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Gamification as technology enabler in SEN and DHH education

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Abstract

Yearly in Mauritius, only a few Special Educational Needs (SEN) and especially Deaf and Hard of Hearing (DHH) students manage to get a passing mark in French language at elementary level. As at date, literature suggests that there is hardly any French language learning tools connected with pedagogical knowledge and technological tools suitable for those children. The rationale behind this paper is to show how gamification of French learning resources can positively affect SEN and especially DHH students' understanding and level of achievement in the language. Research questions were posed about the difficulties faced when students of that specific group learn to read and write in French, about how the gamification of textual resources can be used to improve the students' learning, and the impact the games have on the students. The aim of this research is to embed gamification in the teaching and learning process of French language. Advocating for both qualitative and quantitative methods, the project based itself on the pragmatic paradigm while the theoretical framework is based on action research. Using my methodological inventiveness, data was gathered using techniques such as surveys, interviews, observations and focus group discussions through the lenses of narrative inquiry. On average, most students already did quite well when subjected to their teachers' teaching methods only and showed a slight improvement for some students when games were added as learning aid.

Keywords Gamification, special education needs (SEN) · Deaf and hard of hearing (DHH) · Inclusive education · Deafness · Educational technology

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1 Introduction

In Mauritius, only a few Special Educational Needs (SEN) and especially Deaf and Hard of Hearing (DHH) students manage to get a passing mark in French language at elementary level yearly. This shows that those students are encountering difficulties to perform well in this subject; in that they struggle to read and write. Due to the heterogeneous language background of SEN students in Mauritius, foreign language learning might be more challenging. Although now 'armed' with a national sign language and reformed by the NCF 2015 educational project, inclusive teaching in SEN schools still lack learning resources suitable for this population. As at date, literature suggests that there is hardly any French language learning tools connected with pedagogical knowledge and technological tools suitable for the Mauritian context. The necessity then arises to create learning materials adapted to SEN and DHH students to facilitate language acquisition, in the hope of also assisting SEN teaching and improving the children's academic performance using gamification. The aim of this research is elaborated in twofold; to identify the main difficulties these students face in learning French language, and to describe the impact that pedagogical games have on the students' level of understanding and achievement. To reach the objectives, an overview of literature is first presented and the methodology used afterwards described. The paper then gives way to the result and discussion sections; from which the conclusions are finally derived.

2 Literature review

2.1 Special educational needs

Special Educational Needs (SEN) refer to learners with learning, developmental, and physical disabilities; communication, emotional, and behavioral disorders; and learning deficiencies (Bryant et al., 2019). In Mauritius, around 25% of children with disability are categorized as severe to profound, and those children normally attend SEN schools because they need resource assistance or require direct attention from Special Needs teachers (Ministry of Education Tertiary Education Science and Technology, 2017). A sub-category of SEN includes Deaf and Hard of Hearing (DHH) children. The delayed exposure to a first language in DHH children affects language acquisition and the development of a second one (Humphries et al., 2014; Mayberry, 2007). Goldin-Meadow and Mayberry (2001) found that deaf children do not necessarily read through codes based on phonological sounds as do hearing children. Language processing and structure is not the product of the sensory-motor modality through which it is sent and received, but rather of the human mind (Mayberry, 2007). Further research is necessary, though, to develop techniques to teach deaf children how to map print into sign (Padden & Ramsey, 2000), and how instructions can be best used to turn signers into readers (Goldin-Meadow & Mayberry, 2001).

2.2 Main barriers to literacy development in SEN and DHH children

For over 30 years, literacy has been recognized as a key concern in SEN and especially DHH education, and understanding the main difficulties faced by these children can help inform remedial actions and strategies in the learning and teaching practices (Conrad, 1979; Di Mascio et al., 2013). The main difficulties are therefore grouped and briefly reviewed into the following themes derived from a preliminary interview with the SEN educators: Memory and the Working memory, Abstract and Intangible concepts, Parental Involvement and Absenteeism, Language Differentiation and Code-mixing, and Time Constraints and the Curriculum.

2.2.1 Memory and the working memory

Memory here refers to the process by which a child encodes, stores and retrieves information. Over the past decades, research has shown that performance on short-term memory (STM) and working memory (WM) tasks highly predicted academic achievement in reading and language comprehension (Cain & Oakhill, 2006). Research suggests that learning fails or is hampered when the task demand exceeds memory capacity (Ayres & Van Gog, 2009). Further, deficits in memory processes have been found for children with disabilities (Pickering, 2006); such as reading disabilities (Swanson et al., 2009), speech and language impairments (Archibald & Gathercole, 2006), attention deficit or hyperactivity disorder (Rapport et al., 2008), and intellectual disabilities (Henry & Winfield, 2010). Areas of memory where DHH individuals perform less well than those who hear are further discussed.

Sequential memory is the ability to process or recall a list, such as words in a sentence, in the same order as it was presented. It has been found that in comparison to hearing individuals of the same age, DHH people had immediate sequential recall deficits when encountering printed words, fingerspelled words, sign languages (ASL, BSL), and digits (Denmark et al., 2016; Marshall et al., 2011).

Processing speed is the speed with which an individual performs a cognitive task such as understanding a sentence or recognizing a sign or a word. Language processing speed has been found to be slower in late second language (L2) learners than in native speakers (Felser & Clahsen, 2009), due to comprehension and recall deficits in signing (Mayberry & Fischer, 1989).

Attention is of great importance to the function of WM, and refers to the cognitive process of focusing on an aspect in the immediate environment (Engle, 2002). Deaf children have been found to have deficits in ignoring task-irrelevant distractions and in sustaining attention (Dye & Bavelier, 2013).

Memory load refers to the cognitive complexity that a task presents to an individual. Performance often decreases as memory load increases (Dehn, 2011). In the same way tongue-twisters increases memory load for hearing individuals, 'finger-fumblers' or signs that share similar movements and locations, increases task complexity and reading comprehension levels often decrease (Quer & Steinbach, 2015).

2.2.2 Abstract and intangible concepts

In semantics, abstract and concrete are classifications that indicate whether an object exists in any particular place or time, or if it has physical referents. Generally, compared to hearing children, DHH ones often underperform in language comprehension due to linguistic deprivation (M. L. Hall et al., 2019). It has been speculated that DHH children who do not share a signed or spoken language with their parents would be disadvantaged in acquiring abstract concepts, given the social context in which language is employed (Villani et al., 2019), compared to those with signing parents (Borghi et al., 2021). The difference in research findings about conceptual knowledge in DHH children could be explained in terms of the children's language background, the language task being assessed, the children's age and the social context in which abstract words were chosen (Kunisue et al., 2007; Marschark & Wauters, 2008). It appears that difficulty in acquiring abstract concepts progressively develops with age (Borghi et al., 2021). The absence of various kinds of knowledge such as semantic and syntactic knowledge may all contribute to poor linguistic comprehension (Wauters et al., 2006).

2.2.3 Parental involvement and absenteeism

On a global scale, parental involvement in a child's education has long been heralded as an important variable. Positive reciprocal interactions between families and schools contribute positively to a child's cognitive and socioemotional development (Catalano & Catalano, 2014). Empirical findings have shown that there is a positive association between parental involvement and academic achievement (Lara & Saracostti, 2019); demonstrating improved children's academical performance and self-esteem, and also school attendance and retention (Englund et al., 2014). Children with disabilities struggle with various difficulties at school and consequently are prone to developing a poor school engagement which is often related to a high level of school absenteeism (Blackorby & Cameto, 2004).

2.2.4 Language differentiation and code-mixing

Language differentiation is one of the difficulties faced by emergent multilingual students. The mix and inconsistency of languages used at school and at home does not help the Deaf and hard of hearing Multilingual Learners (DMLs) in acquiring the mastery of one or more languages (Mayberry, 2007). Adding to individual factors that delay exposure to a L1; which in turn affects the development of a L2 (Humphries et al., 2014); the societal and familial factors further affect the mastery and the rate of language development in DMLs (Pizzo, 2016). It is more difficult for DHH children to acquire a language from print when they have variable or low sign exposure at home (Csizér & Kontra, 2020). Without a strong L1, DMLs will be required to map print words of a L2 to nonlinguistic concepts

they have been using to communicate, and many will stagnate (Hoffmeister & Caldwell-Harris, 2014).

