

Designing Gamified E-Learning Applications for Children with Down's Syndrome

The Case of Teaching Literacy and Language Skills

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Abstract: Down's syndrome (DS) is the most common genetic cause of intellectual disability worldwide, with language being one of the most affected area. Language skills and literacy acquisition thus require special care. It is still rare to use software to support such care while, simultaneously, providing education and entertainment. This paper presents results of research on the design of gamified software applications to support pedagogical processes of literacy and language acquisition, making them fun, motivating and effective for children with DS. The paper analyses rankings of design domains of gamified e-learning applications done earlier in the research according to pedagogical benefits in entertaining education of DS children. The paper is believed to offer contributions to requirements engineering of e-learning, gamified software applications in general and to computer-assisted education of DS children in particular. The paper directly contributes to the concretization of article 24 (access to Education) of the General Principles, Accessibility, of the United Nations Convention on the Rights of Persons with Disabilities (UNCRPD). Usage of applications that implement most beneficial requirements may also indirectly contribute to UNCRPD article 19 –Living independently and being included in the community; article 21 – access to Information and communication services; and, article 27 - Work and employment.

1 INTRODUCTION

The Global Down Syndrome Foundation (www.globaldownsyndrome.org) estimates the worldwide population of people with DS to exceed 6 million. This estimate should significantly increase in the next 20 years because of the increase of live births and lifespan of people with DS. DS is caused by extra genetic material in chromosome 21. (Henceforth, individuals with DS will be referred to as “DS individuals”.) The extra material influences development, being the most common cause of intellectual disability.

If not for the economics of its growing population, the importance of providing services for DS individuals derives from the United Nations (www.un.org) Convention on the Rights of Persons with Disabilities (UNCRPD). Amongst its articles, UNCRPD establishes the rights of persons with disabilities to education (article 24), to living independently and community inclusion (19), to

access information and communications services (21) and to work and employment (27). Literacy and articulation facilitate claiming and guaranteeing these rights. Unfortunately, in DS, language is one of the most affected areas and it is common for individuals with SD display deficits in both receptive and expressive vocabulary (Cleland et al., 2010) (Owens, 2013) and present specific developmental challenges in phonology, syntax and some aspects of pragmatics when trying to express the language (Martin, 2009).

Studies suggest that the process of teaching language and literacy skills should start early on to avoid speech and language acquisition difficulties lasting until adulthood (Martin, 2009). Pedagogical efforts for DS children are usually supported by games, songs, play, and oral motor exercises (Ghirello-Pires, 2016). Such support is often implemented manually, at a slow pace, by specialists, therapists, and instructors dedicated to teaching DS children, mainly because e-Learning tools and applications specifically designed for DS users are

still scarce. Further, lack of automation makes it challenging to customize support for individual DS users: excessive repetition and other discomfort causes (e.g., hearing impairment) may demotivate users to carry on with certain pedagogical drills and thus, reduce their learning performance.

Reports on the use of educational software including serious games to stimulate the cognitive and motor processes of DS children are beginning to accumulate in the literature (Torrente et al., 2012) (Augusto et al., 2013) (Buzzi et al., 2016). Nevertheless, one still needs e-Learning software applications that: are specifically designed for DS contexts, with drill creation and customization facilities; gamified - i.e., have built in game-based features; alternate realities to motivate doing “real world” activities; are more productive for professionals; and, are more attractive to DS students, maintaining their engagement. The literature however, scantily addresses the design of e-Learning gamified apps for literacy and language acquisition by DS children in a way that blends interactive learning and entertainment both in the app virtual reality and that of the actual world. (Here, such apps are referred to as *DS GeL-apps* for short.)

This paper adds to the literature on *DS GeL-apps* to teach literacy and language skills to DS audiences by proposing a generic design for these applications and examining their major requirements. It expands analysis of an initial ranking of requirements domains and discusses requirements for the top ranked domain. As such, the paper contributes to the implementation of UNCRPD, to computer-supported education of DS children, and to software design and requirements engineering.

The remaining contents of the paper are organized as follows. Section 2 briefly surveys the academic literature and products on proposed or existing gamified apps for entertaining and educating DS children. Section 3 presents the methodology adopted for developing *DS GeL-apps*. Section 4 proposes a generic architectural design for these apps and summarizes initial findings of an ongoing research to elicit their requirements. Section 5 expands previous results on ranking requirements domains of *DS GeL-apps*. Section 6 discusses requirements for the top ranked domain. Section 7 brings conclusions and suggestions for further research.

2 RELATED WORK

Game-Based Learning (GBL) uses game concepts and technology to teach a particular target audience

and to motivate the audience to learn. GBL is becoming increasingly common in the area of education and some of the contributing factors for that are, as Shih, Squire and Lau (2010) claim, the fact that there are no limitations of subject or course to the use of this practice and that, with the development of pervasive communications technology, students have been allowed to play and learn in a social community, so that, when well applied, the students' motivation is higher and the learning performance can be improved. Gamification of educational apps just like GBL makes good use of these factors.

