

**THE USE OF DIGITAL GAMES BY KINDERGARTEN STUDENTS
TO ENHANCE EARLY LITERACY SKILLS**

by

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Abstract

The present work reviewed the literature associated with the low levels of student achievement in literacy among early grade students in Brazil, the problem of practice. Under an ecological systems theory perspective, I identified that the usage of assessments, phonological awareness instruction, and quality learning materials could be key factors within the Brazilian context. An empirical needs assessment revealed that teachers did not use assessments, did not provide adequate phonological awareness instruction and lacked quality learning materials. Based on evidence found in the literature, this work proposed the adoption of digital games that can scaffold students' phonological awareness, word reading and writing development as a way to increase their early literacy skills. Additionally, it argued that games can provide learning analytics that can be employed as a cost-effective assessment method. The empirical work assessed the impact of the phonological awareness games in early literacy skills, determined if learning analytics could predict student achievement according to standardized assessments and identified potential barriers to the widespread adoption of the program. Using a mixed methods design, I conducted a cluster randomized controlled trial with 749 students from 62 classrooms from 17 schools in Brazil. Quantitative pre- and post-testing procedures using standardized instruments were employed. Qualitative data about teachers' perceptions about the program were also collected. The results indicate that the experimental classrooms which used the games gained 68% in their reading scores than control classrooms. They also gained 48% more in the writing scores. The regression analysis revealed a model which used students' scores in two games to predict their reading scores in the standardized assessment, explaining 99% of the variance. Another game can also be used to predict the reading score explaining 90% of the variance. Based on the teachers' perceptions, the conclusions demonstrate that using digital games to develop

phonological awareness activities is a viable option for the Brazilian schools. Beyond the beneficial effect of the digital program in reading and writing gains, the experiment revealed that the games can be a reliable, cost-effective and unstressful tool for assessing PreK students' word reading and writing skills.

Primary Reader: Lieny Jeon

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Disclaimer

In some situations, the results of this study may lead to a financial gain for the researcher. This financial interest has been reviewed in keeping with Johns Hopkins' policies. It has been approved with certain conditions, which are intended to guard against bias and to protect participants.

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Chapter 1. Understanding the Problem of Practice

The long-term effects of early childhood programs have been extensively studied in many countries, especially focusing on students from low socioeconomic status families (Barnett, 1998). Many of such programs provide short-term and long-term effects on academic and social achievement (Barnett, 1995). Academically, providing quality early childhood care and education is related to increased rates of high school graduation, more years of completed education, lower rates of retention and school dropout, and reduced placement in special education (Anderson et al., 2003; Reynolds, Temple, Robertson, & Mann, 2001). Social benefits of early childhood programs include reduced antisocial behavior, reduced risk of illegal substance abuse (Campbell, Ramey, Pungello, Sparling, & Miller-Johnson, 2002), and lower rates of juvenile arrest (Reynolds et al., 2001; Yoshikawa, 1995). High quality early childhood programs are essential for at-risk students, such as those living in poor areas of developing countries like Brazil.

Brazilian schools face important challenges such as high dropout rates and low student achievement (Marchelli, 2010; Neri, 2009). According to the national assessments (e.g. Avaliação Nacional da Alfabetização and Prova Brasil), in the public schools of a Brazilian state capital named Fumaça (pseudonym), 74% of the third-grade students (Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira, 2016a) and 71% of fifth-grade students did not meet the requirements in reading (Qedu, 2015). These data indicate that reading failure increases as students advance towards the end of primary and secondary school. Although there is no formal information about the literacy levels in kindergarten because Brazilian national assessments start in the third grade, it is plausible to explore achievement in literacy among students in earlier grades given the statistics from primary and secondary schools.

Prior research conducted in different places, such as North America, Europe and Latin

America, established that language and reading skills in kindergarten are strongly correlated to reading achievement in the first and second grades (Campos, 1997; Catts, Fey, Zhang, & Tomblin, 2001; Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004). Verbal skills in kindergarten are also significant predictors of reading achievement in fourth-grade students (Kurdek & Sinclair, 2001). These results indicate that improving literacy skills in kindergarten contributes to students' later reading achievement.

The present study is designed to fill the gap in the literature and practice in Brazil, through generating knowledge that can be used to improve Brazilian student achievement in preschool. Brazilian preschools include a class of four-year-old students and another for five-year-old students; the latter is equivalent to kindergarten classes in United States and Europe. The present study is also relevant to the social development of children's families because it was found that illiterate families experience an immediate gain in their health and income once their children learn how to read and write because they can help their parents to look and apply for better jobs as well as also find and demand better public services such as healthcare (Ribeiro & Cechin, 2012; Ribeiro & Carraro, 2014). Improving literacy also opens better opportunities for students' lives (Salvato, Ferreira, & Duarte, 2010). Within such context lies the intended problem of practice (POP), which focuses on the low levels of student literacy achievement, measured by standardized assessments, among early grade students in Brazil.

An Ecological Systems Lenses over the POP

To develop an adequate understanding about the problem of practice (POP), I adopted Bronfenbrenner's ecological framework for human development (1981) and developed a comprehensive literature review. The analysis starts with a depiction of how the chronosystem affected the development of the macrosystem, from the first initiatives to provide education for

Brazilian children to the current state of early literacy instruction. Then, the analysis focuses on the student microsystem and the factors that directly affect the children, including the family, the school and the teachers.

The Chronosystem and Evolution of Literacy Instruction

Brazilian literacy instruction is a recent phenomenon. The first attempts to organize Brazil's education started in 1876 with the implementation of the pioneering synthetic and alphabetic methods for teaching children how to read (Mortatti, 2006). The second phase of Brazilian literacy efforts began in 1890, with educators that advocated for the importance of pedagogy (how to teach) and analytical methods, starting a ferocious debate with the adopters of the synthetic approaches (Mortatti, 2006). The term *alfabetização*, which means the act of teaching someone to read and write (M. Soares, 1998), was created, however, the focus remained on teaching pupils how to read. Educators considered writing a mere calligraphy issue, a perception that lasted many decades (Mortatti, 2006).

The third phase of *alfabetização* started in 1920 when teachers were openly opposing the analytical methods that had become the mandatory standard during the second phase (Mortatti, 2006). This period is represented by the birth of mixed methods and the first Brazilian early literacy assessments such as *Testes ABC*, which measured children's reading readiness through vocabulary, speech, memory and focus skills (Lourenço-Filho, 1933; Monarcha, 2008). However, one of the strongest changes was that the pedagogy became increasingly subordinate to the psychological aspects (to whom we teach). The battle between methods, the combined use of old and new, and the perception of frailty results still occur in current days (Mortatti, 2009). The fourth phase started in 1980 (Mortatti, 2006) and was marked by the rise of constructivism, a radically evolved paradigm compared to the previous behaviorist tradition. The downside was that

the principles of constructivism were not incorporated in a systematized teaching method; therefore, a weakness was still present in many schools (M. Soares, 2004) which may contribute to the low student achievement in current days.