2.2.5 Grammatical rules and morphological complexity

In the study of languages, or more precisely in second language acquisition (SLA), two notions to the approach of complexity can be distinguished; namely: a relative and an absolute approach (Dahl, 2004; Stolz, 2008). The relative approach describes complexity in connection to language users. The absolute approach to language complexity is defined in quantitative terms; as the number of connections and separate units that a language feature or system consists of (Bulté & Housen, 2012). Many morphological systems, such as French language, are said to have high entropy (Ackerman & Malouf, 2013), because a small set of systematic rules cannot straightforwardly define the relationships among different units in the linguistic system. Acquiring inflectional morphology in a L1 or L2 is therefore not an easy task (Lardiere, 2006). French language also depends on markers expressing grammatical gender and article finiteness or prepositions, which adds to its complexity compared to English (Kettunen, 2014).

2.2.6 Time constraints and the curriculum

One of the major challenges faced by education systems around the world is that of finding ways to include all children in schools. In a comparative review of training between Norway and Finland, these dilemmas could be found in approaches to the preparation of SEN educators (Hausstätter & Takala, 2008). Similarly in both Germany and Sweden, an increased segregation in the educational system regarding special education was reported because resources for special educational support are less accessible at mainstream ones (Sansour & Bernhard, 2018). This brief overview of international literature on equity and inclusion reveberates with some aspects of the Mauritian primary curriculum access. To further meet the inclusive requirements set by the UNESCO, the National Curriculum Framework (NCF) 2015 has been implemented by the Ministry of Education in Mauritius (MIE, 2015); setting the Primary School Achievement Certificate (PSAC) as a Level 1 qualification recognised on the National Qualification Framework. However, the main challenge remains that of creating a good balance between the specific and the general or between special and adapted education (Ogden, 2014).

Another challenge arising from the imposed school curriculum is that of ensuring inclusion within the available timeframe, which also frequently appears in literature (Horne & Timmons, 2009; Travers et al., 2014). Unfortunately, busy teachers often feel pressured to cover the curriculum content (Ware et al., 2011).

2.3 Multimedia and games in educational context

It has been more than three decades that computer multimedia technology has been applied in the field of education, and with the progress of computer technology,

computer multimedia technology is becoming more and more of a crucial tool in education (Yue, 2017). Channels of communication with instructional purposes are referred to as educational media. The messages they carry are usually utilized with the goal of supporting teaching and learning(Ritakumari, 2019). Educational media, in turn, includes game-based multimedia which is also a tool to facilitate learning processes. The interactive nature of game-based multimedia can not only be used as a communication tool between teachers and students, but also in-between students; fostering good learning processes (Rohendi, 2019).

Gamification, as defined by Deterding et al. (2011), is the "use of game-design elements in non-game contexts". Popularly recognized for their entertainment value, gamification or serious games are driven by their potential to shape users' behavior in a desirable direction; which serve to promote better decision-making and human understanding with respect to some phenomenon (Dichev et al., 2015). While the goal of gamification is often to create and maintain intrinsic motivation, it is also the application of extrinsic motivators (Richter et al., 2015). Game elements and rewards serve as a starting point to understand the effectiveness of gamification (Deterding et al., 2011). Advantages of gamification are also known to be psysiological (McGonigal, 2011).

In his bestselling book, titled 'Play: how it shapes the brain, opens the imagination, and invigorates the soul', Stuart Brown makes a compelling case for play in all the aspects of life, including that of learning (Brown & Vaughan, 2009). He postulates that play is at the center of innovation and creativity. Moreover, Iosup and Epema (2014) used game analytics to analyze the behaviour and performance of students in the gamification of an educational course. They stated that game analytics allowed them to understand what students were interested in, how each performed, and where they needed more guidance; and as a result some lecture information were repeated to students who had not yet assimilated.

However, good technological infrastructure and the simple use of technological tools in the classroom do not ensure an improved learning process or automatically yield passing marks for students (Johnson et al., 2016). The target audience and scenarios in which games and multimedia are applied are some of the factors which affect how students acquire new knowledge. Educational strategies to effectively integrate technology and games in the classroom must therefore consider external and internal factors to the target audience.

2.4 Games and game design in SEN and DHH education

Research has shown that gamification has had the most success with struggling learners or students with SEN (El Mawas et al., 2019; Jong, 2015; Lan et al., 2018; Wajiuhullah et al., 2018). In their study, Wajiuhullah and colleagues (2018) found that students with intellectual disabilities could enhance their concept of numbers using digital games. Similarly, El Mawas and colleagues (2019) showed how an interactive educational 3D video game could help elementary children with hearing impairment acquire knowledge of the Solar system. Positive correlations between deaf children's cognitive skills and playing digital games have also

been found, and it seems that improvement in deaf children's memory skills were directly related to the number of games they played (Marschark & Hauser, 2008). In their study on designing collaborative strategies to support literacy skills for children with Cochlear Implants using serious games, Cano and colleagues (2018) found that the children did not feel shy from making mistakes or from participating when collaborating during the serious game. They neither completely relied on the teacher, who instead acted more like a moderator of the game. The studies (Cano et al., 2018; El Mawas et al., 2019; Jong, 2015; Wajiuhullah et al., 2018) also indicated a higher level of motivation and learning participation when games were used with children having SEN. These students often receive this type of specialized instruction because of the lack of success with the sole use of a traditional approach (de Freitas, 2018; Jong, 2015). Nowadays, teaching strategies not only include frameworks from past approaches, but support their incorporation with new findings and technologies for the growth of the education system (de Freitas, 2018; Florian, 2021).

Making students participate in game design, along with the ability of games to serve as ideal learning environment to facilitate systems thnking, is a powerful tool for learning (Kafai, 2006). Based on the Instructionist and Constructivist approaches to educational game design, and supporting the latter perspective, Kafai (2006) states how those at the receiving end; i.e.: the learners or game players, should be engaged in the design process because this not only assures technological fluency, but most importantly develops new ways of thinking through knowledge of how to make things of significance with those technological tools.

Differentiating games according to cognitive characteristics such as visual attention, text comprehension skills and memory abilities turn out to be crucial for the suitability and accessibility of students with SEN, and more specifically those with sensory deficiencies such as hearing impairment (Di Mascio et al., 2013). According to deaf studies(Marschark & Hauser, 2008), the reading skills of DHH people are lagging behind compared to those who hear, while both groups are considered to have similar visuoperceptual skills. Such differences call for specific guidelines when designing educational games that are both accessible and usable for DHH and SEN students.

Di Mascio and colleagues (2013) suggest developing digital learning systems that follow the Evidence Based Design and the User-Centered Design. To produce pedagogically effective systems, the Evidence Based Design framework ensures that the system design is based on empirical evidence gathered from domain experts; whereas User-centered Design places the users at the center of the design process using iterative prototype evaluation to produce usable systems. Further along, Di Mascio and colleagues (2013) provide guidelines clustered into five main areas for the design of digital pedagogical games for DHH children: words, other characteristics and position of textual elements, choices and interaction, feedback, game genres and devices. The guidelines are summarized as follows:

1. Words should preferably be familiar and unambiguous. If abstract or unfamiliar, their meaning should be easily inferred from the surrounding context. Moreover, choice for length of words is important; therefore they should not be too long.

2. Key textual information, such as game instructions, should be short and simple, without distant or complex referential expressions. Visual cues are encouraged for directing the attention of the student on relevant textual information.
3. In general, giving few and only necessary choices and using same items in the same position across screen interfaces should aid the recall of DHH children. For example, using similar icons with distinct colors for the exit or home buttons throughout the different interfaces. Avoid distracting stimuli that could distract the children from their main playing task. Use single interaction task or single communication channel at a time; because unlike hearing children, DHH ones cannot listen and answer simultaneously.
4. Immediate feedback is encouraged to compensate the usually short attention span of DHH children. Motion of objects or vibration feedback can be used to re-direct attention towards specific targets; and the timing and type of feedback should be carefully calibrated so as not to adversely affect attention focus.
5. DHH children generally prefer single-player games. In particular, from seven to nine years old, the majority of DHH children prefer non-photorealistic consoles; whereas those aged from nine to eleven years old prefer photorealistic ones. Moreover, DHH children prefer action and brain-teasing games, and games for male children should have progressive challenges, extrinsic rewards, sport, and adventure elements. The timing of games should also be carefully calibrated because of short attention spans. Illustrations provided in games should be informative and highly coherent with textual information.