The literature on the use of gamification in education in general was surveyed by Caponetto et al. (2014) who argued that interest in gamification is due to its capacity to support learning, promoting desirable attitudes, activities and behaviors through participatory approaches; collaboration and friendly competition; self-guided study; facilitation and effectiveness of assessments; integration of exploratory approaches to learning; and the strengthening of creativity and student retention. However, there are still few gamified approaches for teaching audiences with special needs, with DS in particular.

Among the few reports on gamified approaches for teaching audiences with special needs, one may cite: Colpani and Homem (2015) propose a new educational framework with the use of virtual reality and gamification to aid in the learning by children with intellectual disabilities. The limitation of the set of requirements for the framework and its pioneering approach require new research and experiments to verify the effectiveness of this framework in practice; and the serious game *Moviletrando* (Farias et al., 2013) to stimulate the motor and cognitive functions of DS children, while assisting in literacy teaching: children move around in a virtual reality game to learn the letters of the alphabet. Although this game teaches fundamentals of literacy (the alphabet), it does not consider the process of acquisition of oral and written language by its players; others examples of serious games are the *Jecripe 2* (Brandão and Joselli, 2015) that attempt to stimulate the cognitive process, the memory, the phonological awareness in DS children and Torrente's (2012) “My First Day at Work” that was design to train a specific set of social and self-autonomy skills and concepts in adults with DS adults and “The Big Party” that work on the inclusion of individuals with DS in the job market. However, they do not focus on literacy acquisition.

Studies on the use of educational software and tools – not necessarily gamified – to facilitate

learning and stimulate the cognitive process in DS contexts include those by Fernández-López et al. (2013) and Campigotto, McEwen and Epp (2013). These works argue how mobile devices support the learning by DS children and they help the children maintain attention and focus on particular stimuli. However, since neither study used software aimed at DS children only, some of the important special needs that these children possess may not have been considered, leaving room for further analysis on the subject.

There are also studies on the benefits of tangible tools for the development of literacy and reading skills in DS children, such as Jardan-Guerrero et al. (2015) and Haro, Santana and Magaña (2012). In these studies, tangible tools seem to reduce the consequences of attention deficit, making the learning more fun and interactive. However, few statistical results on the impact of these tools on the learning by DS children were considered.

Implementation of *DS GeL-apps* may complement the related works in this section by allowing real-life experiments to further validate the presented arguments. Further, the design of *DS GeL-apps* as proposed in this paper, builds on the findings and recommendations of said works by combining mobile devices, Web (virtual) facilities and actual world resources to harness multiple-source benefits.

3 DESIGN METHODOLOGY

In general, a *DS GeL-app* targets two audiences: players and supervisors. Players are DS children who play the gamified app to acquire literacy and language skills. Supervisors are professionals who teach, develop or provide assistance or materials for teaching DS players. Supervisors include pedagogues, psychologists, authors, teachers, instructors, monitors, game designers, relatives and people who assist, produce, apply or use literacy material for DS children such as speech therapists and linguists. A *DS GeL-app* must be designed to provide facilities and resources to support both audiences.

The proposed methodology to design *DS GeL-apps* follows an agile (Larman, 2004), iterative and interactive approach with representatives from both audiences functioning as clients. The methodology has 8 steps:

1. List requirements for DS educational software apps and games. The list is built by eliciting requirements from: a) interviews with DS individuals and their relatives; b) perceptions of user needs and experiences with software

tools by professionals working with DS and app or game design; c) analyses and usages of educational software products, games and tools for authorship and presentation of lessons and entertainment for the general public or for DS individuals in particular; and, d) the literature on educational software in general or which was gamified for DS students.

2. Parse the resulting list to consolidate semantically equivalent requirements, but with different syntaxes. Only one equivalent requirement must be left in the list so that they become mutually exclusive and thus serve to separate and organize domains in the design, implementation and test of the gamified, pedagogical software application of interest.
3. Identify design-implementation domains of requirements in the consolidated list. (A requirements domain is a grouping of requirements which will be implemented as a unit, according to a common set of rules and procedures, to support a common, specific purpose - such as inputting and displaying information or offering communications facilities.) Distribute listed requirements amongst the identified domains.
4. Consult clients on the relative importance (ranking) of the resulting domains of requirements for the intended activities of teaching DS children literacy and language skills.
5. To organize design and implementation of *DS GeL-apps* evolutionary versions, specify requirements for the ranked domains, by checking existing requirements or eliciting new ones, and validate the resulting requirements with clients.
6. Depending on objectives (e.g., elicit an initial set of requirements or enrich existing set), constraints (e.g. time-to-launch a test prototype), and validation results, cycle through steps I to IV to account for clients' comments or suggestions of changes or additions of domains or requirements.
7. Lay out or update a roadmap for versioning of the *DS GeL-app* of interest by packaging requirements from the ranked domains. An individual package of requirements defines the scope of a next evolutionary version of the *DS GeL-app* and encompasses the scope of the

previous version - i.e., versions are to have increasing utility for the intended audiences.

8. Implement, test, launch, and validate next version of the *DS GeL-app* according to the next package down the evolution road.

If a new version is to be implemented with requirements to be adjusted or yet to be elicited, cycle through steps I to VI. If not, cycle through step VII.

