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Development of a General Framework for Evaluating Games-Based Learning

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Abstract

The field of games-based learning (GBL) has a dearth of empirical evidence supporting the validity of the approach (Connolly *et al*, 2007a; Connolly *et al,* 2007b; de Freitas, 2007). One primary reason for this is a distinct lack of general frameworks providing guidelines for structured GBL evaluation. The literature has a wealth of articles suggesting ways that GBL can be evaluated in terms of particular areas with particular measurements, experimental designs and analytical techniques. This paper will present the results of an extensive literature search to identify measurements that have been taken in relevant studies. A new evaluation framework will be presented based on the compilation of all the particular areas and analytical measurements found in the literature. The paper will also briefly review existing frameworks applicable to GBL and will provide general guidelines to focus researchers on particular categories of evaluation, individual measurements, experimental designs and texts in the literature that have some form of empirical evidence or framework relevant to researchers evaluating GBL environments. Due to the extensive nature of the framework, this paper will specifically focus on the GBL environment category composed of evaluation of environment aspects, pedagogical aspects focused on scaffolding, usability, social presence and embedding games within the curriculum.

Keywords: games-based learning, evaluation, framework, pedagogy, scaffolding, usability, deployment, social presence

1. Introduction

Games-based learning (GBL) has captured the interest of educationalists and industrialists, as it is perceived as an engaging form of supplementary learning, however the field has a dearth of empirical evidence supporting it's validity (Connolly *et al*, 2007a; Connolly *et al,* 2007b; de Freitas, 2007). One primary factor exacerbating this problem is the lack of general frameworks for the evaluation of GBL environments focusing on pedagogy. Moreover there is a lack of general evaluation frameworks specifying what particular measurements can be taken prior to contact, during contact and after contact with a GBL environment. During a recent pilot study deduced from the formation of a new framework for GBL evaluation it became apparent that particular measurements identified in an extensive literature review are more effectively applied at particular times in an evaluation. The GBL environment category of the new framework contains a variety of criteria, which is generally better assessed in the post-test, as the category is mainly applicable after the learners have been exposed to the environment.

This paper will make a contribution to the GBL literature by discussing some previous evaluation frameworks and presenting the results of an extensive literature review producing a new evaluation framework focusing on pedagogy for GBL. A section of this framework will be presented focusing on the GBL environment category allowing researchers and educationalists to appropriately plan evaluations of GBL environments with regards to particular measurements. The learner performance category of this framework has already been discussed in a previous study (Connolly and Hainey, *in press*). This paper will also briefly discuss appropriate experimental methodologies identified, how the framework can be adapted to individual GBL applications and future research directions in terms of framework validation.

2. Previous Frameworks

When developing an evaluation framework for GBL, it is logical to design the framework from a perspective of pedagogy as the entire ideology of GBL is using games/simulations to motivate and engage; resulting in more effective learning even at a supplementary level. There are few evaluation frameworks in the literature specifically addressing the effectiveness of GBL from a pedagogical perspective. The majority of available frameworks are focused on e-Learning or commercial games such as World of Warcraft. Two examples of these frameworks are based on Jakob Nielsen's Heuristic Evaluation developed in 1990 (Nielsen and Molich, 1990). Heuristic Evaluation consists of ten recommended heuristics and is to be performed by a small evaluation team. The technique focuses on finding interface usability problems as it was developed from a Human Computer Interaction (HCI) perspective and has been extended with additional heuristics encompassing website specific criteria. The technique has also been expanded and developed to produce a framework for web-based learning (Ssemugabi and de Villiers, 2007) and a framework for heuristic evaluation of Massively Multi-player On-Line Role Playing Games (MMORPGs) (Song and Lee, 2007). One main difficulty associated with evaluation frameworks developed from Heuristic Evaluation is that the quality of a Heuristic Evaluation is dependent on the expert reviewers knowledge. By extending frameworks to encompass web-based learning and MMORPGs, a suitable reviewer has to have sufficient knowledge of HCI and games to perform an evaluation of quality. The primary difficulty from a GBL perspective is that these developed frameworks do not focus on pedagogy. Tan *et al* (2007) reviewed four GBL frameworks and models including: the design framework for edutainment environments, the adopted interaction cycle for games, the engaging multimedia design model for children and the game object model. According to the results of their criteria, only one framework: the game object model (Amory, 1999) (developed to allow identification of suitable game elements to be supported by valid pedagogical elements) significantly addressed pedagogy and game design. The game object model has been further developed using theoretical constructs and developments in the literature to become the game object model version II framework (Amory, 2006). It can be used from both a game design perspective and an evaluation perspective. Kirkpatrick's four level framework particularly takes pedagogy into account (*Figure 1*). It was developed in 1994 as a framework for evaluating training and it has been proposed that it can be used to evaluate business simulations as educational tools (Schumann *et al,* 2001).