The Brazilian education system saw an expansion towards offering education for all children after 1990. School access across all grade levels increased and the country could proudly say that 96% of the children attended school (Oliveira, 2007). At the same time, retention rates were very high, around 13% (Ferraro, 1999), and standardized tests revealed alarmingly poor performance among students, which persists until today (Qedu, 2016).

The Brazilian Macrosystem

A definition about what the Brazilian society currently expects from early literacy instruction for their students is essential to advance the study of the POP. This research adopts the *letramento* as the ultimate goal of early literacy instructional efforts. The term *letramento* appeared in 1980s in Brazil, France (*illettrisme*), and Portugal (*literacia*). It emphasizes the social practices of reading and writing that arise from the learning process (M. Soares, 2004).

Letramento is “a state or condition that a social group or an individual acquire as a consequence of having mastered the writing and its social practices” (M. Soares, 1998, p. 4). It contrasts heavily to *alfabetização*, which means to have learned how to read and write.

To summarize, *letrado* is someone who learned how to read and write (*alfabetizado*) and uses such competencies to perform regular social activities (e.g. work; interacting with family and friends, etc.). It requires skills to read from simple news to complex romances, as well as the capability to write a note, a letter, an essay or even a dissertation (M. Soares, 2004). The difference between *alfabetizado* and *letrado* is important. For example, according to Brazilian Census (Instituto Brasileiro de Geografia e Estatística, 2014), *alfabetizado* is someone that is able

to read and write a simple note. Using that criteria, 90.4% of Brazilians were alphabetized and only 9.6% were illiterate in 2010. At the same time, the independently assessed national literacy study pointed out that 27% of Brazilian are illiterate, 47% have basic literacy skills and only 26% are fully literate (*letrados*) (Instituto Paulo Montenegro, 2011).

A new aspect of Brazilian literacy is that the usage of written language is dramatically increasing for the traditionally underserved classes as they start using mobile phones and social media (Google, 2015). Digital technology is beneficial for individuals because it allows them to read and socially interact more, but it also presents some challenges for poor citizens, especially regarding their personal and professional images when they make reading comprehension and writing mistakes. The present study is developed based on the premise that the current goal of Brazilian education system is to teach students how to read and write (*alfabetização*), ensuring that students grasp the social use of their reading and writing skills, thus becoming literate citizens (*letrados*; M. Soares, 2004).

The following sections will evaluate the four POP microsystems: family, school, teacher and student. The review is based on the evolution of the Brazilian literacy chronosystem, the current microsystem and societal expectations towards literacy instruction.

The Family Microsystem

Poverty

The family microsystem includes students' parents and siblings. The Brazilian society is rich in inequalities (Silva, 2011), and poverty is probably the most serious issue. Families living with less than R\$ 2,364.00 (USD \$600) per month account for 82% of the households (Ibope, 2014). One of the historical issues that affected the poor population of Brazil was malnutrition, which is related to the POP because it seriously influences the cognitive development of young

children, inhibiting them until the end of their lives (Fuller, 1987). Critical malnourishment was a widespread problem until the 1990s when successful social programs were created by the federal government to eradicate hunger. Nowadays the situation improved, but malnourishment still occurs with certain groups of at-risk students (Senna, Burlandy, Monnerat, Schottz, & Magalhaes, 2007).

Furthermore, poor families still live in unsafe areas with poor water and sanitation infrastructure. These citizens depend on public services (e.g., healthcare, transportation, education) which are not available in many parts of the country and, when they exist, most lack quality (M. P. D. Santos, 1995). Public infrastructure is relevant to the POP because unhealthy students experience more difficulties to learn (Costante, 2002). This ranges from simple visual acuity (Gomes-Neto, Hanushek, Leite, & Frota-Bezzera, 1997) problems that could be remediated if minimal attention was provided to such families for these serious impairments.

Parental Educational Attainment

Parental educational attainment is an important factor because the experiences that families provide to their kids at home strongly influence language development, which is an important predictor of early literacy achievement (Hart & Risley, 2003). In Brazil, mothers' school attainment is strongly correlated with children's literacy achievement (Fuller et al., 1999). Nevertheless, 56% of Brazilian parents did not finish high school (Ibope, 2014) so their children will be among the first members of their families to receive full basic education. Within this context, some argue that policies should incentivize parents to read to their children before and after they join school even if such parents are illiterates and do not master the written language (Fuller et al., 1999). Joint book reading can also expose kids to richer linguist experiences and is related to early reading acquisition (Bus, van IJzendoorn, & Pellegrini, 1995), improving student's

readiness to join the school.

Family Engagement

Research revealed that parent involvement is associated with reduced rates of dropout and improved rates of high school completion (Barnard, 2004). Parental engagement in teaching their children about reading and writing is also related to the children's improved early literacy skills (Sénéchal & LeFevre, 2002). In Brazil, 18% of the parents do not attend school events and 39% of them attend only sometimes (Ibope, 2014). A comparative data regarding early literacy engagement is that only 42% of the parents read books, 17% read newspapers, and 5% read magazines (Ibope, 2014). These data demonstrate that the majority of families in Brazil do not interact with children using the written language in their daily lives, so those children may not have an opportunity to learn how to read from their parents. Nevertheless, a study with 16,425 kindergarten students revealed that when schools develop deliberate actions to engage parents, family involvement and student achievement in reading increase (Galindo & Sheldon, 2012).

The School Microsystem

Within the Brazilian ecological environment, the educational exosystem is partially responsible for the cognitive development of students because it defines the general goals and policies that schools should implement. Nevertheless, schools are still responsible for executing the actual efforts that directly affect student achievement. Thus, the school microsystem includes factors that affect daily activities of teachers and students. Some of these factors can generate a direct impact on teaching and learning (e.g., learning materials) while others may have a secondary effect (e.g., principal engagement).

Inadequate Physical Infrastructure

In developing countries, inadequate infrastructure is a frequent issue that affects teaching

and learning because it often makes the processes of teaching and learning extremely difficult (e.g., a broken roof raining inside the class, lack of chairs and tables, etc.). Infrastructure flaws also influence the attention and motivation of students and teachers, whose physiological, safety, and esteem needs will not be met (Maxwell, 2016). Physical infrastructure is important because the quality of school facilities is associated with student achievement in language (Uline & Tschannen-Moran, 2008). Nevertheless, investments during the last two decades have improved Brazilian schools considerably (Neto, de Jesus, Karino, & de Andrade, 2013), which diminished the challenges stemming from a lack of physical infrastructure. School staff is usually responsible for daily conservation activities, but principals play an essential role in keeping the infrastructure up to standards because they are the ones with access to city officials and federal grants to improve their schools (Lück, 2009).