Steps I to III produce a set of generic requirements for a *DS GeL-app*; steps IV and V adapt requirements for the context of literacy and language acquisition; step VI consolidates the domains / requirements into ranked sets, that is, prioritized sets, which will serve to guide the evolution of versions of *DS GeL-apps*. Step VII transforms the research effort on the design of *DS GeL-apps* into practical software offerings whose usage will create more pathways, in terms of feedback by DS audiences, for such research. These steps can be better observed in Figure 1 below, where a flow chart is presented with the step-by-step of the methodology.

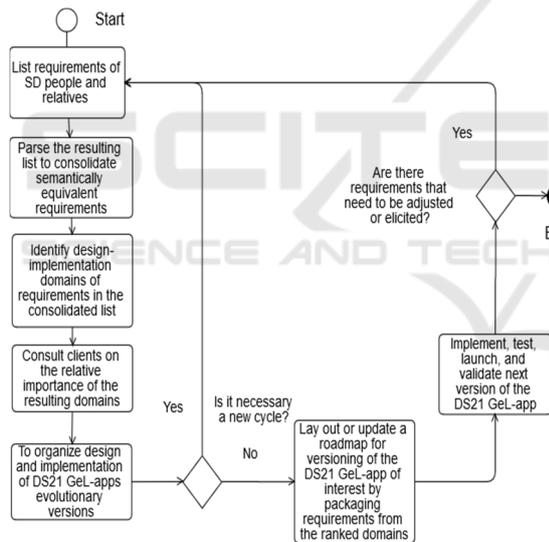


Figure 1: Proposed methodology for the design and implementation of *DS GeL-apps*.

Validation studies (rankings) are carried out in steps IV, V and VII. Ranking is important for it supports decisions on the profile and quantity of resources to be allocated for application R&D. Clients are the linchpin of such rankings. Their opinions or votes steer the design and development of *DS GeL-app*, as they (should) do with other software applications. In ranking requirements domains (or requirements within a domain), one may decide to attribute different weights to the votes (rankings) of individual clients (validators) to reflect their

experiences with DS, say. Further, if voting clients are set into classes, say $C = \{DS\ Children, Parents, Instructors, Psychologists, Game\ Designers\}$, one may in turn attribute a weight to each class $c \in C$. If that is the case, the *Overall Rank* of a domain D_i , $R_{Overall}^{D_i}$, for $i = 1, 2, \dots, n$ where n is the total number of domains in step IV, is given by the weighted sum of ranks attributed by voting clients within each class $c \in C$:

$$R_{Overall}^{D_i} = \sum_{\forall Client \in Class} (W_{Client} * R_{Client}^{D_i}) * \sum_{\forall Class} (W_{Class}) \tag{1}$$

Where W_{Client} is the weight of *Client's* vote (for a given rank = 1, 2, ..., n) and $R_{Client}^{D_i}$ is the vote (rank) of *Client* for domain D_i , with $1 \leq R_{Client}^{D_i} \leq n$. Without loss of generality, here it is assumed that $0 \leq W_{Client} \leq 1$; $0 \leq W_{Class} \leq 1$; and, $\sum_{\forall Client \in Class} W_{Client} = 1$ and $\sum_{\forall Class} W_{Class} = 1$.

In a "perfect" democracy scenario, all validators (voting clients) are considered equal and each of their votes carries the same weight - i.e., all voting clients belong to a single class and for any client (discrete uniform distribution), where is the total number of voting clients. Equation (1) collapses then, into a simple arithmetic average.

In another interesting ranking scenario, one may want to seek consensus amongst voting clients. For that, a Delphi technique (Hsu and Sandford, 2017) may be used in steps IV, V and VII. In the Delphi technique, each opining client anonymously registers and justifies the ranks s/he attributes to requirements domains (or requirements within a domain) in writing. To seek consensus, the written, anonymous registers are shown to all clients participating in the ranking who may then decide to alter their rankings in the next "voting" round, influenced by the justifications they read. For brevity purposes, the number of rounds is kept small, usually 2.

This methodology was defined based on the second principle of the agile manifesto: "Welcome changing requirements, even late in development. Agile process harness change for the customer's competitive advantage" (agilemanifesto.org/iso/en/principles). *DS GeL-apps'* users present cognitive characteristics which are complex, heterogeneous and, difficult to categorize and to model. These characteristics require greater attention to the process of requirements elicitation and validation to improve the system usability and accessibility.

In addition, according to Leffingwell (1997), about 40% to 60% of all problems encountered in a software development project occur due to flaws in

the requirements process. Such flaws are caused by the use of inadequate techniques for design by developers and the fact that there is no standard design technique. The 8-step methodology in Figure 1 allows one to perform repeated cycles of requirements elicitation and validation to ensure that elicited requirements are as close to users' expectations as possible. However, cycling through all steps of the methodology takes time, years even, if feedback from actual DS GeL-app usage is to influence the design and engineering of later versions. The investigation herein reported upon is in its beginnings, having reached step V in a first pass.

The Research Question (RQ) of interest of the investigation is: Which are the most important requirements for gamified, pedagogical applications to support literacy and language skills acquisition by children with Down's syndrome? This paper brings new results of and new insight into a first ranking experiment in step IV (De Souza, Moura and Ghirello-Pires, 2017); and, for step V, explores possibilities for the requirements of the top ranked design domain. Albeit its preliminary discussions, the paper already creates pathways for further research and the practical usage of results in directing and prioritizing the development of software tools to support literacy and language acquisition by DS children.