Level 1: REACTION	Trainee's reaction to the program: level of satisfaction
Level 2: LEARNING	Trainee's attitude change, increased knowledge, and/or increased skill, due to the training
Level 3: BEHAVIOUR	On the job change in behavior because of program participation, i.e. transfer of learning to the job setting
Level 4: RESULTS	How the organization benefited from the learner's participation in the program (e.g. increased profits)

Figure 1: Kirkpatrick's four levels for evaluating training (1994)

Dondi and Moretti (2007) reviewed Uni-Game (Games-based Learning for Universities and Life Long Learning) and Sig-Glue (Special Interest Group for Game-based Learning in Universities and Lifelong Learning) which are projects funded by the European commission. This lead to the development of a 'classification of games by learning purposes' and an 'evaluation framework for assessing games'. The framework takes into account that "*a learning game should be a 'good*

game' through which the player will achieve the stated learning objectives." The framework covers pedagogical and technical criteria in terms of quality. The quality criteria framework is considered when producing the new framework for effective GBL presented later.

Another example of a framework taking pedagogical aspects into account is a Four Dimensional Framework (FDF) addressing aspects of future and existing simulations and games (de Freitas and Oliver, 2006). The framework is designed for practitioners to take four dimensions into consideration in advance of using games and simulations in their curricula. The four dimensions are not to be considered in isolation but all dimensions should be considered as a collective whole. The FDF is applicable to various e-content forms and has been applied to two particular examples: Firstly: An example evaluating the potential of *MediaStage* to support the curriculum and Secondly: An example evaluating *Savannah* to analyze educational practices. The FDF is "*designed to aid tutors selecting and using games in their practice. The framework includes: context, learner specification, pedagogy used and representation as four key aspects for selecting the correct game for use in learning practice*" (de Freitas, 2007). The FDF is displayed in *Figure* 2