Principal Engagement

The relationship between the school microsystem and the Brazilian public education policy exosystem (Neal & Neal, 2013) is complex. While schools have autonomy to decide about pedagogic issues, they are not autonomous financially neither managerially. The principal role is dual – they have the obligation to lead the pedagogic team of the schools, but at the same time, they also have to perform bureaucratic work that is mistakenly called managerial tasks (Paro, 2015). The school principal has little financial control because the secretary of education manages most of the funds. For example, principals cannot use funds from the budget to fix an air conditioner because they do not have access to the budget; a request must be made to the secretary of education to fix the air conditioner. This process usually results in prolonged delays to fix simple issues. School principals also do not have the hiring and firing autonomy. A process led by the secretary of education selects public school teachers; the person in this position also decides

where each teacher is sent to teach (Krawczyk, 1999).

However, not having administrative decision power does not hinder the importance of principals when speaking about pedagogic matters. Principals play a key role regarding teaching and academic achievement (Robinson, 2007). Principals and pedagogic coordinators, who do not possess good managerial and leadership skills, or who are not engaged, may seriously contribute to student failure (Falsarella, 2013). The leadership team is a key component of teaching and learning because they are responsible not only for taking care of the school infrastructure, but they also shall develop a positive relationship with the community, coach the teachers, monitor student achievement and assure that the classrooms have learning materials (Lück, 2000).

The school principal is also responsible for supervising teachers' decisions about which textbooks they will use. The federal government then purchases the books and delivers them to the school. Principals are also responsible for submitting proposals for grants that will allow schools to receive resources to implement small construction work, computer laboratories and special funds to hire dance, music and sports teachers (Lück, 2000). Principals also contact the secretary of education to request consumable supplies that are essential to early literacy development (e.g., papers, pens, crayons).

Learning Materials

A multitude of learning materials such as textbooks, manipulative materials, whiteboards, and educational technologies can be used to foster early literacy student achievement (Mortatti, 2000). The introduction of textbooks was associated with strong learning gains in developing countries (Heyneman, Farrell, & Sepulveda-Stuardo, 1981; Tornroos, 2005). In Brazil, early literacy textbooks have a high importance in student achievement because they usually serve to shape the content that is taught. Textbooks also act as the standard curriculum of the discipline,

and establish tacit conceptions about early reading and writing (Mortatti, 2000). Many books still focus basic reading and writing skills. Such books fall short in fostering literate citizens, those that use written language in their daily activities. They offer content that is developmentally inadequate, decontextualized and made of repetitive activities (Mortatti, 2000).

Unfortunately, teacher education in Brazil is deficient in pedagogy, focusing on the content matter (Saviani, 2009). Within this context, it is fair to say that textbooks still play the primary role in shaping classroom activities (Saviani, 2009), indicating that the quality of the textbooks will remain a factor of highest importance to student achievement until teachers are better prepared. Nevertheless, textbooks per se probably will not solve the POP. It was noted that some schools have textbooks of good quality, but teachers keep teaching using their traditional ways, ignoring recommendations from their principals and textbooks (Macedo & Almeida, 2013). This finding brings to attention that assessing the literacy problem exclusively from a resource-based approach may be fruitless.

The Teacher Microsystem

The teacher dimension could be included under the school microsystem, however, it is reviewed as a separate microsystem due to its high importance. Teachers are affected in many ways by multiple entities, policies, and persons. However, for studying the current POP, the focus will be limited to the factors that directly influence teaching and learning, such as their ability to design an effective instructional strategy, which includes phonemic awareness instruction, their motivation, and usage of assessments. Tanuri (2000) argued that most Brazilian teachers were educated in one of two dichotomous approaches: the content model, which emphasizes a general background allied with specific knowledge about the discipline that the future educator will teach, and the pedagogic model, which focuses on teaching strategies. Historically, Brazilian universities

focused on the content, ignoring *how to teach* (Tanuri, 2000), a characteristic that shaped today's workforce.

Effective Instructional Strategy

An effective instructional strategy with a mixture of child-initiated activities and direct instruction in phonological awareness and print knowledge has been found to be highly important for student achievement in literacy (Justice, Mashburn, Hamre, & Pianta, 2008; Taylor, Roehrig, Hensler, Connor, & Schatschneider, 2010; Wharton-McDonald, Pressley, & Hampston, 1998). Since 1980, the Brazilian government and academia have promoted constructivist principles, and the national curriculum guidelines are based on classical constructivist works (Ferreiro & Teberosky, 1982; Piaget, 1952; Vygotsky, 1987). Kindergarten schools operating under these principles usually employ child-initiated activities such as playing, visual and performing arts, music, and motor skills development (M. Soares, 2004). Unfortunately, based on the assumption that students create their knowledge, a substantial portion of Brazilian educators developed the misconception that careful instructional design is not necessary to ensure student achievement (Mortatti, 2006).

Phonological Awareness Instruction

Some groups even argue that systematic instruction should not occur and this may be one reason for the lack of an established method for teaching Portuguese, which has negatively affected student achievement (Mortatti, 2006). The misconception that direct instruction should not occur is challenged by researchers who identified strong correlations between phonological awareness and reading achievement (Kirby, Parrila, & Pfeiffer, 2003; MacDonald & Cornwall, 1995). While Wagner and Torgesen (1987) argued that there is a causal link between phonological awareness and reading success, Castles and Coltheart (2004) claimed that no research obtained

unequivocal evidence about such causality. The debate continues with additional research indicating that many factors including phonological awareness (Hulme, Snowling, Caravolas, & Carroll, 2005) contribute to improved reading achievement.

Based on the expanding evidence that phonological awareness is, at least, a critical component of reading achievement, several institutions in U.S. and Europe created comprehensive school programs (Cosgrove, Fountain, Wehry, Wood, & Kasten, 2006; Hulme et al., 2005; Melby-Lervåg, Lyster, & Hulme, 2012). These programs employ child-initiated activities aligned with constructivist principles but also offer direct instruction for developing phonological awareness, letter, and word identification skills (Chambers, Cheung, Slavin, Smith, & Laurenzano, 2010). In their review, Chambers et al. (2010) studied 27 comprehensive programs and identified strong effectiveness in six programs (ES of at least 0.20 in two or more studies), while five other programs showed moderate evidence of success (ES of at least 0.20 in one randomized controlled trial or two matched design investigations). Their findings suggested that comprehensive preschool programs had immediate and long-term impacts on achievement. Chambers et al. (2010) also noted that successful programs usually provide stronger support for the teachers than what was offered before their implementation, and that continuous coaching was a key aspect of program implementation. This finding suggests that interventions dealing with innovative ways of instruction have to provide adequate support for teachers and that has to be taken into consideration when planning and budgeting.