4 BASIC ARCHITECTURAL DESIGN, INITIAL REQUIREMENTS AND DESIGN DOMAINS

Architectural details of a *DS GeL-app* facilitate elicitation of some requirements as well as communication among development stakeholders (e.g., designers, programmers, testers). Hence, this section presents architectural elements of a DS GeL-app first.

4.1 Basic Architecture

The high level, basic architecture for a *DS GeL-app* consists of three modules (Figure 2): two major DS service-oriented modules (one for each type of audience); and, a third, to support marketplace activities.

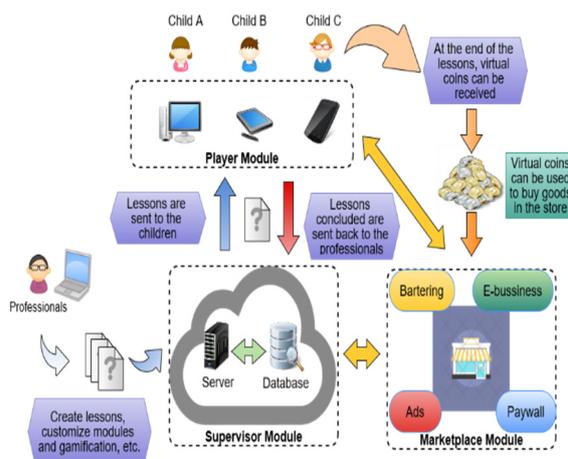


Figure 2: Basic *DS GeL-app* architecture.

The player module is to entertain the user (i.e., as if playing a game for fun) while s/he studies lessons or takes part in activities as part of pedagogical work. Work may correspond to responding to drills, doing assignments or homework and carrying out “missions” – such as in a regular virtual or real game or a combination of both, typical of alternate reality. Work may be done alone, by a group of players or under the supervision of parents or instructors. Missions may be carried out online or offline, as well as in the real world or both (alternate reality). Successfully finished work leads to merit points and rewards for the player. The player module is to be a gamified app as in (Deterding, 2011), an app that exhibits gaming characteristics to run on mobile devices – such as smart phones or tablets – and even on desktop machines connected to the Web.

The supervisor module is to run on the Web to assist its users (supervisors) to prepare lessons, customize player module’s pedagogical and gamification characteristics (e.g., frequency of answer attempts and rewarding) for individual or group of players, check assigned work, define and dispatch missions and monitor players’ performance. This module supports the teacher’s role of mediator of knowledge. Here, s/he can create activities according to the needs of the students with the tools provided by the system. In addition, it will be possible for the teacher to customize some aspects of the player module for a better student experience. In essence, this module is to be an e-Learning authoring-presentation tool of gamified lessons for DS children.

The architecture also includes a third, marketplace module, to support advertising, bartering, e-Business or even, a pay-wall. This module transverse the other two, being accessible by both types of audiences, or even, by the public at

large. The marketplace module promotes sustainability by generating revenue streams and offers a practical and quick way for gamers to exchange game points for tangible assets of the real and virtual world, making the gamified apps more attractive. The marketplace may be considered an incidental module in DS literacy and language acquisition contexts. It is included here for comprehensiveness of the discussion on *DS GeL-apps* structural elements and as basis for requirements elicitation.

4.2 Requirements and Design Domains

Although there are common requirements of software in general that are also applicable to *DS GeL-apps* (e.g., user authentication), they are not discussed here; nor are requirements related to specific lesson contents which may vary to accommodate pedagogical objectives and language characteristics. The interest here lies in requirements that highlight the differences that one should consider to the advantage of both DS audiences. The differences may be subtle at times, but the requirements of a game or generic software and those of *DS GeL-apps*, in fact, differ. For example, in game mechanics, the player is usually penalized for not completing a certain task after a certain number of attempts or within a tight time limit. Depending on the context, the player may even be punished with flashing messages on the screen, rude music or verbal scolding. However, this is not the case of DS contexts: there should be a more elastic limit to the time or attempts and the mechanics should persuade players to keep trying longer, by providing frequent feedback and congratulating players for their success.

Design domains and associated, example requirements for *DS GeL-apps* were initially presented in (De Souza, Moura and Ghirello-Pires, 2017) after a one pass through steps I to IV of the proposed methodology in section 3: data collection with clients in a) and b) of step I was done through semi-structured interviews and produced a total of 19 requirements; I.c) produced 18 requirements (from examined software); and, 82 in I.d) - literature review. The 119 requirements were then reduced to 76 in step II. These initial 76 requirements were then distributed over 8 identified domains in step III. Table 1 summarizes results.

Table 1: *DS GeL-app* design domains and example requirements.