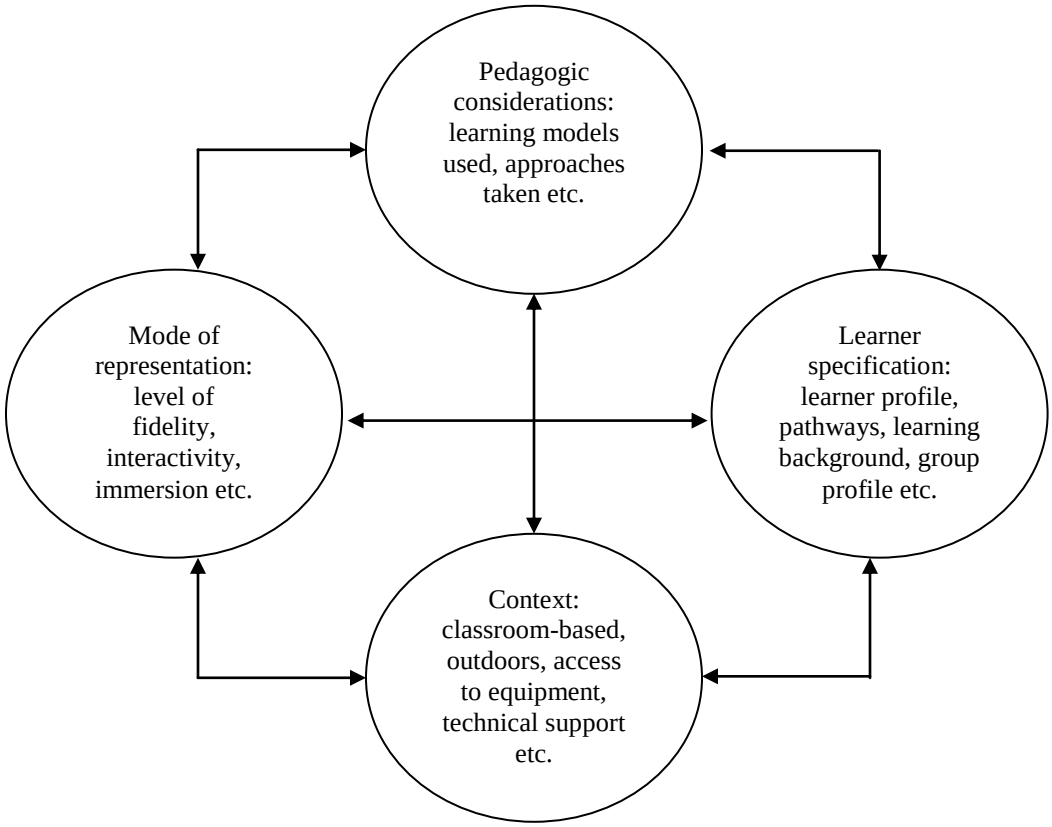

Figure 2: Four Dimensional Framework (2006)

3. Literature review

This section will present a literature review in terms of: method used to collect the data, the framework for effective evaluation of GBL extrapolated from the literature review, measurements encountered specifically associated with the GBL environment category, experimental methodologies and adapting the evaluation framework to a specific application of GBL.

3.1 Method used to collect data

An extensive literature review was performed by reviewing various electronic databases including: ACM, ABIINFORM Global Database, Academic Search Premier, ScienceDirect, Blackwell Synergy, EBSCO (consisting of Psychology and Behavioural Science, PsycINFO, SocINDEX, Library, Information Science and Technology Abstracts, CINAHL), ERIC, IngentaConnect, Infortrac (Expanded Academic ASAP) and Emerald. All relevant Simulation & Gaming journal papers from 1996 were extracted and assimilated into the final results. As well as general search terms, the following detailed search terms were used:

("computer games" OR "video games" OR "serious games" OR "simulation games" OR "games-based learning" OR "MMOG" OR "MMORPG" OR "MUD" OR "online games") AND ("education" OR "learning") AND "evaluation"

The main objective was to take all papers from 1996 to the current date from each particular database search. Extract all papers that performed some form of empirical evaluation or contain evaluation frameworks applicable to GBL to identify particular measurements taken, experimental methodologies used, statistical analytical techniques applied and what particular context the intervention was used. Out of nearly 10,000 articles observed approximately 1,400 articles were collected. When the search was further refined using the empirical evidence criteria – 72 articles were the final result. All articles identified have taken some form of measurement through either qualitative or quantitative research methods. The literature review results have been highly instrumental in constructing the GBL evaluation framework in terms of being able to categorize particular measurements already present in the literature. The literature review results are highly extensive; therefore the next section will present a brief summary of the categories of the formulated framework and will particularly focus on the GBL Environment category. The learner performance category has already been described in a previous study in terms of measurements (Connolly and Hainey, *in press*). Experimental methodologies will also be briefly discussed.