In a more recent systematic review, Chambers, Cheung, and Slavin (2016) evaluated the outcomes of early literacy programs by comparing developmental-constructivist and comprehensive approaches. Developmental-constructivist programs usually focus on child-initiated activities, such as art, play, make-believe, and movement, but do not offer systematic and

direct instruction of early literacy skills. Alternatively, comprehensive programs tend to provide developmental-constructivist activities that are supplemented by direct instruction on phonological awareness and phonics. Chambers et al. (2016) reviewed 32 studies that employed randomized or matched control groups and identified that comprehensive programs generated statistically significant gains in literacy and language development in preschool and that such effects remained in kindergarten years. The research also indicated that developmental-constructivist programs yielded fewer gains in literacy achievement than comprehensive programs. These findings provide evidence to support the claim that phonological awareness is a fundamental component of reading development and needs to be appropriately instructed to promote students' learning better.

In Brazil, the national curriculum established in 1997 explicitly recommended that teachers shall not promote phonemic training activities, including grapheme-phoneme instruction (Morais, 2006). During the same period, phonics has been strongly criticized (Mortatti, 2009) by scholars who argue that it focuses too much on technicalities, in a mechanistic way, and fails to promote activities that foster the social use of written language (Macedo & Almeida, 2013). While the Brazilian debate is still dichotomizing in nature (constructivism vs phonics), international research seems to be approaching the consensus that combining both approaches provide the best outcomes in terms of student achievement (Chambers et al., 2016).

Use of Assessments

One strategy to prevent reading failure and increase student achievement is using assessments as a diagnostic tool (Caldwell, 2007). If the teacher has adequate data about which students are lacking and their specific struggles, he or she can devise a plan and act upon it (Wang & Strong, 1996). With this idea, Good, Kaminski, Simmons, and Kame'enui (2001) proposed a

preventive model to assess the development of early literacy skills. They established a sequence of major goals (i.e. phonological awareness, alphabetic principle, accuracy, and fluency with connected text) that end with the student ready for high stakes reading assessments. By defining the timeline for the development of each skill and measurement indicators, they created a framework that allows schools to measure and improve early reading (Good et al., 2001).

Another important benefit from using assessments is that they exercise student recall of information, which assists in retention (Karpicke & Roediger, 2008). It also provides useful feedback that allows children to understand their progress and helps them persevere and improve (Pashler, Cepeda, Wixted, & Rohrer, 2005). To better prepare the students and minimize the stress caused by high-stakes assessments, teachers can use multiple forms of assessments during the school year in order to prepare students for the external tests (Hardiman, 2012). Modern forms of assessments such as computer-based or stealth assessments that are built-in literacy apps can provide a cost-effective way of assessing student progress during their interactions with the subject matter (Shute, 2011). Another good practice is to use alternative ways of assessing student learning that foster creativity and problem-solving skills such as creating learning portfolios and student journals (Hardiman, 2012).

Unfortunately, assessments do not seem to be a popular practice in Brazil. External standardized tests started in the 1990s but until now they only take place at the end of middle school and when students graduate in high-school (De Castro & Tiezzi, 2004; Franco, Alves, & Bonamino, 2007; Sobrinho, 2010). The national literacy assessment, targeted to third-grade students, began in 2013 (Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira, 2016a). Unfortunately, the results of the mandatory assessments are usually delivered to the schools at least one year after the tests, reducing their utility to improve teaching for the current

students (Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira, 2016a).

The only test that is targeted to teachers' usage is *Provinha Brasil*, created by the federal government, which is administered twice a year for the second-grade students (Morais, 2012a). However, these tests are not compulsory and schools are not required to submit their results, therefore, there are no data about the adoption of such tools and their effects on student achievement. Moraes (2012) identified that many teachers do not use the *Provinha Brasil* results to improve their instructional strategy or for providing personalized instruction for specific students. In kindergarten, the situation is worse, there seems to be no assessments at all. There is also no data about the phonological awareness of kindergarten students and no large-scale efforts are being made in this direction.

The Student Microsystem

Many Brazilian educators view early literacy as a process to develop autonomy, which means fostering a reflexive student that actively seeks learning (Freire, 2000). Under this view, teaching students how they can manage their learning can be a natural approach (Juliebo, Malicky, & Norman, 1998). Metacognitive training can be provided to improve student achievement in literacy and the other disciplines, but it does not seem very popular in Brazilian schools (Monteiro, 2010).

The lack of knowing how to learn may contribute to reduced motivation and self-efficacy. Neri (2009) revealed that the majority of Brazilian dropouts said that the most important reason for abandoning the school was the lack of motivation. Student failure in literacy during the early grades leads to failure in the later grades (Costa, Loureiro, & Sales, 2009). Curiously, children of underserved families that have access to a computer at home displayed higher achievement rates (Costa et al., 2009). This finding may corroborate Couse and Chen (2010), indicating that such

students have higher levels of self-efficacy and motivation.

Conclusions

This work reviewed the literature under an ecological systems perspective to develop a better understanding of the factors associated with student achievement in literacy in Brazil. The conceptual diagram presented in the Figure 1 synthesizes the findings and highlights the mutual influences among four main microsystems that affect young students' literacy and reading achievement. Multiple factors affect student achievement including, (a) poverty (Costante, 2002; Fuller, 1987; Gomes-Neto et al., 1997; Senna et al., 2007; Silva, 2011), (b) parental educational attainment (Bus et al., 1995; Fuller et al., 1999; Hart & Risley, 2003), (c) family engagement (Barnard, 2004; Galindo & Sheldon, 2012; Sénéchal & LeFevre, 2002), (d) inadequate physical infrastructure of the schools (Maxwell, 2016; Uline & Tschannen-Moran, 2008), and (e) principal engagement (Falsarella, 2013; Krawczyk, 1999; Lück, 2009; Robinson, 2007).