#	Design domain	Total elicited requirements in methodology step				Example requirements
		Ia Ib	Ic	I.d	II	
1	Navigation & Interface	2	6	29	31	Screen-related features, such as buttons (big, dark colored with lighter color lettering); images (photographs preferable to drawings); colors (should be bright); and, fonts (Serif).
2	Gamification elements & Incentives	1	2	21	11	Alternate reality gaming; support for avatar and game currency; integration with other online and physical board games; trust and reward systems; creation and management of tangible and intangible incentives, and, of leaderboards.
3	Game mechanics & System configuration	7	5	7	11	Repetition, duration and other rules concerning activities and rewards; and, configuration of user profiles and privileges.
4	Authoring	4	4	6	8	Specification of tools to assist developers of multimedia material (lessons, tasks, missions) by instructors and other professionals.
5	Tools & Support for supervisors	2	1	5	5	Facilities to assist supervisors (therapists, instructors...) in managing the learning process with player performance metrics, customization of tasks for specific players and granting of rewards.
6	Feedback & Help	3	0	7	5	Support for multimedia interactions with the players; alerts and reminders of pending assignments; praise upon successful completion of a task or parts of it; (frequent) positive feedback and stimulation of corrective recommendations; responses to help requests.
7	Input	0	0	2	3	Guidelines for usage of mouse, keyboard (both to be minimized) and touch screen (preferable).
8	Socialization	0	0	2	2	Requirements to support players’ interactions with the persons anchoring the presentation of lessons or interactions with other players within the app itself for chatting, doing group work, bartering, exchanging gifts or redeeming points for goods or services.

Table 1 offers a very initial set of requirements of *DS GeL-apps*. Additional passes through the agile methodology steps will consolidate this initial set through elicitation and validation of additional requirements. While an initial set serves to steer the design of early but useful, versions, a consolidated set of requirements, ranked in importance, will serve as a reference for the evolutionary design of such apps. Developers will thus have a basis for defining software versions in terms of which requirements to include in a new version of a gamified app, given their importance in terms of utility for its audiences.

5 REQUIREMENTS VALIDATION AND RANKINGS BY IMPORTANCE OF DESIGN DOMAINS

Additional interviews were carried out and surveys were applied to clients in step IV. The questions in the surveys were open format and intended to determine the relative importance of the domains, validate their requirements in the initial set of Table 1, and to respond to the Research Question (RQ). As this research on *DS GeL-apps* is being carried out by

cooperating researchers in Brazil and in Australia, the ranking and validation experiments involved clients in these two countries.

In Brazil, nine clients participated in the experiments: four parents of DS children (2 dentists, 1 with specialization in Letters, and 1 in Social Work); and, five professionals working with DS (1 specialist in Vernacular Languages, 2 in Psychology, 1 in Speech Therapy, and 1 in Pedagogy). In Australia, there were two software/game design experts - one of which had an adult DS individual for a sibling. Three classes of clients were then represented in the experiments and functioned as proxies for DS individuals: $C = \{Parents, Professionals, Designers\}$. The average experience with DS of the 11 class representatives was 9.6 years. Note that, at this stage of the research, no DS individual contributed to the ranking and validation experiments directly. Note further, that the small number of participating clients implies that results should be taken as preliminary.

5.1 Validation and Ranking Results

The 9 validation-participating clients in Brazil assessed each of the 76 requirements in the initial set, with the following results: 39 of the requirements were accepted “as initially presented”; the semantics of 16 was adjusted (e.g., “unlimited repetitions” was reworded to “customizable number of repetitions”); 16 new ones were added (e.g., “Use Artificial Intelligence tools to monitor player performance and adjust the pedagogical process”); and, 21 were quarantined (e.g., “Use Italic Serif fonts”) – by giving each of these, at least a vote for removal from the set (De Souza, Moura and Ghirello-Pires, 2017). The total of requirements could end up being 71 (76 + 16 - 21) if all quarantined requirements are accepted back; or, 92 (76 + 16) if all quarantined requirements are removed. For rigor of statistical significance, one should have all requirements, quarantined ones in special, undergo further validation studies with more clients (since their small number is a validation threat).

The design domain with the most quarantined requirements was "Navigation & Interface" and the one with the highest “as initially presented” acceptance rate was the “Authoring” domain. Another domain with well accepted requirements (8 out of 11) was that of "Gamification Elements & Incentives"; but this domain also had 2 out of 11 quarantined (“tangible rewards” and “leader boards” might discourage players instead of motivating them).

The 16 new requirements were all accommodated in the existing 8 domains.

All 11 participating clients found “unnecessary to add to or discard domains from” those in Table 1. They also thought that the requirements domains will lead to useful implementations of DS GeL-apps for teaching language acquisition and literacy to DS children. When asked to rank the design domains in terms of importance for these implementations - and thus answer the Research Question of interest here, their “perfect democracy” overall average ranking, with 90% confidence intervals and 10 degrees of freedom, is given in Figure 3. In this Figure, a domain whose average rank is closer to 8 is considered the most important; the one with lowest average rank, the least important. In case of a tie of averages, the domain with the narrower interval, or equivalently, smaller variance or smaller standard deviation – which would denote less doubt by the validators, would be considered more important. (That is the case with the two last domains on the far right of Figure 3).