2.5 Survey design and special needs

An important goal of test and evaluation is to not only understand how a system performs in its environment but also users' experiences operating the system. Surveys are specific forms of social interactions which are appropriate for measuring such user experience. They systematically measure people's feelings, opinions and thoughts. Going through several mental processes, users respond using the response options provided by researchers. Survey design should construct questions in a way that facilitates a user's ability to recall relevant information from memory, understand the question and respond truthfully. In a good survey, the target population is represented by the studied sample and the concepts of interest are represented by the information which has been collected. Surveys are usually classified according to a number of criteria, and selected based on purpose, target population, concepts of interest, time restrictions, budget, and availability of resources. (Gideon, 2012; Wojton et al., 2016).

The question of validity when surveying students with SEN is another important aspect. Nusser and colleagues report on this issue when using a survey questionnaire for students with SEN and learning difficulties in Grade 5 and Grade 9. Challenges they encountered were mainly with regard to completion rates and congruency between students' and parents' reports. For some subject items, students with SEN were able to respond accurately and validly. Items without mental representations, such as the birthplace of grandparents, especially for those who have

a background of migration, could yield low completion rates or reduced validity. Nusser and colleagues also admit that congruency between students' and parents' data does not necessarily indicate validity. However, congruency can be taken as evidence regarding the value of the children's data. Moreover, when parents' information is not available, it is rather important to collect proxy reports from the students themselves. The mode of administering the questionnaire is yet another aspect to be considered when working with students with SEN. (Nusser et al., 2016).

The standardised procedures used to collect data are often questionnaires which are presented to the sample by an interviewer or completed by the sample themselves. Interviewers are especially helpful when the survey includes more than one person in the household, when the survey is long and that additional data has to be collected, and when participants need an interpreter, as in the case of SEN and DHH children. If the design elements are not properly executed, even a well-designed survey will not yield quality results. Interviewers should therefore be trained and instructed in how to administer the survey. Gideon and colleagues suggest that each item of a questionnaire should be reviewed so that interviewers learn how to read each question and what probes, explanations or definitions, if any, should be used and provided to respondents. The review should then be followed by practice and mock interviews with a debriefing session which aims at minimizing interviewer variation in the administration of the survey (Gideon, 2012).

2.6 Arcs motivation model

Keller's (2010) ARCS motivation model has been extensively used to provide guidance in motivational aspects of instructional design and teaching. The model is represented by four categories which when applied to instructional materials, can condition students to be fully motivated(Li et al., 2018). The categories are Attention, Relevance, Confidence and Satisfaction. Attention is used to stimulate or maintain learners' interests. Sustaining attention will keep learners focused and engaged; allowing learning to take place. By relating instruction that is familiar to learners, the learning experience becomes relevant and meaningful; thus increasing the perceived value of the task and increasing motivation at the same time. Strategies to enhance self-efficacy, such as experience of success, can be applied in order to build confidence in instruction. Another way to enhance confidence is to foster the learners' belief that they have control over their performance. Satisfaction pertains to the learner's continued motivation to learn. Students are likely to develop a persistent desire to learn if they experience satisfying outcomes. Satisfying or positive consequences of instruction can result from both extrinsic and intrinsic matters. The most common extrinsic outcomes are certificates, badges, high grades or other tangible rewards. Intrinsic motivation, according to Deci and colleagues (1999), energizes and sustains activities through the spontaneous satisfactions inherent in effective volitional action. It is manifest in behaviors such as play, exploration, and challenge seeking that people often do for no external rewards.

Over the years, the ARCS model has been used to understand learners' language learning efficiency, and researchers found that students' achievement in English as

Foreign Language was enhanced (Li et al., 2018); positively increasing their confidence, autonomy and learning motivation (Li et al., 2018; Refat et al., 2020).

An important aspect of the ARCS model survey is the Likert scale. Pictorial scales are commonly used to survey children to replace text response options in surveys (L. Hall et al., 2016). In smiley face scales, respondents match their attitude or emotions on a scale showing faces with varying curvature of the mouth line, systematically varying from a large smile to a grimace (Toepoel et al., 2019). Stange and colleagues (2018) found that the smiley faces could speed up processing of questions, especially for lower literacy respondents, and made the question-answering process more enjoyable (Toepoel et al., 2019).

Understanding the main difficulties faced by DHH children can help inform remedial actions and strategies in the learning and teaching practices (Conrad, 1979; Di Mascio et al., 2013), and while several studies have reported the successful application of gamification in SEN and Deaf education (Cano et al., 2018; El Mawas et al., 2019; Jong, 2015; Lan et al., 2018; Wajiuhullah et al., 2018), none, or at least of those reviewed, addressed French language learning and teaching using games. Moreover, a preliminary interview with the SEN educators and School headmaster revealed that literacy in French language; which is a compulsory subject taught at elementary level; is the most difficult for DHH students. The following section therefore describes how the problem statements were addressed and filled this gap; both in the real-world and in literature.

3 Methodology

Advocating for both qualitative and quantitative methods to complement limitations and strengths of the different approaches, the project was based on the pragmatic paradigm while the theoretical framework based itself on action research. Pragmatism is based on the proposition that the methodological approach which works best for particular research problems being investigated should be employed, and justifies the methodological inventiveness used in this study. Action research is the process of acquiring knowledge of and improving a real-world situation while pursuing trustworthiness or establishing the 'truth claim' (McNiff & Whitehead, 2012). In this study, the widely used four-phase which are: Plan, Act, Observe and Reflect, have been employed. The Plan phase consisted of gathering data about the difficulties faced by the children in French language, which then informed the Act phase on the collaborative design and administration of the pedagogical games. The Observe phase ensured that students' educational data were gathered to be interpreted in the Reflect phase, where each participant reflected on his own action.

With the aim of researching teaching and learning strategies, and evaluating the use of gamified learning resources in French language and in SEN and DHH education, research questions have been formulated as follows:

1. **RQ1**: What are the main difficulties faced by SEN and especially DHH students that affect reading and writing in French language?

2. **RQ2**: What is the impact of a multimedia learning environment and gamification on the level of understanding and achievement of SEN and especially DHH students, in French literacy?

3.1 Participants and procedures

The development of French literacy, in the context of embedding pedagogical games in French studies of the Mauritian Curriculum, in a group of SEN, and especially DHH students, was followed over a period of 3 years. The sampling size obtained at a SEN elementary school allowed for the longitudinal study because of the small number of DHH and SEN students. Two classes with the greatest number of DHH students in the SEN school were selected, i.e.: Grades 3 and 4 in the first year of assessment; applying the purposeful sampling strategy with 8 students in Grade 4 and 6 students in Grade 3. In that sample, 8 students were DHH while the rest had different special learning needs as described in Table 1. Obtaining consent from parents/carers and children was central to the research relationship, and the students were informed that they could quit participation at any point during the research. The participants also included the 2 SEN teachers of both grades and 14 of the students' parents; counting a single parent/carer per student.

Table 1 Demographic profile of the children

Gender	Frequency	Percentage (N = 14)
Male	11	79%
Female	3	21%
Grade & Age (at 1st year of assessment)	Frequency	Percentage (N = 14)
G3 (8yrs – 11yrs)	6	43%
G4 (8yrs – 12yrs)	8	57%
Special Needs	Frequency	Percentage (N = 14)
General Learning Disability (GLD) / ADHD	7	50%
Speech Impairment / Dyslexia	2	14%
Emotional disturbance / behaviour problems (EDBP)	3	21%
Intellectual Developmental Disorder	2	14%
Hearing Impairment	8	57%
Physical Impairment	1	7%
Other chronic health conditions	1	7%
Assistive Technology or Degree of Hearing Loss	Frequency	Percentage (N = 8)
Cochlear Implant (CI)	1	13%
Hearing Aids	4	50%
Severe to Profound Deaf (when hearing aids may not help)	3	38%

3.2 Measures and analysis

To address **RQ1**, and determine the main difficulties faced by SEN and DHH students, semi-structured interviews with the students, their teachers and parents were conducted to understand each participant's point of view. Three different questionnaires were designed and used for each of the three participant categories. Interviews were conducted one-on-one and face-to-face for all participants, except for some parents who were only reachable through phone calls. The interview transcripts were reduced to include only relevant information, then color coded and categorized. The categories were finally grouped to reveal themes which served as guideline for subsequent observation sessions. The teachers and students were directly observed during French classes which cumulated to a total of approximately 13 h. The researcher assumed the non-participant role, and field notes were taken as often as possible. To record specific statements and describe the learning environment, narrative accounts of each day's observation were documented in a similar style as described in Clandinin and colleagues' (2016) narrative inquiries with children and youth. The accounts were then reviewed by the teachers to ensure that exchanges described were correctly interpreted by the researcher.