Three additional factors that influence student achievement emerged as highly important and potentially actionable within the Brazilian context. These factors help to shape the objectives of this investigation. The first factor is teachers' instructional strategies encompassing the direct instruction of phonological awareness (A. G. Capovilla, Dias, & Montiel, 2007; Catts et al., 2001; Chambers et al., 2016). The second factor is the use of assessments (Caldwell, 2007; Good et al., 2001; Hardiman, 2012; Shute, 2011) and the third one is the adoption of quality learning materials, such as textbooks, manipulative materials, and educational technologies (Heyneman et al., 1981; Mortatti, 2006; Saviani, 2009; Tornroos, 2005).

Concluding, to better understand the low levels of student achievement in literacy among early grade students in Brazil, it is important to focus on teacher's instructional strategy, use of assessments, phonological awareness instruction, and the quality of learning materials. Further

investigation will happen around these factors during the empirical phase of the current project.

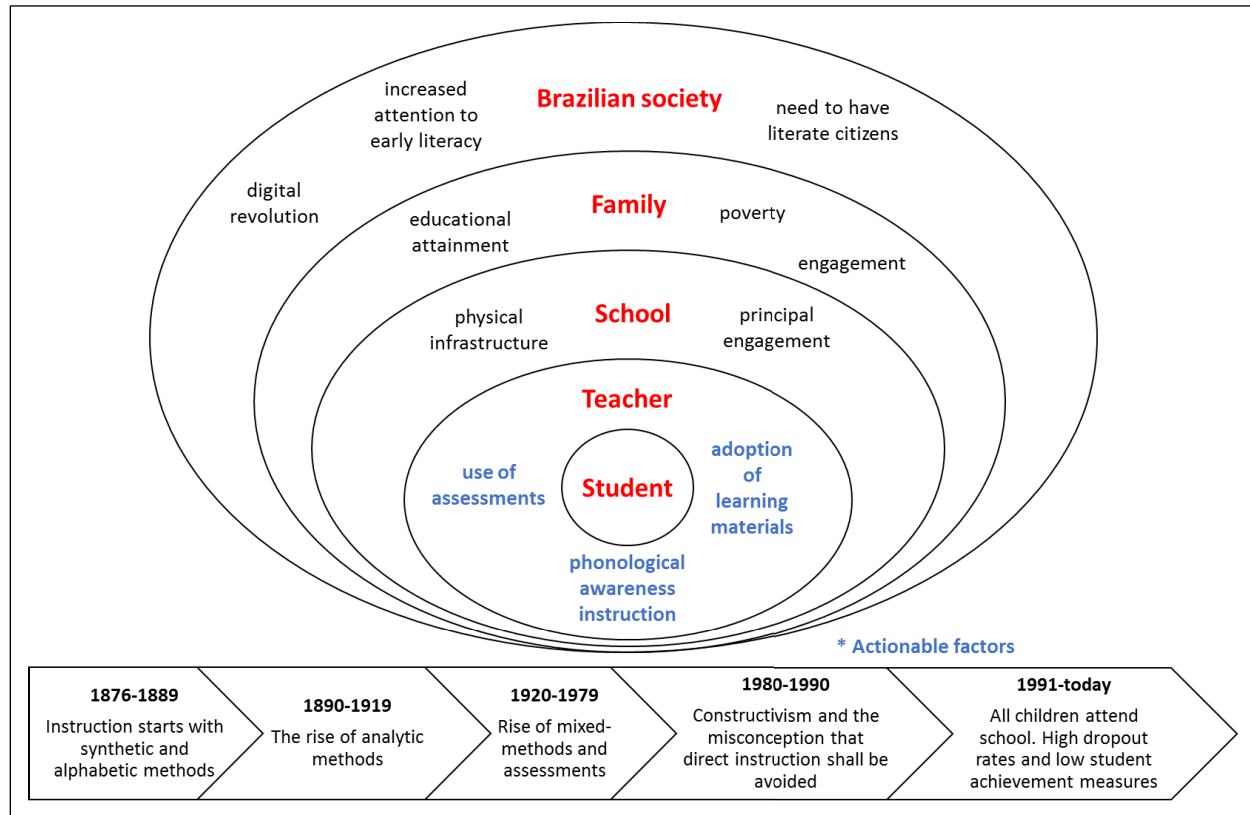


Figure 1. Conceptual framework with major underlying factors

Chapter 2. Needs Assessment Report

As discussed, low student achievement in literacy is a major educational problem and the national assessments show that 71% to 74% of the third- and fifth-grade students in *Fumaça* public school students demonstrate delay in early reading (Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira, 2016a; Qedu, 2015). This problem may also occur in private schools. However, there are no data about their students' literacy skills because private schools do not participate in the national assessments. Within such context lies the intended problem of practice (POP), which focuses on the low levels of student achievement in literacy among early grade students in Fumaça.

Previous research has established that language and reading skills in kindergarten are strongly correlated to reading achievement in the first and second grades (Catts et al., 2001; Schatschneider et al., 2004). Verbal skills in kindergarten are also significant predictors of reading achievement in fourth-grade students (Kurdek & Sinclair, 2001). These results indicate that improving literacy skills in kindergarten may contribute to students' later reading achievement.

Goals and Objectives

The purpose of this needs assessment was to investigate the POP further, evaluating how the factors that were identified from the literature were associated with reduced kindergarten students' achievement in early literacy in the schools of Fumaça. To that end, this study tried to understand the current state of instructional strategy, use of assessments, phonological awareness, learning materials. The following research questions were developed based on the literature and established the basis for this needs assessment.

Q1. To what degree are teachers adopting an effective instructional strategy that combines phonics and whole language activities (Xue & Meisels, 2004)?

Q2. To what degree are teachers using instructional tools such as external assessments (i.e. *Avaliação Nacional da Alfabetização*) and self-administered tests (i.e. *Provinha Brasil*) to improve teaching and learning?

Q3. What is the teacher-perceived phonological awareness level of students in kindergarten? How, if at all, do teachers and pedagogical supervisors detect and prevent reading failure early?

Q4. To what degree, if at all, do teachers use learning materials? What are teachers' perceptions of the textbooks available for students and teachers? Do teachers feel they need more materials than they have? Which types of materials?

Q5. To what degree, if at all, do teachers use technologies with their students? What are teachers' perceptions of the technologies available for early literacy?

Methodology

The present needs assessment was developed to explore the factors associated with the POP and did not have any explanatory or confirmatory aspirations.

Identified Population

The needs assessment aimed to study the factors related to the POP in the schools of Fumaça. According to the national education census of 2015, there were 987 schools in the city and 678 served kindergarten students. From those, 230 were public and 448 were private schools. Public schools served 10,157 kindergarten students, and private schools functioned for 20,434 children. Public kindergarten schools were staffed by 10,448 professionals while private schools had 12,115. Public schools had an average of 43 employees while private schools had 25 (Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira, 2016b).