3.2. Compiled evaluation framework for effective GBL

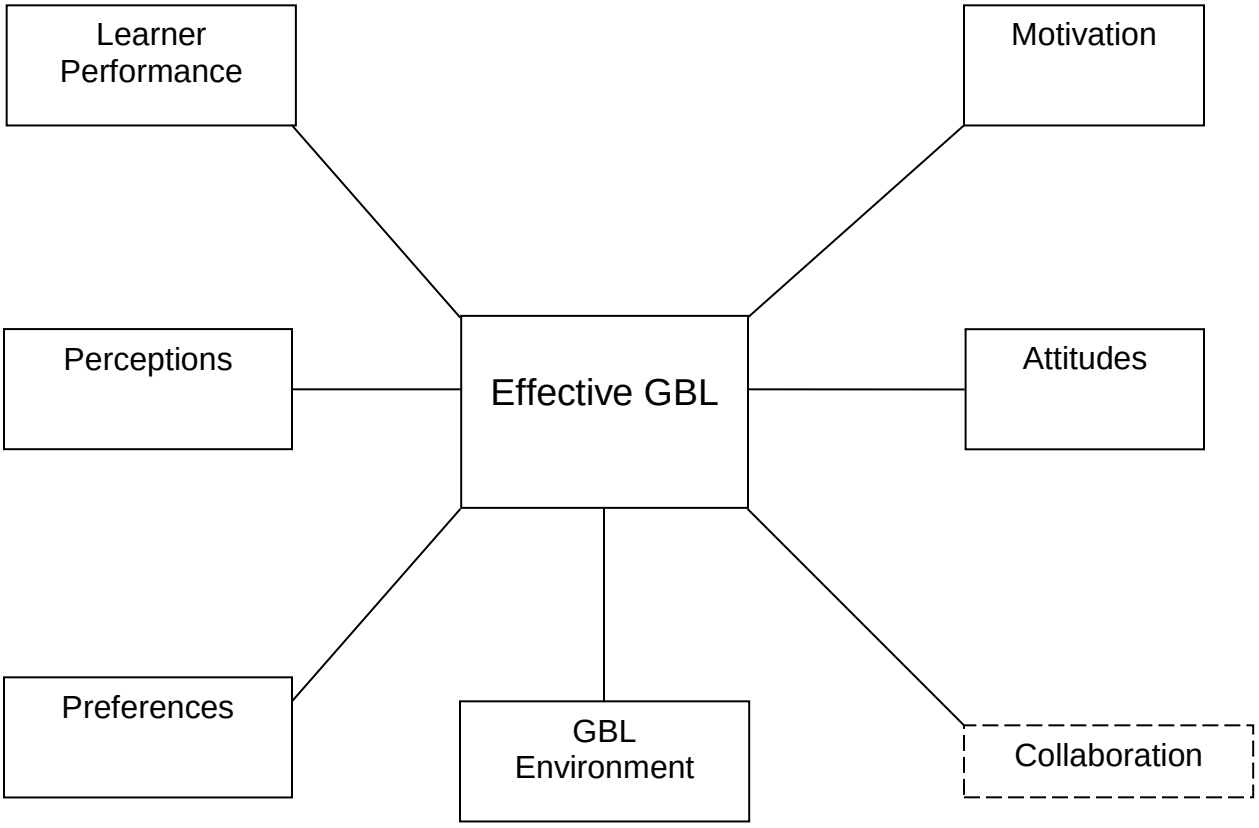

Figure 3: Evaluation framework for effective GBL

The purpose of the framework (*Figure 3*) is to identify the main potential evaluation categories of GBL highlighted in the scientific literature. Like the Four Dimensional Framework (de Freitas and Oliver, 2006) presented previously, categories do not necessarily have to be viewed in isolation but as a collective whole depending on what is to be evaluated. Unlike the four dimensional framework it can be used in both a developmental sense to inform design during the implementation and embedding a GBL environment into curricula in a formative evaluation sense and also points to examples of individual analytical measurements already present in the literature for focusing on an evaluation at the end of development in a summative evaluation sense. Detailed descriptions framework categories have been provided in a previous study (Connolly and Hainey, *in press*). As a result a brief description will be provided of each category and the GBL environment category will be discussed in greater detail.