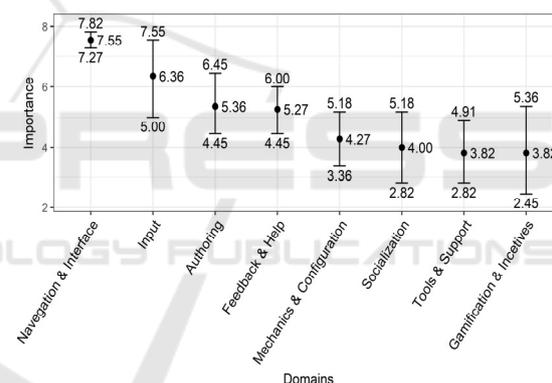


Figure 3: Overall average ranking of DS *GeL-app* design domains (mean and 90% confidence interval).

As shown in Figure 3, some domains have overlapping confidence intervals and therefore, it is not yet possible to identify with certainty, relative priorities among most classes. However, it is possible to affirm with 90% confidence that the “Navigation & Interface” domain presents a significantly higher importance - i.e. it is ranked in first place - than all others, except for the “Inputs” domain, whose interval [5.09; 7.45] overlaps that of “Navigation & Interface” partially. It is also possible to state with 90% confidence that the “Inputs” domain is more important than the “Tools & Support” domain. The sample means in Fig. 3 appear to indicate that the “Gamification elements” domain, in the opinion of the interviewees, is the least important.

One possible reason for the “Gamification elements” domain ranking last in importance is that DS individuals are not themselves, part of set C. The members of the classes in C, being designers, DS professionals, and DS parents or relatives, may value pedagogical content and instruction more than entertainment. Indeed, Figures 4, 5 and 6 show rankings by representatives of these classes – and none brings the “Gamification elements” domain higher than 4th place. In fact, this domain sports the widest 90% confidence interval in all rankings, making it the one domain whose importance validators had the more doubts ranking.

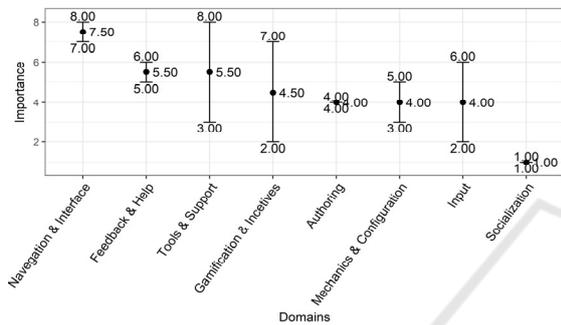


Figure 4: Ranking by designers.

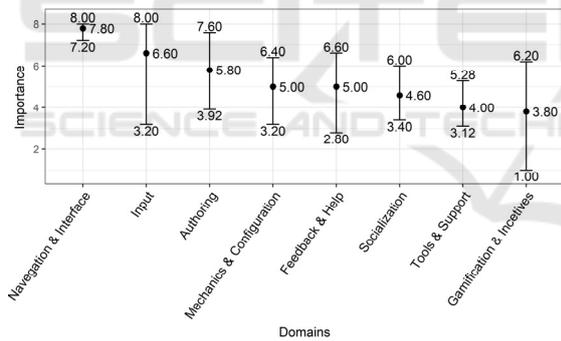


Figure 5: Ranking by professionals.

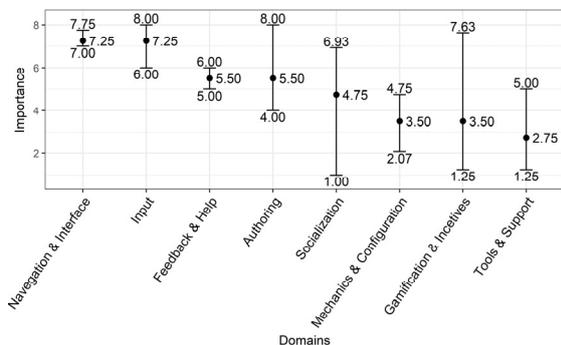


Figure 6: Ranking by parents. Rankings according to client class of DS GeL-app design domains (mean and 90% confidence intervals).

Variations in rankings due to client classes' preferences may be emphasized by means of the Principal Component Analysis (PCA) graph in Figure 7: most parents-relatives are grouped in the opposite direction of the vector that represents the “Gamification elements” domain, demonstrating that, at least during this first validation experiment, relatives believe that the other domains of requirements - such as “Activities” and “Inputs” - should have higher priority than the domain linked to the elements of fun and motivation. Expert opinion seems more varied, ranging from professionals' opinions that the Gamification domain is to be ranked higher in importance (specialists in red, to the left in Fig. 7) to lower importance (specialists in green, to the right in Fig. 7).

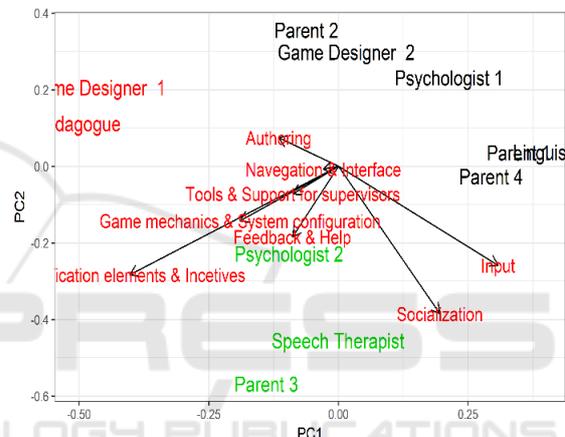


Figure 7: Behaviour of DS GeL-app stakeholders relative to domains ranking (ordering).