Along with the interviews and class observations, an initial Vocabulary Test was individually delivered to assess the students' knowledge from the previous grade. This assessment offered insight into some of the more tangible difficulties faced by the SEN and DHH children in French literacy as addressed in **RQ1**. The Vocabulary Test, which was also later used to address **RQ2**, is a variation of the Peabody Picture Vocabulary Test (Frey, 2018), and has been adapted to include DHH participants. The adaptation was mainly twofold; Part A tested the participant's ability to read or recognize a presented picture by choosing or pointing to the correct word between four options (A, B, C, D); while Part B tested the ability to write the correct French word of a presented picture. The selection of 40 French vocabularies for each grade was made from assessing the students' test papers of the previous year. The vocabularies were then reviewed by the teachers to make sure each list was grade-appropriate. Assuming a participant role this time to deliver the Tests, the researcher again documented each students' Test sessions through narrative accounts as previously described. The test papers were then corrected; where each correct answer yielded a point, making a total of 80 points for both part A and B; and analysed to uncover individual difficulties faced by each student.

The themes that emerged from the triangulation of data obtained from the interviews, observation sessions and initial Vocabulary Test were then used to describe the main difficulties faced by the SEN and DHH students.

RQ2 addresses the impact the developed pedagogical game has on the level of understanding and achievement of students. The aim is to descriptively assess the academic achievement of each student when using the games that were co-developed as teaching and learning tool. To differentiate between the influences the game and the confounding variable 'teacher' has in relation with the student's learning; teaching strategies were designed and administered within specific timeframes to the students. After each specific teaching strategy a Vocabulary Test, as described in the previous paragraph, was administered to the children. For example, during the

first and second session the teachers used their base and additional teaching strategies respectively to teach 10 French vocabularies to their students for a week each; after which a Vocabulary Test was administered. During the third and fourth session, the pedagogical games were added as teaching aid to the teachers' base and additional teaching methods respectively to teach distinct sets of 10 French vocabularies for another week each; and again Vocabulary Tests were administered after each session. In the fifth session, only the pedagogical games were used as learning aid so the students could learn yet another set of 10 vocabularies on their own without teacher intervention. Again the Vocabulary Test was administered, and the results obtained from each session, together with the teachers' comments on each performance through focus group discussions, were used to describe the students' understanding for each teaching strategy. Understanding here, defines the level of comprehension. It was therefore measured through the scores obtained by each student in the adapted Vocabulary Tests, in an attempt to evaluate the efficacy of the games that were co-developed. Through focus group discussions with the teachers, the latter's comments on each students' progress were also recorded after the correction of each Test. Because of the small number of participants; i.e.: the two SEN teachers, it was possible to carry out focus group discussions after each teaching and learning strategy administered. As for the interviews, semi-structured questions were employed and notes were taken as often as possible, while the responses were recorded in an online shared Excel sheet. The centralization of data was useful for the researcher to relate back to any specific comments and remotely discuss further with the teachers, especially in the face of Covid-19 when schools were closed.

The students' level of achievement, here, is defined by their level of motivation while using the pedagogical games. Motivation was measured using the standardized Instructional Materials Motivation Survey (IMMS) questionnaire which consisted of 5-point scale questions based on the ARCS model (Keller, 2010), and using a smiley face scale which is more adapted to the low literate children (Stange et al., 2018; Toepoel et al., 2019). Drawing from Li and colleagues' (2018) IMMS questionnaire for Hospitality English Vocabulary Learning, the instrument consisted of 16 items divided into the four categories of the ARCS model. For example, the first four questions pertained to Attention with questions such as "I wanted to know what the games were about", or "I liked using the games to learn new words". The fifth to eighth questions pertained to Relevance and included questions such as "Learning words through games is easier for me", "Learning words through the games will help in my communication skills". The ninth to twelfth questions were to evaluate Confidence with questions such as "If I score more points in the games, I will also perform better in vocabulary tests" and "Using the games can increase my knowledge and vocabulary". The last four questions were for evaluating Satisfaction, and consisted of items such as "I feel satisfied/ happy when I score points in the game", and "I feel that I am learning to read using the games". After reviewing the questions with the teachers to ensure accurate interpretation of each, as also suggested by Gideon and colleagues (2012), the questionnaire was administered to the students through oral and sign language by the teachers, while the researcher took the role of non-participant observer at the back of the classroom. The questions were projected onto the classroom whiteboard and each student was handed with a similar printed

version to mark their choice. The teachers were asked to use impartial examples when conveying the questions to the students to avoid biased responses.

3.3 Game Development

3.3.1 Game concept

The pedagogical games which were co-developed with the teachers were aimed at being used as learning aid for the children. The games requirements were gathered from interviews with the children, the SEN teachers together with observations of their French classes. In general, all students liked and spent much time on mobile or console games although not every one of them owned a mobile phone at that time. A recurring preference among the students was time constrained games: 'I like racing in the game', and the boys were particularly sensitive to challenges and points: 'I like to win' or 'I like competitions'.

Implementation of the games was also driven by several factors: being able to play and all the while learn from home, and adapt to the new sanitary measures imposed by the pandemic Covid-19 when schools remained closed. While co-developing the games, the teachers' requirements of the games only seemed to enhance their current teachings as can be noted from my reflections later during one of my observation sessions:

> In that interim moment, I thought about how the teachers of both grades used their teaching methods to influence the implementation of the games we co-developed. The similarity between the activities they often carried out with the children and the games echoed their current teaching methods. (October 08, 2020)

The games have been developed in LiveCode (a cross-platform rapid application development runtime system inspired by HyperCard) and imported as both mobile and desktop applications to allow children who do not own mobile devices to play the games at school. Before the final administration of the game, several prototypes have been deployed to ensure a good usability of the games' interface and that the intents of implementing pedagogical games were met.

3.3.2 Design and implementation

The games were based on the adaptive model described by Chan and colleagues (2019); and complemented the teachers' teaching methods while addressing the children's vocabulary learning needs by enabling the "learning for fun" concept. Also based on Keller's (2010) ARCS model to include motivational aspects, the different game elements used were classified into each of the four categories. For example: animated mouse-overs and the dynamic content were classified in Attention; while the choice of games was classified in Relevance. The Confidence category included the game prompts and timely feedback; while the Satisfaction category included the scores and the reward system. Following guidelines

Fig. 1 Main menu to choose a game

from Di Mascio and colleagues (2013) on the designing of games for DHH children, short-worded and familiar instructions are given on the main screen and are accompanied by their respective signs (i.e.: 'Choose a game') as seen in Fig. 1. Moreover, icons used to indicate home or exit buttons were consistently used across the screens to aid the recall of DHH children. Each game was designed to require single interaction tasks from the children. For example, only one letter or image could be selected at a time to avoid distracting stimuli. Immediate feedback was also used after each correct or wrong answer, to compensate the usually short attention span of DHH children. Although initially designed to be single-player games, as generally preferred by DHH children (Di Mascio et al., 2013), the desktop version installed on the school laptop allowed for collaborative play in class, with each child taking turns as directed by their teachers. Since the games focused on vocabulary learning, the pictorial representations of each word were carefully selected and validated by the teachers to ensure that they easily inferred meaning.

As a result, three distinct games have been used as teaching and learning aids as seen in Fig. 2. The first is a classical hangman game allowing for only 5 mistakes; while the second is a multiple-choice game with 3 options to choose from; and the third is a re-ordering letters game with the aim of forcing the player to complete the whole word correctly before proceeding to the next round. Each game is made up of ten rounds (10 words) allowing for a maximum of ten points, with intuitive and timely correct or wrong answer screens as immediate feedback.

Tapping into the strengths of DHH students in free recall of unordered lists, word and image pairs are randomly presented for each round, and letters can be randomly selected for the hangman game. The time taken to complete a game is also recorded for each student. The score board has been designed in three parts; a first to compare the highest score obtained in the minimum possible time, a second to compare the last

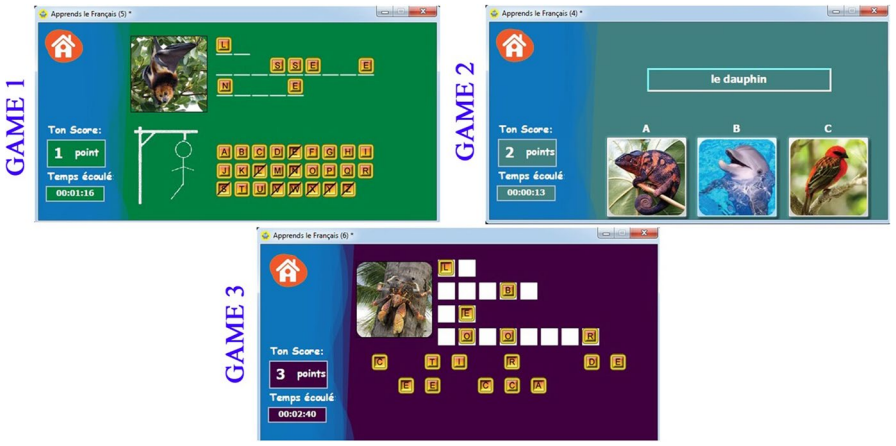


Fig. 2 Pedagogical Games 1, 2, and 3

score obtained, and the last to evaluate the player's overall performance; giving a statistic of the number of times each game was played, the best score obtained for each game and badges for each 10 scores obtained in a single round.