The present needs assessment focused on kindergarten teachers from private and public

schools in the Fumaça metropolitan area. The sample included educators teaching children between four- and five-years-old. The participants were five female teachers from a city school that serves around 140 kindergarten students, and two female teachers from a private school that has over 50 kindergarten students (Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira, 2016b).

From the five teachers of the city school, three were the main teachers of their classrooms and two were assistant teachers that lead instructional activities when the main teachers leave for planning, evaluation and bureaucratic work. In the private school, one participant was the main teacher of the classroom, and the other was the academic coordinator that also worked as a teacher in another institution. In the private school, all teachers had an intern in the classrooms while in city school there were no interns; a single teacher handled the class.

Measures

Several variables were developed to explore the POP and answer the five research questions. Environmental variables were collected using the Early Childhood Environment Rating Scale Extension (ECERS-E) instrument (Sylva, Siraj-Blatchford, & Taggart, 2011). Due to the nature and objectives of this needs assessments; the ECERS-E Literacy subscale was used. Other subscales were out of the research scope and thus not included. The literacy subscale is composed of the following variables: (a) print in the environment, (b) book and literacy area, (c) adult reading with children, (d) sound in words, (e) emergent writing/mark-making, and (f) talking and listening. Using the rubric provided by the instrument, I graded each item from 1 (inadequate) to 7 (excellent).

Interviews included the collection of demographic characteristics such as gender (male or female), grade in which is teaching, experience as an educator and expertise in teaching the

current class. The age of the students designated to the current class determined grade levels. The experience as an educator and expertise in teaching the current class were measured in years.

To answer the research questions 3, 4, and 5, a set of exploratory and open questions was created. I first asked the teachers what was their early literacy goals for their students when they finish the current school year. This query intended to identify if early literacy goals were uniform among teachers. The interview continued with three questions below (Q2a – Q2c) to measure the level of adoption and perceived importance of assessments:

- Q2a. Did you receive the results from assessments such as the *Avaliação Nacional da Alfabetização* from your previous students? If yes, did they help you improve your understanding of your current students' needs?
- Q2b. To what degree have you used assessments such as the *Provinha Brasil* in the last two years? Who graded these tests? Have you received the scores and analytics data? Did they help you improve your understanding of your students' needs? In what ways?
- Q2c. Did you employ any other diagnostic tool with your previous and current students? Which one(s)? Was it effective?

Three questions below (Q3a – Q3c) aimed to measure the phonemic awareness level of the students and training activities provided by the teacher:

- Q3a. What is the average phonological awareness level of your students?
- Q3b. Do you use any tests to assess the phonological awareness level of your students? Which ones? How, if at all, do you detect and prevent reading failure early?
- Q3c. Do you develop phonological awareness activities? What is your focus?

The following questions (Q4) measured the availability and quality of the learning materials and digital content:

- Q4. To what degree, if at all, do you use learning materials, such as textbooks, literacy books, and manipulatives? How good are the textbooks and digital content? Do you feel that you need more materials? What kind(s)?

The following questions (Q5) measured the level of technology adoption by the teachers:

- Q5. What kind of technologies do you use with your students? And in your personal life? Have you seen something interesting for early literacy?

Table 1 summarizes the research questions and the instruments used to collect data.

Table 1. Data Collection Summary

Questions	Instrument
Q1	Observational data using ECERS-E (items 1 to 6)
Q2	Interview with teachers
Q3	Interview with teachers
Q4	Interview with teachers
Q5	Interview with teachers

Data Collection Procedures

The collection process was inspired in the steps described by Seidman (2013). Since this needs assessment was exploratory in nature, it allowed me to use a convenience sample. The city school was one where a friend from a colleague of mine worked as a teacher. The private school was a client of Escrito, where I work. I contacted the leaders of both institutions, explained the research goals and asked for their participation, which was granted after a few days.

The interviews were scheduled during the regular school hours, the afternoon for the city school and the morning for the private institution. Upon arriving in each school vicinity, I tried to observe the sanitation infrastructure and the existence of public services (e.g. healthcare, law enforcement, and transportation) to determine the socioeconomic status of the area where the

school was located. Upon finishing the observation, I identified myself to the school staff and entered the facility. In the city school, the interviews were done in the teachers' room. During the first visit, four interviews were done and a second visit happened the next day. The second visit served to interview one more teacher and to spend the appropriate time needed to rate one classroom using the ECERS-E instrument. The interviews in the private school were done in the pedagogical coordinator room and were followed by the observation and grading of one classroom using the ECERS-E.

Before beginning the interview, I started the research protocol by explaining the research goals, informing consent procedures, highlighting that the interview would be recorded, and asking if the teacher wanted to proceed. All teachers accepted the request and signed the consent form. I then started the recording, using a Motorola Moto X Play mobile phone running the "Green Apple Studio" audio recorder. Then the interview began and I asked the demographic questions. The average interview time was approximately 23 minutes, within the expected duration. Upon finishing the questions in the protocol, I asked the teachers if they had any additional information that could be used to understand the early literacy POP further. Once the teacher answered this last prompt, I thanked and stopped the recording. Table 2 summarizes the interview procedures.

Table 2. Interview Procedures

Participants:	Seven teachers, five from the public and two from private schools.	Recording device:	Motorola MotoX smartphone.
Duration:	23 minutes (average).	Location:	In the school
Time:	During regular class hours.		

Summary of Results

Following the data collection, a structured process for qualitative analysis was set up, inspired by Bogdan and Biklen (1997). Contextual coding is a key component in developing a

deep understanding. The research was developed in two different contexts detailed below.

Research settings

The first setting was a city school, which will be called under the pseudonym Demoiselle, located in a low socioeconomic status (SES) peripheral area of a typical Brazilian state capital that will be called under the pseudonym of Fumaça. A house, originally developed as a family domicile, is now a school. The city government adapted the real estate to be used as a kindergarten school. It is a small property considering its use as a school, but it has a good infrastructure regarding furniture and bathrooms. There was an air conditioner in all rooms; this is needed because Fumaça is a very hot city, the average temperature is 95 degrees Fahrenheit (35 degrees Celsius), but it is still surprising that a public school could afford to buy and maintain this type of equipment because most Brazilian schools are poorly equipped and maintained (Balmant, 2012).

The school is located near low SES communities. The families that reside in these low-income areas depend on public health care, schooling and safety services that usually lack quality (Confederação Nacional da Industria, 2016). It is common to find unpaved streets with no sewerage system, which increase disease dissemination (Teixeira & Guilhermino, 2006). Families live in small houses, but most of the ones that I saw were built with brick and mortar. Many houses were built over the other so that the piece of land can serve two families. This indicates that this is not an extremely poor neighborhood since the lowest SES families in Brazil live in improvised conditions, in houses built with wood and cardboard (Rissin, Filho, Benicio, & Figueiroa, 2006).