3.2.1 A brief description of each category

Learner Performance - Encompasses pedagogy from the perspective of the learner and is to evaluate aspects of learner performance. It is primarily concerned with whether there is an improvement in learner performance.

Motivation – The particular motivations of the learner using the intervention, the level of interest in participating in the intervention, participation over a period of time and determining what particular motivations are most important.

Perceptions - Encompasses perceptions associated with the learner such as overview of time, how real the game is, it's correspondence with reality, whether the GBL intervention represents a holistic view of a particular organization or process, game complexity, advice quality and level of self reported proficiency at playing games etc.

Attitudes - Learner and instructor attitudes towards various elements that may alter the effectiveness of the GBL intervention. Elements include: learner attitudes towards the taught subject, learner attitudes towards games (Connolly *et al,* 2007b), instructor attitudes towards the incorporation of games into the curricula etc.

Preferences - This category is designed to consider learner and instructor preferences during a GBL intervention. There are different learning styles (Kolb, 1984) therefore it stands to reason that different learners have different preferences, for example, preference for medium used when teaching the material.

Collaboration - Collaboration is optional when considering GBL as it is dictated by whether the game is played on an individual level, cooperative group level, competitive group level etc. The main ways of evaluating collaboration are through log files monitoring interaction, mapping team aspects to learner comments, measuring the regularity and level of collaboration and learner group reflection essays.

3.2.2 GBL Environment category

This category encompasses all aspects that could potentially be evaluated about the GBL environment. It is one of the most complicated categories as it can be divided into five subcategories: environment, scaffolding, usability, level of social presence and deployment. In terms of the actual virtual environment itself the evaluation criteria can be: validating the background environment and characters including virtual agent expressiveness (Dugdale *et al,* 2006), evaluation of factors with regards to environmental alteration, advice importance, the environment context in terms of real-world decision making support and general game difficulty. Scaffolding refers to advice and resources within the environment supporting the learner in completing their learning outcomes. Scaffolding can be evaluated through monitoring of realism and feedback, learner perception of advice quality, expert reviews of advice quality and monitoring of resources utilization. Usability can be analyzed by looking at task completion times, average task completion times, ease of the task; the number of errors made performing a task and ranking of the tasks by learners. Usability can also be evaluated through conversation analysis, correlation of the learner demographics to the susceptibility of the problem to be overcome by the intervention. With regards to developing a GBL intervention, player reactions to initial and incremental prototypes in an iterative fashion may be monitored to evaluate improvement of usability aspects. Level of social presence is to do with immersion and interaction in the game world. It can be monitored but looking at relationship frequencies, player evaluation of game character personalities, and attitude and mood statements towards characters and events in the game. Deployment is intended to encompass the most effective method of appropriate incorporation into the educational context and can also mean the preference of different gaming conditions i.e. particular format of delivery.

3.3 Measurements encountered associated with a GBL environment

The GBL environment criterion is split into environment, scaffolding, usability, level of social presence and deployment. The framework GBL environment criteria will direct researchers to relevant texts and specific measurements (*Table 1*). Studies by the same author are grouped together.