3.3.3 Post-production and production

At the end of the development phase and after testing several prototypes of the games with the teachers, the games were introduced to the children. Gathering both grades in a single classroom, with the game projected onto the whiteboard from a laptop, the teachers both signed and explained the purpose of the game. After a first demonstration of how to play each game, each student took turn to give a try at playing the vocabulary games. From the impressions shared by the teachers and observed by the researcher, adjustments were made to ready the game for the upcoming experiment. Among the several feedback implemented was that of enlarging the letter placeholder for the 3rd game, locking the game screen size, and adding a score board based on the last score obtained.

During the experiment period, the games were used as a class activity where each child would take turn to play the games; or sometimes as a collaborative one where the whole class would participate using their mini whiteboards to write their answers. The teachers and students often played the games in a sort of friendly competition to score the most points in the least amount of time. The games were also used as refresher training for students who missed class lessons, and acted as teaching aid which facilitated and decreased preparation time for class lessons.

4 Results

4.1 RQ1: What are the main difficulties faced by SEN and especially DHH students that affect reading and writing in French language?

The main difficulties faced by SEN and especially DHH children were grouped into themes; drawn from a thematic analysis of interviews carried out with the students, their teachers and parents, together with observation sessions of French classes and the individual administration of the Peabody Vocabulary Test. The themes were synthesized with literature and are discussed in frequency order as follows: Memory and the Working memory, Abstract and Intangible concepts, Parental Involvement and Absenteeism, Language Differentiation and Code-mixing, and Time Constraints and the Curriculum.

4.1.1 Memory and the working memory

Literature suggests that children with disabilities have deficits in memory processes (Pickering, 2006), and that this results in speech and language impairments (Swanson et al., 2009). This was also observed during the teaching of the present tense in the French verb system: "Vin had trouble with syllables. He had a list of the basic syllables in his copybook from which he was trying to read out to be able to spell the first singular person 'je'" (February 26, 2019).

Still on the teaching of the French verb system, while rehearsing the order of the singular and plural persons, one of the DHH students found it difficult to sequentially recall the persons from both printed words and signs: "Sha had the most trouble remembering the sequence of the six persons of the verb system; so Heena helped him once while he was rehearsing through signs" (February 26, 2019).

Correlating with literature, in comparison to hearing individuals of the same age, DHH people had immediate sequential recall deficits (Denmark et al., 2016). French as a FL during the narration of a short passage also revealed a slower language processing speed in the SEN children:

> Shenaz (the teacher) would read the passage out loud while also signing to the DHH children, but both the hearing and DHH found it difficult to follow up with the reading exercise. So the teacher wrote the keywords and illustrated them with diagrams on the whiteboard. (March 06, 2019)

Felser and Clahsen (2009) rightly found that late L2 learners had a slower language processing speed. The disparity between non-native and native signers were made clear during the administration of the reading and signing task of the initial Peabody Vocabulary Test with DHH students who did not have cochlear implant:

> Lina was very 'talkative' and quick at signing as she expressed herself with her little hands. She had a very good memory of the words presented to her and could identify most from the list. However, Sha who was less fluent in sign

> language also had a lower retention capacity; based on the number of words he could recall or recognize. (March 28, 2019)

According to Mayberry and Fischer (1989), this could be explained by the lack of automatic sign recognition in non-native signers due to comprehension and recall deficits in signing.

DHH children have been found to have deficits in ignoring task-irrelevant distractions and in sustaining attention (Dye & Bavelier, 2013), as also noted during an observation session: "Wesley (the teacher) spent several minutes on the reading task with Vin... During that time, the DHH students would sign in-between themselves from across the class, lost in their own worlds of play and stories" (September 17, 2020).

Appropriately directing and sustaining attention in the inclusive classroom seemed to be troublesome for the DHH students. This also held true for Jamie during the written task of the initial Peabody Vocabulary Test:

> Jamie had hearing aids and knew the alphabets, both how to pronounce and sign them . . . At the fourteenth word, I could notice that he seemed tired and much less focused to recall the average maximum letters he usually could after re-testing. We took a break, and he performed much better afterwards. However, at the twenty-ninth, he said and signed that he was tired and would do one last round. (May 30, 2019)

Writing required more cognitive effort than that of recognizing or signing a word; and maintaining the attention span for long periods of time seemed tedious for the DHH students and this negatively impacted WM. As Dehn (2011) states; performance often decreases as memory load increases, which also correlated with observations from the more demanding task of writing during the tests.

4.1.2 Abstract and intangible concepts

Classical conditioning is a method used by both SEN teachers to introduce new topics in class. An example during an observation session would be when the SEN teacher stressed on the importance of associating multiple different images to the word 'tourists'; because of some perceived misconceptions about the term:

> Using the class' wide screen to visualize pictures and videos so as to reinforce visual memory for words or concepts that would otherwise be difficult to explain using signs and words or symbols only; Shenaz (the teacher) displayed an image of "tourists swimming in burqas" to explain that the word "tourist" did not exclusively mean "white people", as often demonstrated in the Mauritian context. (September 20, 2020)

Without visual associations to new words or terms, the topic becomes abstract and thus difficult for the children to derive meaning; much less allow semantic learning to take place (Wauters et al., 2006). Correlating with literature that difficulty in acquiring abstract concepts progressively develops with age (Borghi et al., 2021), SEN teachers of both grades advocate that "vocabulary is fairly easier while

verbs are more challenging... verbs are abstract and more difficult to teach with the different tenses and conjugations... but animals are easier to teach because they (can be) related to them; they can see the animals" (Shenaz, personal communication, February 13, 2019).

The teachers found that teaching vocabulary was easier because the French curriculum for both grades (5 and 6) did not include high numbers of abstract concepts yet. On the other side, conjugations of verbs can hardly be explained through images and videos only. The level of abstraction requires that the children learn the conjugation rules which are often not logical; making teaching and learning of verbs in French language more difficult. As noted during one of the verb lesson; when the teacher re-introduced the three main tenses, even so some students still struggled to understand the associative sign and marker for the tenses:

> Wesley (the teacher) used the same object (an apple) in all sentences so as not to confuse his class with a different word. During the class exercise, the students were asked to identify the tense used in a given sentence and write it down. Vin who still struggled with tenses wrote all the three tenses for a given sentence. (March 13, 2019)

Conceptual knowledge here could be explained in terms of the children's language background, the language task being assessed, and the children's age which also defined their expected ability in a given task (Kunisue et al., 2007; Marschark & Wauters, 2008). In this instance, verb tenses presented an abstract concept that some students still found difficult to grasp.

4.1.3 Parental involvement and absenteeism

Inasmuch as parental involvement is described as being a positive and important variable on a child's socioemotional and academic development, interviews carried out with the SEN educators of both grades show that often parents neglect this responsibility:

> The children have difficulties in their academical education because of parents' negligence . . . most parents don't even communicate with their DHH children using sign language. We can see the difference in academical performance of those whose parents are involved and those whose parents are not. (Shenaz and Wesley, personal communication, February 21, 2019)

Indeed, when interviewed, most parents of DHH children did not know sign languages (MSL / ASL) well enough to use them as means of communication at home. Instead, some use natural signs (75%) or spoken languages (75%) as recorded in the following extracts: "Spoken Creole language is used as means of communication; my child is used to lip-reading" (Parent 4, personal communication, September 23, 2019); or "Natural signs are used as means of communication at home, and spoken Creole language also" (Parent 2, personal communication, September 23, 2019).

Unfortunately, this lack of parental involvement also negatively impacts on the children's education (Englund et al., 2014). For some children, the lack of parental

involvement in their education comes from the latter's own illiteracy. Another factor affecting parental involvement comes from working or single parents who find it difficult to set aside some time for their child's education: "Most of the time I am not home when my child returns home from school... He sometimes asks his sisters for assistance in his homework" (Parent 9, personal communication, September 23, 2019).