Contrasting with the city school, the Tucano School (pseudonym), a private entity owned by a Catholic church branch is installed in multiple buildings. The kindergarten is separated from

the primary and secondary grade buildings. The school is located in a high SES neighborhood that is very well served by public services (Rissin et al., 2006). I saw clean sidewalks and realized that the school is located in one of the most expensive neighborhoods of Fumaça city, with apartments costing more than one million *Reais*, which suggest that the students of such school are from the upper class and have experienced rich early literacy experiences in their home environment.

During the observation of the school, it was found that Tucano School is located in this area, but it does not attract the students that live there. They only manage to draw kids from class B- families, which are the Brazilian lower middle class. Although they do not live in this expensive area, they live in good places with decent housing and public services (Rissin et al., 2006).

The contextual information about where the schools are located and where the families live is relevant to the POP because it provides an overall picture of how literate are the parents and the experiences they offer for their children. The SES areas where the schools are also located provides underlying evidence about where are the most attractive work conditions for teachers and staff. After the school environments had been observed, it was hypothesized that the private school would provide a better early literacy instruction for the students because its students and staff had better socioeconomic conditions than ones from the public school. The following environmental analysis was developed using the ECERS-E instrument to assess this hypothesis and to establish the characteristics of each institution in regards to early literacy.

Instructional strategy that combines phonics and whole language (Q1)

Data about the literacy environment of each school was collected and analyzed according to the ECERS-E proposed by Sylva, Siraj-Blatchford, and Taggart (2011). ECERS-E evaluates physical characteristics and teacher attitudes towards promoting a comprehensive literacy

experience with activities that integrate whole language and phonics perspectives. The present needs assessment was exploratory in nature, so I observed and graded only one classroom in each school. Inter-rater reliability scoring was not necessary since the statistical analysis was out of the scope. Table 3 presents the scores for each item.

Table 3. ECERS-E Literacy Scale Grading

Item	City School	Private School
1. Print in the Environment	5	4
2. Book and Literacy Areas	2	2
3. Adult Reading with the Children	5	5
4. Sound in Words	4	2
5. Emergent Writing	5	3
6. Talking and Listening	3	3
Total Score	24	19

Regarding the first item, print in the environment, the city school earned a score of five (good), which means that many labeled pictures were visible in the classroom, and the teacher encourages students to recognize the printed words and letters. The private school earned a score of four because there was less encouragement for recognizing printed words.

The books and literacy areas item was graded with two for both schools. This means that the conditions are between inadequate and minimal. This was due to the lack of a dedicated literacy book area with easy access for the students. In the public school, most of the books remained locked in a drawer while in the private schools there were only a few books available for the students.

The adult reading with the children item scored five (good) for both schools. This means that reading activities take place every day and that children take an active role in such activities. They were encouraged to think about the stories and to create alternative endings.

The sound in words activities were prevalent in the city school, which scored four, between minimal and good conditions. This happened because while rhyming was developed

multiple times per week, there was no work regarding the initial sounds of the words. The private school scored two, between inadequate and minimal, because rhyming activities took place only a few times per month.

The emergent writing item earned a score of five in the public school because the students observed the teacher writing what they said and a writing space existed in the room. In the private school, which scored three, there was a space for writing but observation of the teacher writing student speech occurred less frequently.

Talking and listening scored a three, minimal, for both schools. This score occurs when conversations between students and teachers take place. This score was not higher because most of the encouragement provided by the teachers was for one-word answers and no extended talking experiences were planned by teachers.

The total score for the city school was 24 and the private school achieved 19. These results, however, cannot be used to say that the city school was better than the private school due to the limitations of the study, especially taking into consideration that only one class of each school was graded. The absence of inter-rater reliability procedures and the fact that the other dimensions of the ECERS-E scale were not scored also limits the findings. Nevertheless, it was clear that, regarding the literacy scale, the two classes were in a similar level, with a slight advantage for the city school. These results, however, are not sufficient to answer the research questions by themselves.

Sample Composition

The analysis of the interviews was based on the seven steps described by Rubin and Rubin (2011). The first goal was to create an exact, word-for-word, transcription of the interviews, which were in Portuguese. Two research assistants used Windows Media Player to play, stop and

rewind the audio files and the Windows Notepad to type and edit the transcription files. When the seven interviews were transcribed, I proof-edited them looking for inconsistencies.

The first coding procedure was to read each set of data and assign it to the corresponding question that was asked during the interview or to a new category when it extrapolated the planned themes. After reading and coding all chunks of data from the seven interviews, I read each category again, highlighted the most relevant portions and wrote the summary of the category. The combination of the summaries into a conceptual path was developed in the sections below.

First, it is important to describe the sample, whose demographic characteristics are presented in Table 4. It is a heterogeneous mix of less experienced teachers, with one having less than two years of experience, experienced and veteran educators, including one with 24 years of experience. All teachers were responsible for kindergarten classes with four and five-year-olds. Most of the teachers spent more than half of their careers teaching in the current grade.

Table 4. Demographic Overview

Teacher	Gender	Class ^a	Years of experience	Years in current grade
City school 1 (C1)	Female	G4 and G5	19	13
City school 2 (C2)	Female	G4 and G5	24	13
City school 3 (C3)	Female	G4	1.5	1.5
City school 4 (C4)	Female	G5	15	7
City school 5 (C5)	Female	G4	13	3
Private school 1 (P1)	Female	G5	20	10
Private school 2 (P2)	Female	G5	5	5

^a G4 serves 4-year-old students and G5 serves 5-year-old students.

Early Literacy Goals

There was uniformity among teachers regarding their objectives for early literacy. On group four (G4), the main goals were to “learn vowels, how to write his name alone, how to

identify numbers” (C3). The instructional focus relies on learning “all vowels and the consonants that the student uses in his name” (C3), but only “the first name” (C5). There is also some instructional work to develop “fine motor skills” (C5) to write in print letters, but some teachers like to present cursive writing as an optional practice (C5, P1).

These objectives were amplified when students entered in group five (G5) as teachers try to develop their skills to “read and write small words” (C2). Working to develop “reading readiness” (P1), some teachers try “to stimulate the student to get as close as possible to a reading status... but if the student does not achieve it, he will not be penalized” (C4).

To achieve this goal, students should not only “master the alphabet, how to join letters and how to read simple words” (P2), but also how to “connect small words into small phrases” (P2), understanding and knowing how to deal with “all difficulties of the written language” (P1). It is important to note that such difficulties are symbolized by different letters that have the same sound and special syllables of Portuguese.