Table 1: GBL environment measurement criteria

Environment
• Background environment validation (Johansson and Kuller, 2002).
• Virtual environment navigation (Frey *et al,* 2007).
• Character validation (Johansson and Kuller, 2002; Paiva, 2005).
• Validation of content in terms of extendibility and integration. Enjoyment in terms of clearness of goals, concentration, challenge and immersion. Social interaction in terms of cooperation and competition (Garzotto, 2007).
• Entertainment (Kelleher *et al,* 2007).
• Environment alteration regarding usability, acceptability and improvement of learning outcomes (Goodman *et al,* 2006; Leemkuil *et al*, 2003).
• Assessing and gauging virtual agent expressiveness (Dugdale *et al,* 2006). • Assessing the context in terms of decision-making support as found in the real world (Dugdale *et al,* 2006). • Indexicality verification supporting agent interaction (Dugdale *et al,* 2006).
• Advice importance (Constantino-González and Suthers, 2001; Leemkuil and de Hoog, 2005).
• Environment usability (Maguire *et al,* 2006; Piper *et al,* 2002; Adamo-Villani and Wright, 2007; Sim *et al,* 2005; Leemkuil *et al*, 2003; Virvou and Katsionis, 2008; Blasi and Alfonso, 2006).
• Environment acceptability (Roubidoux *et al,* 2002).
• Environment credibility (Beale *et al,* 2007).
• Business model performance (Dugdale *et al,* 2006; Leemkuil and de Hoog, 2005; Christoph, 2007).
• Learning in GBL environment (Squire *et al,* 2004).
• Enjoyability (Shaw and Dermoudy, 2005).
• Beneficial or detrimental effect of the environment (Fery and Ponserre, 2001).
• Game difficulty (Shaw and Dermoudy, 2005).
Scaffolding
• Average amount of times scaffolding/advice resources were used – including feedback, intervention handbooks, indicator handbooks, history files, shared worksheets in relation to history files and visualization tools (Leemkuil and de Hoog, 2005).
• Expert review knowledge of advice quality (Constantino-González and Suthers, 2001).
• Students perceptions of advice quality (Constantino-González and Suthers, 2001, Leemkuil and de Hoog, 2005)
• Appropriate feedback and realism (Lainema and Makkonen, 2003)
Usability
• Correlation of user demographics to susceptibility of the problem the environment is attempting to overcome (Sheng *et al*, 2007). • User performance (Sheng *et al*, 2007). • User confidence (Sheng *et al*, 2007).
• Player reactions to first and incremental prototypes (Johansson and Kuller, 2002; Christoph, 2007).
• Average task completion time (Göttel, 2007).
• Ease of tasks (Wagner *et al*, 2006).
• Ease of use (Kelleher *et al,* 2007).

• Conversation analysis (positive, aggressive, non-responsive) (Piper *et al,* 2002).
• Measurement of key usability factors such as learning time, time to complete a task, number of errors and completion or non-completion of a task (Adamo-Villani and Wright, 2007). • User task scenarios ranking and rating (Adamo-Villani and Wright, 2007).
• Measurement the usability of multimedia software focusing on attractiveness, control, efficiency, helpfulness, learnability and excitement (Sharp and Hall, 2003).
Level of social presence
• Frequency of relationships (Robertson and Oberlander, 2002) • Learner evaluation of game character's personalities (Robertson and Oberlander, 2002; Paiva, 2005).
• Mood and attitude statements towards characters and events (Robertson and Oberlander, 2002; Paiva, 2005).
• Level of immersion and interaction (Lim *et al*, 2006; Garzotto, 2007).
Deployment
• Preference of different gaming conditions (Wagner *et al,* 2006).
• Method of appropriate incorporation into an educational context (Snow *et al*, 2002).

3.4 Experimental Methodologies

The general experimental designs of all the studies taken into account in the literature review are experimental as opposed to quasi-experimental and range from the following general prototypical designs:

- Pre-test (possibly to determine if the population sample is adequate (Maguire *et al*, 2006))
- Intervention → post-test
- Pre-test → Intervention → post-test
- Pre-test → Intervention → post-test → long term follow up post-test

It was discovered that the experimental designs producing the most impressive results used the standard pre-test → post-test, experimental - control group design. Whereby a particular group is exposed to the intervention and a particular group is not. Examples of literature with this design include:

- Learning Physics with digital simulation games (Squire *et al,* 2004).
- An effective instructional strategy in understanding complex, abstract and dynamic science concepts (Talib *et al,* 2005).
- Civil engineering in Higher Education (Ebner and Holzinger, 2007).

One of the few studies to discuss a long-term follow up group is:

- A psychoeducational video game to improve cancer related knowledge (Beale *et al,* 2007).