DS children may not endorse the interviewed DS professionals' nor their own relatives' rankings: a bit of fun may make lessons more engaging for them. (Does not the same apply to anyone?) Additionally, the variations in Figures 4 and 5 suggest further validation studies. Further validation studies should have DS individuals as validators.

Interviewees' responses were given without them experiencing any real software app or mock-ups (an electronic model used to demonstrate functionality). Validators had to imagine possible benefits and constraints of the design domains and associated requirements. Therefore, the validation that was carried out is said to be a “face validity” (Gravetter and Forzano, 2012), since it has a strong subjective component embedded in its judgment. Due to such subjectivity and the fact that the response sample came from only = 11, 90% confidence intervals were adopted. The subjectivity embedded in these results may have been reduced however, since voting clients

were experts on teaching literacy to DS children, making results possibly consistent with their reality (Holden, 2010).

Despite the discussed threats to validation and its limitations, the interviewees provided (early) evidence the answer to the Research Question at the end of section 3, is “requirements for the Navigation & Interface domain are the most important for DS teaching of literacy and language acquisition”. So far, this domain also happens to have the most requirements.

6 DS NAVIGATION & INTERFACE DESIGN INSIGHTS

Cho, Cheng and Lai (2009) found that there are many ways of conceptualising supported learning within the Vygotskian tradition, including scaffolding (Wood, Bruner and Ross, 1976), assisted performance (Tharp and Gallimore, 1989), dialogic enquiry (Wells, 1999), guided participation (Rogoff et al., 1993) and guided interaction (Plowman and Stephen, 2007).

To successfully develop a User Interface (UI) that works not only for the learner but also for the instructor it is important to take above perspectives into account when analysing existing game-based learning apps and non-game learning apps to gather data for the development of a system and UI that helps scaffolding the student technology-mediated learning.

Preliminary data collected by visiting DS students at special needs schools show that students get easily stressed and upset by failing to interact successfully with a variety of learning and teaching apps installed on iPads. The frustration resulting into discontinuation with the interaction of the learning app is mainly due to cognitive overload.

Cognitive overload refers to the total amount of mental effort being used in the working memory (Sweller, 1988). Cognitive load theory developed by Sweller has many implications in the design of learning materials which must, if they are to be effective, keep cognitive load of learners at a minimum during the learning process (Culatta, 2016). Cognitive workload is thought to be multidimensional and multifaceted. Mental workload can be defined as the ratio of demand to allocated resources (Da Silva, 2014). Spirkovska (2005) writes that multiple resource theory stresses the importance of distribution of tasks and information across various

human sensory channels to reduce mental workload. She continues stressing that one sensory channel has been touch and that unlike the more typical displays that target vision or hearing, tactile displays present information to the user’s sense of touch.

The authors thought that they should investigate the role of touch further to see how it could be used as an add-on or alternative to auditory display based UIs. It is hoped by providing the user with UI choices that suit them best to be able to help reducing cognitive overload.

As suggested by literature, it was decided to develop a UI that is based on both visual and audio and also looking into touch to provide input to the app system and feedback to the user (auditory & sensory displays). It is envisioned to investigate existing specifically and practical guidelines, middle-level principles and high-level theories and models as suggested by Shneiderman, (2017) to apply best practise and achieve a high-quality UI design.

Literature correspondingly recommends that criteria for the design and evaluation of the user interface of gamified language (literacy) multimedia software (apps) need to be developed for the prescribed audience and should be based on hybrid models that are combining a cognitive and software engineering approach (Park & Hannafin, 1993; Ravden & Johnson, 1989). Those criteria will help to determine if the UI is effective in supporting the cognitive processes involved in learning linguistic skills such as speech, memory and association.

Games and gamified apps can immerse players through deep level engagement, intricate and dynamic structures, high quality visuals and audio and by providing highly rewarding experiences with near instantaneous feedback (Terton and White, 2014).

Engagement within gameplay can be generated through being challenged, through arousing the players’ natural curiosity, by providing a sense of and by stimulating the player’s imagination. To design for games and gamified apps poses challenges due to the individual nature of users’ playfulness and different levels of experiences with games and play. Arrasvuori et al. (2011) have developed the Playful Experiences (PLEX) framework, which is a conceptual tool for understanding the playful aspects of user experience (UX) and at the same time also practical tool for designing for experiences through established user centred design (UCD) methods (Arrasvuori et al., 2011). It is hoped to collect user data that helps in the iterative development process of designing the best visual and auditory UI for the game based app.

But not only should the UI work best for the students but also for the teacher, Frauenberger (2009) has identified the need for a structured design approach to create an UI that caters for both the learner as well as the teacher. Frauenberger has developed the *paco* – pattern design in the context space framework, which provides methods to capture, apply and refine design knowledge through design patterns.

The goal is to design an effective dynamic system personalised adaptive user interface (PAUI) that automatically adapts to the individual skill levels of the user and reacts to different situations and requirements helping to minimise cognitive load, facilitate learning. It is planned to have an operating system that can detect and learn individual behaviour patterns so that the PAUI can be changed to assist the user in a more effective manner.

