of games from different perspectives – the trainer , the trainee and the stakeholder as well.

The future work will consist in the definition of qualitative and quantitative parameters for each one of the above items, in order to allow for a multi-aspect evaluation of SGs from the educational effectiveness point of view. A test and assessment phase will follow, whose feedback will lead to a finalization of the metrics and a discussion with relevant bodies also for a possible standardization. Similarly, differentiation with corporate training performance indicators will be made, as this aspect triggers more than learning outcomes' point of view ; we can mention here stakeholders indicators of effectiveness (i.e. return of investment), user's satisfaction and elements that render a complete return of expectation for all the parties involved. This and all the other mentioned aspects are to be covered in the following years.

3.2. Measuring the entertainment aspect

The second major axis for SG validity is represented by entertainment and fun, as Serious Games are also „games that use pedagogy to infuse instruction into the game play experience"-[23]

In addressing assessment of SG from this perspective, we highlight that there are several qualitatative and quantitative approaches to modeling player entertainment, fun and satisfaction.Thus:

Qualitative approaches for modeling player enjoyment mostly rely on psychology, where a comprehensive review of the literature leads to the identification of two major lines: Malone's principles of intrinsic qualitative factors for engaging game play [24] namely challenge, curiosity and fantasy, and the theory of flow, based on Csikszentmihalyi's foundational concepts[12] [25]. Incorporating flow in computer games as a model for evaluating player enjoyment has been a focus of few studies [26];][27], that highlight the following elements: concentration, challenge, player skills, control, clear goals, feedback, immersion, social interaction.

[12] The 10 factors of flow according to Csíkszentmihályi are: clear goals, concentration, loss of self-consciousness, subjective experience of time, direct feedback, balance between challenge and ability, sense of control, intrinsic reward, lack of awareness of bodily needs, absorption into the activity

On the other hand, the quantitative approaches to entertainment capture attempt to formulate entertainment in mathematical models which yield reliable numerical values for `fun', entertainment or excitement. These techniques, however, are very application-specific, and studied in particular for board games [28] or for specific dimensions (e.g., player-opponent interactions in computer games) .[29]

A major drawback of the current approaches for user enjoyment assessment is given by the fact that they use tools and measures based on concepts pre-defined by the researcher (e.g. pre-defined questionnaires), which may bias the user report [30]. [Bellotti et al., 2009][31] implemented user tests exploiting the Repertory Grid Technique (RGT) methodology [Hassenzahl and Wessler, 2000][32].The RGT assumes that individuals perceive and evaluate the world through similarity-dissimilarity poles, called "personal constructs". The RGT is used to extract an individual's personal construct system relevant to a topic. The main praise of RGT is that the test-leading researcher does not supply users with a predefined set of constructs. Rather, constructs are defined a posteriori, based on an analysis of the free user comments. In the video-game user tests [31], players used own criteria in describing similarities and differences among videogames. Analyzing the players' personal constructs, 23 major dimensions for game assessment were identified, among which the most relevant were (with the corresponding score) Ability demand (94), Dynamism (58), Style (48), Engagement (38), Emotional affect (35), Likelihood (33).

We believe that these dimensions are significant axes along which to measure player fun /enjoyment /satisfaction. These evaluations can be obtained through direct user feedback. The next steps of our research will consist in trying to identify indirect measurement modalities and possible correlates with game mechanisms and components.

IV. CONCLUSIONS

As shown in the pages above, the approach we took in designing a taxonomy for serious games and finding a methodology for defining metrics is fastidious and entails yet a multidisciplinary tackling of the issue of metrics since a vast array of elements concur in rendering the effectiveness of a game in training, both related to game mechanics, psychology, pedagogy, Human Computer Interaction, Artificial Intellligence and Neuroscience.

Hot topics and gaps have been identified by means of literature review, process that left the door open for cross- confrontation with the fields of applications in order to fill the gap between researchers and practitioners, since considering the educational effectiveness of SGs means taking into account a multiplicity of factors: the actors, the stage and the play as well. [33] Once these sides overlap, then the tool we produce will be efficient and effective.

It is expected that by joining effort and addressing fragmentation, by correlating expertise from various fields, performance indicators will be defined in order to measure the effectiveness of Serious Games deployed on the realm of education and training, from multiple points of view-knowledge transfer, affective or soft skill improvement or development and entertainment which eventually enhances and sets the ground for learning., as successful adoption of SGs is not only a question of identifying a suitable game for a given subject, but also of knowing what subjects and skills can benefit from a games-based approach, when and how an SG is best deployed, what stage of the learning path is most appropriate, and how to manage contextual factors. [33] This is considered a subsequent step after we have identified some key dimensions along which to assess validity and appropriateness of SGs metrics, it is work in progress and will have to be developed carefully in the following years.

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