One particularly detailed description of an experimental methodology for the GBL application KMQuest is summarized by Christoph *et al* (2005) as follows:

- The study was performed over a four week period before any knowledge management instruction in any institution:
- *Week 1* **–** All of the students from both conditions were introduced to the game. Firstly an introductory lecture was performed, which was followed by a specific training session developed for each condition. The primary difference between sessions was the demonstration and explanation of the KM model. The pre-test measurements were then administered in the form of KMQUESTions.
- *Week 2* **–** The students begin to play the game during two games sessions. Each session has duration of over 2 hours. Students are only permitted to communicate

with each other through the chat facilities that are present in the game and are located in different rooms. Access to the game is restricted to the designated sessions**.**

- *Week 3* **–** The last session of the game takes place with the primary purpose of reaching quarter 7. The post-test is scheduled the day after and consists of KMQUESTions and the Motivated Strategies for Learning Questionnaire (MSLQ).
- *Week 4* **–** A debriefing lecture is organized for students to share their experiences.

With these particular experimental methodologies in mind a pre-test, post-test evaluation process for GBL can be extrapolated and is shown in *Figure 4*

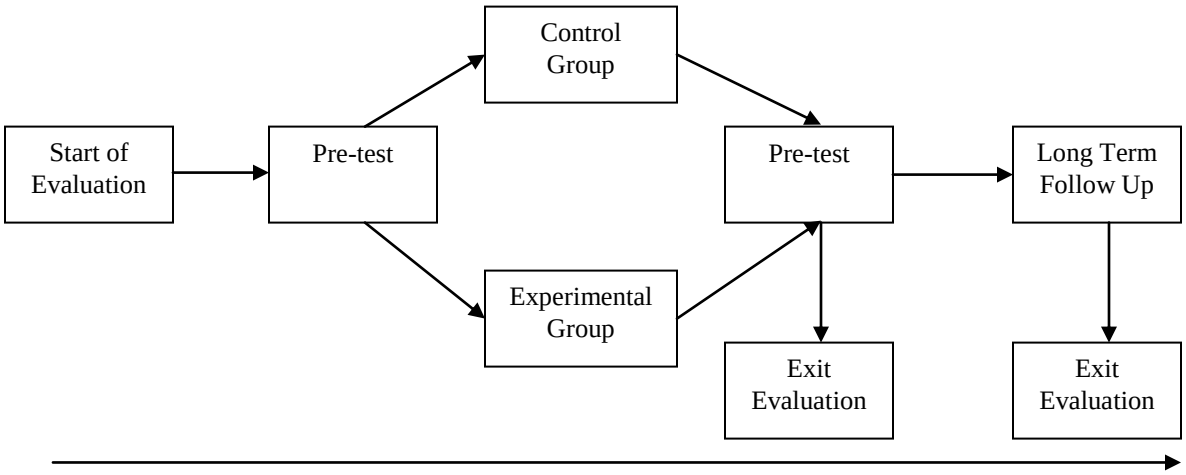

Figure 4: Pre-test, post-test evaluation process

3.5 Adapting the Evaluation Framework to a specific application of GBL

In terms of adapting the framework for a specific application of GBL to teach software engineering concepts, particularly requirements collection and analysis at tertiary education level (Connolly *et al*, 2007a). Each category can be expanded to act as a general evaluation guideline depending on what specifically is to be evaluated. An example expansion of the GBL Environment category is given in *Figure 5.*