In order to achieve this, we analysed a number of the existing platforms and applications that already exist, to determine a way to minimise the cognitive load for individuals with DS as well as being able to better facilitate their learning in a way that is fun and will encourage them to continue with their development.

One of the applications that have been analysed and should be commented on is the current preferred system known as Proloquo2go, this application is recognised at the most comprehensive available at the moment and is used by organisations and therapists for enabling individuals with a number of learning disabilities.

The analysis of proloquo2go showed that although it is an application more focused on creating Augmentative and Alternative Communication (AAC) than on literacy, it has presented several important features that can be used to facilitate the literacy process in individuals with DS making it a very interesting tool for surveying and analyzing requirements. However, because of the complexity of the application there is a great potential for cognitive overload from both user and a tutor who is unfamiliar with the application; this most likely stems from the applications customisability. Additionally, while the proloquo2go application is comprehensive in its learning structure it lacks the fun aspect that can encourage a user to want to continue using it.

During the process of analysing applications, particularly proloquo2go, a number of tutors (either carers or therapists) mentioned that in a number of cases the users needed a lot more guidance when using the application than they had using traditional assistance methods. After some time, analysing applications, the complexity of some applications

showed that a user could easily get lost within the programs and without guidance have trouble finding their way around.

Resulting from the preliminary analysis and interviews with carers and observations of user interaction, it is planned to design a prototype that utilises more than just a tablet device, adding a measure of augmented reality to the learning experience by coupling physical aspects to the program through picto-cards or blocks, combining audio visual cues with tactile interactions with real objects to re-enforce learning and memory.

7 CONCLUDING REMARKS AND FUTURE WORK

This paper dealt with a gamified, pedagogical application to support literacy and language skills acquisition by children with Down's syndrome. Such an application (DS GeL-app) will directly contribute to the concretization of article 24 (access to Education) of the General Principles, Accessibility, of the United Nations Convention on the Rights of Persons with Disabilities (UNCRPD). *DS GeL-apps* may also indirectly contribute to UNCRPD article 19 – Living independently and being included in the community; article 21 – access to Information and communication services; and, article 27 - Work and employment because of users providing with the ability to learn how to communicate information accurately, clearly and as intended. Through improved speech and literacy skills the user will be enabled to get around in the community, communicate effectively with others (face-to-face and using technology), and self-advocate or speak up for themselves.

As the preceding sections have made clear, the most important requirements of developing and designing a gamified, pedagogical application to support literacy and language skills acquisition by children with Down's syndrome are about the learner and instructor. The paper provides information on how to arrive at a selection of requirements needed to develop successful DS GeL-apps by analyzing an initial ranking (agile methodology) of requirement domains carried out by cooperating researchers and clients in Brazil and in Australia.

Additional passes through the agile methodology steps will consolidate initial sets through elicitation and validation of additional requirements. The initial set serves to direct the design of early but useful versions. A more consolidated set of requirements,

ranked by importance, will serve as a reference for the evolutionary design of the DS GeL-apps and thus be the basis for defining different software versions of the app by ranking importance in terms of utility for its audiences.

Early evidence based feedback sought through client interviews indicates “requirements for the Navigation & Interface domain” is the most important domain for DS teaching of literacy and language acquisition and has the most requirements. Analyzing all results indicates that the DS GeL-app project is mainly a task of interface design and interaction features (Inputs), with playful aspects and socialization assuming a secondary position. Further to the ranking method it is suggested to conduct real-life experiments to supplement the validation of findings and recommendations of said works by combining mobile devices, Web (virtual) facilities and actual world resources to harness multiple-source benefits.

The paper reasons to support pedagogical processes of literacy and language acquisition, making them fun, motivating, engaging and effective for children with Down Syndrome (players) and at the same time allowing specialists (supervisors), such as educators, therapists, and instructors to manage content and pedagogical strategies. Paramount to a successful application is a user interface (UI) that caters for both the learner as well as the instructor. Informed by literature it is advisable to proceed with a pattern design framework, that provides methods to capture, apply and refine design knowledge through design patterns resulting in a powerful and effective dynamic system personalised adaptive user interface (PAUI) that automatically adapts to the individual skill levels of the user and reacts to different situations and requirements helping to minimise cognitive load and therefore facilitating learning.

7.1 Limitations

The architectural details of a DS GeL-app that will facilitate elicitation of requirements as well as communication among development stakeholders (e.g., designers, programmers, testers) will be developed in later phases. Although there are common requirements of software in general that are also applicable to DS GeL-apps (e.g., user authentication), they were not discussed here; nor were requirements related to specific lesson contents which may vary to accommodate pedagogical objectives and language characteristics. The small number of participating clients implies that results should be taken as preliminary. Also, data and feedback were mainly gathered from researchers and

clients and not from children with DS. This should occur in the next phases of the project.

7.2 Future

The paper already creates pathways for further research and the practical usage of results in directing and prioritizing the development of software tools to support literacy and language acquisition by DS children that hopefully will improve the quality of life for DS children. With help of a team including speech-language pathologists, physicians, classroom teachers, special educators and families we plan to communicate with DS children to co-design the *DS GeL-app* to cater for their needs and arrive at a fun and engaging application that helps to address the speech and language problems faced by many children with Down syndrome.

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