Although most of the parents reported poor involvement in their child's education, those who were able to actively tutor their children at home proved to benefit their child's academic performance and learning strategy:

> San was a fluent signer who could use both little hands to communicate or to 'spell' the alphabets of a written word . . . Fixing the word, he memorized the letters by spelling out and signing the letters with one hand, while the other would be used to count the letter position by pointing each finger on the printed alphabet. He did so several times until the word seemed 'engraved' in his working memory . . . Later, when asked, San nodded 'yes', and signed that after school he usually plays and learns with mum. (June 21, 2019)

As suggested by Bebko (1984), DHH children generally do not spontaneously utilize the rehearsal strategy, but when they are taught to, they become comparable to hearing ones and this held true for San during the initial Peabody Vocabulary test. Correlating with empirical findings, there is a positive association between parental involvement and academic achievement, and improved learning strategy (Lara & Saracostti, 2019).

On absenteeism, Sha and Manuel often missed school and therefore class lessons and sometimes important assessments; as could be noted from the interview carried out with a parent:

> My son has health issues . . . This is mostly due to the long distance between home and school . . . His health condition is difficult to cope with . . . He missed the 2nd school term assessments because he was sick. (Parent 11, personal communication, March 10, 2021)

Contrary to students without disabilities, those with disabilities often involuntarily miss classes due to health issues, and similarly the teachers thought that academic progress was affected: "It is a come on scenario of Special Needs Education that children have medical appointments which are prioritized, and it is indeed a good thing. Compared to abled children it does seem to affect academic progress". Absenteeism constitutes a real barrier in school participation and to the progression in the learning processes (Blackorby & Cameto, 2004).

4.1.4 Language differentiation and code-mixing

During the interviews carried out, SEN educators explained how some of the DMLs in their class did code-mixing of both English and French languages:

> Students mingle French and English languages; there is no difference for DHH students, for example: they would sign "dog" in the same way for both French

> and English languages, and may write the English word "dog" in a French exercise. (Shenaz, February 13, 2019)

Deafness in itself is not the reason for low language acquisition or code-mixing. As Csizér and Kontra (2020) suggest; it is more difficult for DHH children to acquire a language from print when they have variable or low sign exposure at home.

Without a strong L1, DMLs will be required to map print words of a L2 or FL to whatever symbolic structures they have been using to communicate, and as rightly found by Hoffmeister and Caldwell-Harris (2014) many will stagnate. As noted during one of the French lessons observed, some children did code-mixing while reciting the months of the year: "Shenaz (the teacher) asked the class to read aloud the months of the year, and on the fourth month, I could hear some voices distinctly uttering: 'April', instead of its French pronunciation 'Avril' (March 07, 2019).

The difficulty to distinguish between languages or to respond in the same language as the one being taught could be observed during a grade 6 French lesson on the famous monuments found in different countries: "On seeing the familiar picture, Soub spelled out 'Taj mahal' and added 'India', but was quickly corrected by the teacher to say 'Inde' which is the correct French word for the named country" (February 27, 2020). As could be observed from the above extracts, language differentiation is one of the difficulties faced by emergent multilingual students.

4.1.5 Grammatical rules and morphological complexity

Lardiere (2006) suggests that acquiring inflectional morphology in a L1 or L2 is not an easy task because learners have to simultaneously identify the morphologically conditioned formal variations of lexical bases, together with their functions. The morphological complexity described here also correlates with the difficulties uncovered through interviews carried out with the SEN educators:

> English seems to be the influential language for the students; maybe because the French accents are not important to them . . . prepositions, some adverbs seem to be unimportant to pupils; for example: "le soleil s'est couchée" where (the reflexive pronoun) "s' " holds no meaning to DHH students. (Shenaz, personal communication, February 13, 2019)

As can be assumed from the above extracts; the task of acquiring the inflectionally rich morphology of French as an L2 is a more difficult task than that of acquiring English language, because comparatively the latter is a morphologically poorer language to French (Clercq & Housen, 2016). In the case of DHH children, diacritics in French language ultimately hold no value to them; and are often omitted from their written discourse; because they seem to add to the mental effort required to process and learn the words (Bulté & Housen, 2012). The MSL, unlike signed English, does not map the print system onto a sign, word for word. This adds to the complexity of translating the L1 (MSL) of DHH students into a L2 (French) print system, because some abstract level of word usage such as the reflexive pronoun "s'" may seem irrelevant and meaningless to them. Moreover, syllables in the learning of French vocabularies did not seem to hold

any meaning to DHH students; they almost always tried to memorize the whole word based on the shape of ascenders and descenders as noted during a written task:

> Jamie did not know how to write most of the words from the list, but he seemed to recall how each word 'looked' like and remembered the approximate characters they should contain . . . For the word 'chat', i.e. cat, he interchanged the letter positions and instead wrote 'caht', probably drawing from his WM that the word consisted of a double ascender. (May 30, 2019)

Although seemingly presented with a simple word; taking a relative approach to word complexity, DHH children find it difficult to use syllables, which are based on sounds, in writing tasks. This correlates with Goldin-Meadow and Mayberry's (2001) findings that DHH children do not necessarily read through codes based on phonological sounds as do hearing children.

4.1.6 Time constraints and the curriculum

The necessity to challenge the inclusive educational standards from an equity perspective has been raised around the world, and the same tensions that have been raised internationally as in national level, can be noted from interviews carried out with the SEN educator: "The syllabus is not appropriate and adapted to children with deafness or other disabilities; you cannot test them using the same standards as children in the mainstream, those without learning disabilities" (Wesley, personal communication, February 21, 2019).

While policymakers are more concerned with a discourse of inclusion while prioritizing commercial interests and marketisation; educators feel that the curriculum should be fair and relevant to the child's ability, leading to opportunities like employment and further study. As stated by Ogden (2014), the main challenge remains that of creating a good balance between the specific and the general or between special and adpated education.

As often suggested in literature, ensuring inclusion of the school curriculum within the available timeframe is a challenge (Horne & Timmons, 2009; Travers et al., 2014); and similarly the SEN teachers found it time consuming to cater for the range of children's abilities within the limited time:

> I have a syllabus to follow; I do not have time to teach French language only . . . The children with disabilities need more time to learn, adding to the other difficulties such as parent involvement, and by the time you start a new topic, they would have forgotten what was previously taught. (Wesley, personal communication, February 21, 2019)

Obviously, with such time constraints, the children with SEN will not be exposed to the same breadth of curriculum as mainstream ones by the time they sit for the PSAC exams. When given the latter standardized tests for their age and grade, these children having SEN would evidently obtain unreliable scores and

very low grades as a consequence of assessing the differential learning opportunity of SEN, and especially DHH pupils (Qi & Mitchell, 2012). This disparity in learning and assessment opportunities often sets them up for failure.

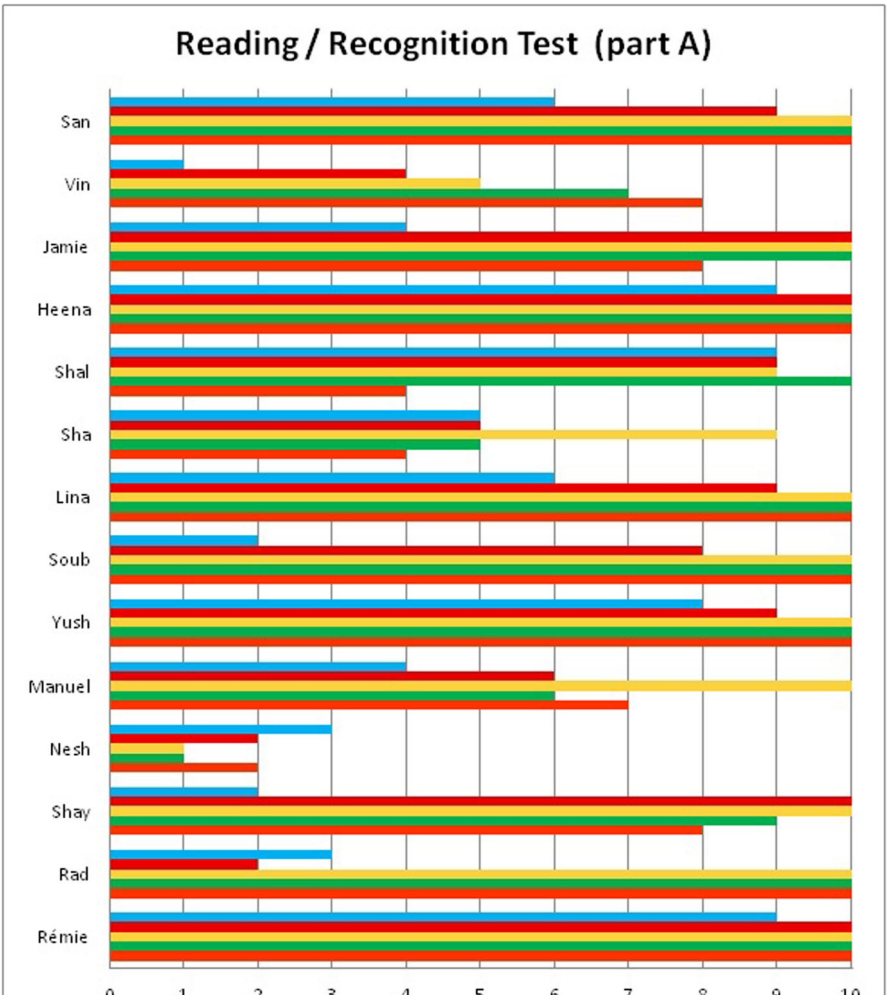
4.2 RQ2: What is the impact of a multimedia learning environment and gamification on the level of understanding and achievement of SEN and especially DHH students, in terms of reading and writing?