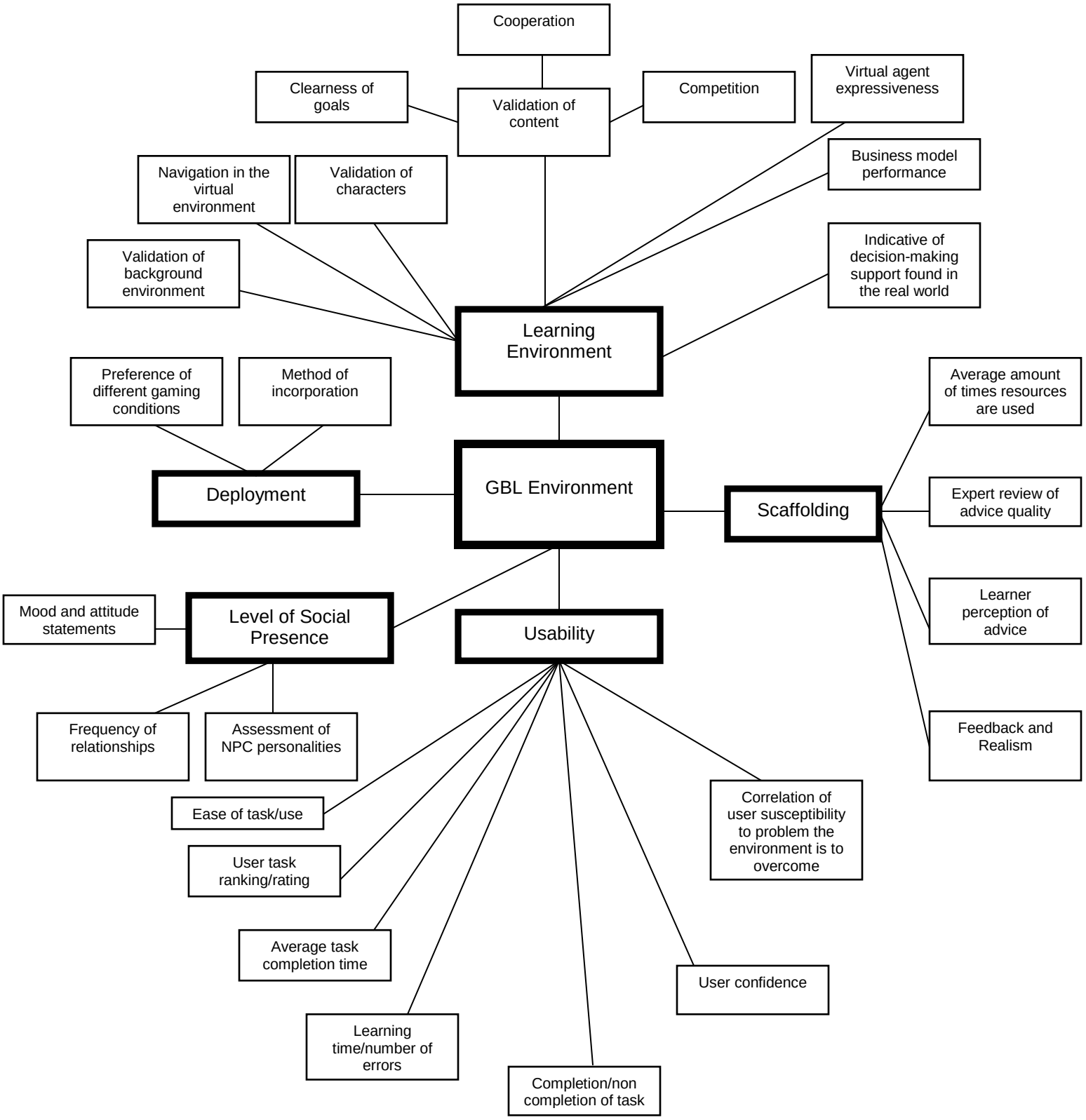

Figure 5: Framework adaptation to a particular application of GBL

4. Future Research Directions

The framework is currently being applied to guide a pilot study evaluation of the application of GBL mentioned in the previous section, which is a game to teach requirements collection and analysis in tertiary education. The framework developed in this paper is a general framework to allow researchers to focus on texts that are of particular interest and use. The framework is of course adaptable and will continue to develop as new scientific texts are encountered and additional evaluations are performed. Future validation of the framework will involve using it to evaluate various different GBL applications.

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