To assess the impact the games had on the students' learning, several Vocabulary Tests were designed to differentiate between the confounding variable of the teachers' teaching influence and the influence of the games on the students' learning. The results of the Tests were then discussed with the teachers so they could comment on each of their students' performance. To describe the level of achievement, the children's motivation level was measured using the standardized Instructional Materials Motivation Survey questionnaire which consisted of 5-point scale questions based on the ARCS model (Keller, 2010).

4.2.1 Results from the vocabulary tests

This section describes the findings from the Vocabulary Tests carried out to assess the children's level of understanding. In trying to differentiate between the influences that the games and the confounding variable 'teacher' have on the students' learning, several Tests were administered to the children. The first (Test I) was aimed at testing the students' vocabulary learning from the teachers' base teaching methods only; while the second (Test II) was for the teachers' additional teaching methods only. The third (Test III) and fourth (Test IV) tests added the pedagogical games as learning aid to the teachers' base teachings and additional teachings respectively. The last test (Test V) was for discovery learning through the games and without teaching influences. Each Test (I, II, III, IV, V) was mainly twofold; Part A where the children had to associate a picture to its written word, and part B where the children had to write the name of a presented picture.

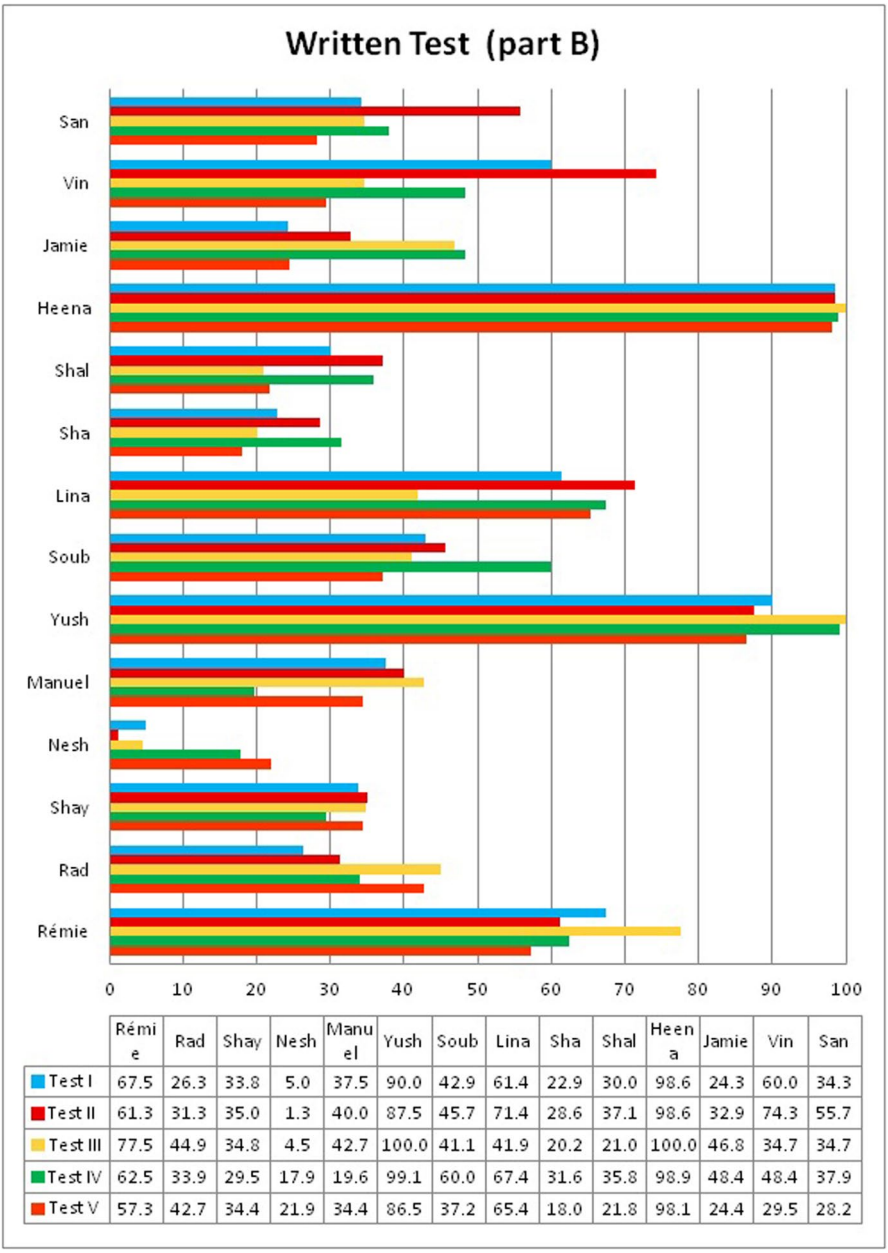
Part A of the Tests was aimed at measuring the children's ability to read and recognize word and image pairs when subjected to different learning methods as seen in Fig. 3. For each correctly matched image and word pair, the student would score a point, and the maximum points a student could obtain was 10. In Grade 5, hearing students such as Yush, Rad and Rémie, could retain a progressively constant pace, independent of the learning method administered; as can be noted from the teacher's comment on Rémie's performance: "The results show that base + games method are important procedures and techniques in teaching, however the games strategy has proven its benefits. The learner was successful to learn by himself". Nesh and Shay, who both use hearing aids, performed poorly as described by their teacher while commenting on Shay's performance: "Despite many strategies used in the additional methods + games, the learner has still room for improvement". In Grade 6, only, Jamie and Shal, who are also equipped with hearing aids, seemed to



	Rémie	Rad	Shay	Nesh	Manuel	Yush	Soub	Lina	Sha	Shal	Heena	Jamie	Vin	San
Test I	9	3	2	3	4	8	2	6	5	9	9	4	1	6
Test II	10	2	10	2	6	9	8	9	5	9	10	10	4	9
Test III	10	10	10	1	10	10	10	10	9	9	10	10	5	10
Test IV	10	10	9	1	6	10	10	10	5	10	10	10	7	10
Test V	10	10	8	2	7	10	10	10	4	4	10	8	8	10

Fig. 3 Summary of tests (part A)

necessitate their teacher's teachings and guidance to keep pace in their reading and recognition skills as commented by their teacher: "Shal definitely needs assistance and cannot be relied upon to learn words using only games.".



	Rémie	Rad	Shay	Nesh	Manuel	Yush	Soub	Lina	Sha	Shal	Heena	Jamie	Vin	San
Test I	67.5	26.3	33.8	5.0	37.5	90.0	42.9	61.4	22.9	30.0	98.6	24.3	60.0	34.3
Test II	61.3	31.3	35.0	1.3	40.0	87.5	45.7	71.4	28.6	37.1	98.6	32.9	74.3	55.7
Test III	77.5	44.9	34.8	4.5	42.7	100.0	41.1	41.9	20.2	21.0	100.0	46.8	34.7	34.7
Test IV	62.5	33.9	29.5	17.9	19.6	99.1	60.0	67.4	31.6	35.8	98.9	48.4	48.4	37.9
Test V	57.3	42.7	34.4	21.9	34.4	86.5	37.2	65.4	18.0	21.8	98.1	24.4	29.5	28.2

Fig. 4 Summary of tests (part B)

In part B of the Tests, the children's ability to correctly write the words was measured by the percentage of the similarity of their reproduction of the words to how the words are actually written. Figure 4 shows a summary of the children's performance

in part B of the Tests. In Grade 5, hearing students such as Yush and Rémie could score above the average of 50 marks; while the rest still struggled to score above average. This could be noted from the teacher's feedback of Shay: "But again here, writing or producing the words is rather difficult for him. Despite supporting with additional method, producing the words are challenging". In Grade 6, both Heena who had cochlear implant and Lina who was profoundly deaf maintained a stable progress as could be noted from the teacher's comment on Lina's progress: "Playing the games alone allowed her to score higher marks in reproduction". Again Sha who also used hearing aids, found it difficult to keep up with the tests because of his high level of absenteeism from school: "Sha, due to his health condition and absenteeism has not performed well in any case".

4.2.2 Results from the IMMS questionnaire

This section discusses the findings from the ARCS inspired survey carried out to measure the children's motivation level when using the pedagogical games. Keller's (2010) ARCS motivation model has been extensively used to provide guidance in motivational aspects of instructional design and teaching. The model is represented by four categories which when applied, to the game design in this case, can condition students to be fully motivated. The categories are Attention, Relevance, Confidence and Satisfaction. The questionnaire consisted of 16 questions; with 4 questions which addressed each category of the ARCS model. Due to the relatively small sample size it was irrelevant to calculate Cronbach's Alpha for internal reliability of items (Taber, 2018), and that an overall Cronbach Alpha of 0.73 for the whole instrument is acceptable. This describes the general link between the different items in the survey; meaning that the instrument captures motivation level and is reliable. Table 2 describes the children's overall motivation level in terms of Attention, Relevance, Confidence, and Satisfaction in playing the games.

As can be observed, most of the 56 responses reported for each subcategory measuring motivation were positive; ranging from 75 to 93%. The average response calculated for each subcategory was over the median value of 2.5; and the most frequent response for all subcategories was relatively positive; meaning that most children thought that the pedagogical games met their motivational requirements.

Table 2 The children's overall motivation level in terms of ARCS

ARCS subcategories	Agree + SA (N = 56)	N%	Mean *	Mode **
Attention	52	93%	4.36	4
Relevance	45	80%	4.04	4
Confidence	42	75%	4.05	5
Satisfaction	49	88%	4.29	5

* mean on a total of 56 responses for each category with median 2.5, and overall mean of 4.18

** on a Likert scale where – 1: strongly disagree, 2: agree, 3: neutral, 4: agree, 5: strongly agree

5 Discussion

In trying to explain the main difficulties SEN and especially DHH children face in learning French language at school; aspects from how the heterogeneous language backgrounds of SEN and DHH students affects the way they acquire French language as a foreign and second language, to how familial, social and educational factors also play a major role have been gathered and synthesized with literature. Comprehension and learning of a language requires the functioning of all processes in the working memory, and children with SEN, especially those who are DHH, have been found with memory deficiencies that affect their attention span and the speed with which they process linguistic data. French language has been found to be especially difficult for SEN and DHH students, where the complexity is to some extent learner-dependent. However, under the objective approach to language complexity, research suggests that French language as a L2 is a morphologically complex language which may take one several years to reach proficiency (Slabakova, 2009). Moreover, the level of abstractness that the French verbal system presents in terms of inflectional and morphological diversity reveals high levels of complexity; and given the memory and cognitive deficiencies, SEN and DHH students would generally find the acquisition of French language more tedious. In the social and familial realm, parental involvement contributes positively to a child's cognitive and socioemotional development, and when interviewed all of the parents thought that their involvement played an important role in their child's academic achievement. Unfortunately for most children, their parents either did not know sign languages well enough (for DHH children), or were themselves illiterate, and others found it difficult to set aside some time for their child's education. Another challenge that directly or indirectly arises from a condensed reflection of the previously described issues is the need for an equal and inclusive educational system; which at its base is informed by a complex interplay of policy imperative and values concerning standards. The SEN educators feel that the curriculum should be fair and relevant to the child's ability; because more often than not students having SEN would require more time than children of the same age in the mainstream, to similarly participate in the curriculum. With such time constraints, the children with SEN will not be exposed to the same breadth of curriculum as mainstream ones by the time they sit for the PSAC exams, resulting in unreliable scores and very low grades as a consequence of assessing the differential learning opportunity of SEN, and especially DHH students. In sum, the myriad of obstacles a SEN or DHH child has to overcome to become literate in French language is indeed challenging.

The Vocabulary Tests administered to the children yielded mixed results, from high performers to medium and low performers. This could be explained by the heterogeneous language background of the children, for example: Heena who has had cochlear implant scored high marks in all the Tests compared to those who had hearing aids or cognitive deficiencies. This highlights the favorable contribution that access to phonological sounds brings when learning to read and write. On the other hand, Lina who is profoundly deaf performed exceptionally

well, emphasizing her good working memory and supporting Goldin-Meadow and Mayberry's (2001) claim that DHH children do not necessarily read through codes based on phonological sounds as do hearing children. On assessing the impact the games had on the children, it seems that the combination of the teacher's teaching methods together with the games yielded the highest marks than when each method was administered separately. For instance Jamie, who uses hearing aids, performed equally when learning vocabularies from either the teacher's base method or through discovery learning only. He also scored higher marks in the written tests when learning from both his teacher's teachings and the games. The same could be said of Shay who is also equipped with hearing aids, or Rad who was diagnosed with speech impairment and emotional disturbance, in the Reading and Recognition Test (part A). For other students, the games seemed to be less effective because they still struggled to progress through the different teaching strategies. This could be due to the students' cognitive deficiencies which hindered working memory; as was the case for Nesh who also used hearing aids and necessitated the teacher's constant guidance. Another factor influencing some students' performance in the Tests would be their high level of absenteeism as also reported in literature (Blackorby & Cameto, 2004). It was difficult for both Sha who also used hearing aids, and Manuel who was also diagnosed with dyslexia; to maintain a stable progress because adding to their special needs, their health conditions did not allow them to attend school regularly. Overall, the children performed much better in the Reading and Recognition Test (part A) than in the Written Test (part B) when learning through the games only; perhaps because writing is a more demanding task and that the games, especially the multiple-choice one, were more adapted for part A of the Test.

As an educational solution, the pedagogical games acted as a motivator in the process of learning French vocabularies, as also demonstrated in other studies (Li et al., 2018; Refat et al., 2020). The majority of the sample approved of and found that the games caught their attention (93%), was relevant to the learning task (80%), inspired confidence (75%) and resulted in satisfaction (88%). Moreover, the average response for each subcategory of ARCS was positive, leading to the stance that the children enjoyed learning to read and write through the games. The potential of using the games as learning tool is demonstrated when combining the results of the Vocabulary Tests and the survey. From both the educational and gaming perspectives, the games have improved the learning experience of the children; although those found with multiple special needs progressed at a slower pace or still struggled (Ayres & Van Gog, 2009). This study therefore joins itself to the successful application of gamification in SEN and DHH education (El Mawas et al., 2019; Jong, 2015; Lan et al., 2018; Wajiuhullah et al., 2018); except that here, the results show the positive application of games in French as Foreign Language learning at elementary level. As postulated by McGonigal (2011), the advantages of gamification are known to be psysiological and can therefore influence learning in a deliberate act of volition as demonstrated through the survey (Dichev et al., 2015). The children played for fun and this encouraged them to pursue literacy at the same time.

6 Conclusion

In sum, despite the good motivation level recorded for each child, the games seem to be more effective and preferred, when added to the teachers' teachings than when used as discovery learning alone; although the latter method has proven to benefit some of the more independent students regardless of sensory or cognitive deficiencies.

Nevertheless, this study employed a small sample size. A study with a larger sample size could give a fuller picture of the effectiveness of the games developed across literacy and other Special Needs subgroups. Additionally, the study focused on students studying at upper elementary levels. Future research should investigate the application of gamification at lower elementary levels and similarly assess its impact in a longitudinal study.

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Availability of data and material Raw data is available upon request.

Code availability The games were developed using LiveCode – Community, the open source edition of LiveCode.

Declarations

Ethics approval The research was ethically approved by the University of Mauritius.

Consent to participate Obtaining consent from parents/carers and children was central to the research relationship, and the students were informed that they could quit participation at any point during the research. Likewise, the teachers agreed to participate in the research. Permission to carry out research at a special educational needs school was also sought.

Consent for publication The research participants agreed to use either pseudonyms or only their first name, instead of their full names for the publication of findings.

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