Level of Adoption and Perceived Importance of Assessments (Q2)

To achieve the early literacy goals described above, the teachers usually develop “an evaluation of the students at the beginning of the school year” (C3). Such evaluation consists of “observing and writing how each student behaves... To identify if they are ready for reading or displaying any deficiencies” (P1). For these teachers, the evaluation is an “ongoing” (P2) process based on student behaviors and the “activities developed in the classroom and at home” (C4). They vigorously said that “there is nothing like tests” (C1), it is all based on observation. According to the teachers, they only write their evaluation “every three months” (C5) in the city schools and “every six months” in the private school, to fulfill “the requirements of the state secretary of education” (P1).

Although teachers were aware of the standardized tests that are employed with their students when they join the second (i.e. Provinha Brasil) and third grades (i.e. Avaliação Nacional da Alfabetização), using assessments for kindergarten students was a new idea for the teachers. The first and unique experience in this sense was a “diagnostic evaluation sent by the secretary of education” (C4) at the beginning of 2016 to be administered by the teachers to the students of group five. The school “pedagogic coordinator corrected the tests” (C4) but no “feedback was sent back to the teachers” (C3), which triggered a feeling that the test was created “to evaluate the teachers, not the students” (C3).

Only one teacher elaborated on the city assessment, saying that the results for her class “wouldn’t help much” (C4) since she had done her evaluation in the first weeks of the year. On the other hand, she expressed that a report comparing her classes to other classes of the school, the district, and the city would “be interesting to develop a comparative analysis” (C4).

Teacher-Perceived Phonological Awareness Level of Students (Q3)

Regarding the perceived level of phonemic awareness of the students, it was expressed that the children of the group have “a lot of difficulties” (C3) to link sounds with printed letters, but it seems that phonemic awareness is not a concern, since teachers “do not have that preoccupation, the real focus is just to learn some letters” (C5). Nevertheless, phonemic awareness was better explored in group five, where most of the students “display phonological awareness in the second half of the school year” (C4).

When asked what kind of phonemic awareness training they provided, teachers displayed different reactions. Some clearly did not understand what was phonemic awareness training and the interviewer had to list some activities related to the construct, while others started to explain their general instructional strategy. There seems to be a strong focus on applying whole language

activities that try to give meaning to tasks using texts, stories, and songs, but deliberate and structured phonemic training was not described.

Nevertheless, some teachers related that they usually “select a word of the text that they just read and write on the board, then read it clapping their hands as they say the syllables” (C2). Others related that they “draw a line under each syllable while they speak” (C3). Another common activity is using rhymes together with the songs that “explore oral language and written skills” (C4). The frequency of such activities varied. Most teachers told that they sing songs and read books with their children every day, but some only developed rhyming “around two times per month when we have a text in the textbook that offers rhymes” (P2).

Learning Materials Usage (Q4)

When asked about the learning materials, teachers said that comparing to other public schools, “this school is very well served regarding learning materials” (C2). Nevertheless, when prompted further, they revealed that “textbooks did not arrive this year” (C1). In 2015, “there was the textbook made by Positivo, but this year there is no one” (C3). One teacher explained the issue, mentioning that, for the first time, the city government bought textbooks in 2014 “in a contract for three years, but they have not fulfilled all the payments, so the contract was canceled ... everything is been canceled” (C5).

The student kit “was also weaker this year, scissors and many other items were not delivered as they had been previously” (C3). Students also did not receive literacy books. The cause for the lack of resources is unclear for the teachers; some “think that it is a lack of funds due to the economy crisis, or perhaps robbery” (C3).

When asked about the quality of the textbook that was delivered last year, teachers usually said that generally speaking “it was good, it included a lot of storytelling, music, dance and fine

motor activities” (C3). However, when prompted further, they revealed that “many activities were out of the children context” (C3) and gave examples such as “it is premature to think that you can explain the regions of Brazil and their cultures for children with only four years” (C3). Other teachers mentioned that thinking in early literacy, “it was a traumatizing (experience), there were many things that did not contribute to the process” (C4) and that “it was awful, we shall give more value to what is ours” (C5), in the sense that textbooks from the local publishers shall be used instead of the ones produced in other regions of Brazil.

Since many inconsistencies were told about the textbooks, I asked the teachers if they used them, and found out that there was an “oversight, we understood that we had to use” (C4). They also said that it was a frustrating experience because the books arrived late. The school year started in February, and the textbooks arrived at the end of the first semester, so “the city government obliged us to use the two books, the first and the second semester, at the same time”. (C5). The delay and the low quality of the textbooks generated behaviors like not following the textbook sequence: “I rebelled ... I tried to make that meaningful for the students” (C4).

Given that this year there were no textbooks for the students, I asked the teachers how they were working. They were using activities from “other materials, and from the internet” (C5). Such activities were printed in the school, but now the printer was also unavailable, so they usually “take copies” with their own money (C3) or “print at home” (C5). They mostly use “google images search” (C3) to locate activities and then they choose the best ones for using. They usually have to find and print “three activities for each day” (C5).

When asked what more was missing regarding learning materials or infrastructure, teachers mentioned that “games are missing” (C1) and that “last year we received the MindLab project,” which includes games for socioemotional and cognitive development, but “this year they

were not delivered” (C3). A playground was mentioned as something that could be useful for the children development as well as a lab. Some teachers also mentioned that having a TV, or at least a sound, in the classrooms would make their jobs easier since they work a lot with music and have to pick up the sound equipment that is shared with multiple classrooms.

Contrasting with the city school, in the private school, learning materials were not an issue. All students had their textbooks and student kit at the beginning of the school year. The teachers chose the books, so they deemed them to be of good quality, “but they could be more complex... my class could handle more difficult tasks” (P2), since they do not have the full authority to decide. This happens because sometimes a publisher offers more benefits for the school (training, equipment, etc.) than other do and that usually means winning the contract for supplying the books for that school year.

Education Technology for Early Literacy (Q5)

The use of education technology was “very high” (C1) according to the city school teachers. While there was no computer in the classrooms, teachers could use “the mobile projectors ... to play movies and music clips” (C2). Another teacher also said that she “thank God that there is a computer room here” (C5), and she takes her students there twice a week to play literacy games. Last year, “all teachers went twice a week, but this year it is less used because we no longer have one intern to help us there” (C3). There are only two computers equipped with interactive tables, so it is very difficult to manage ten students in each table at the same time (C5). Beyond that, some teachers said that they “have difficulty to use” (C4) and that more training sessions would be appreciated.

While a reduction seemed to happen in the usage of the computer lab of the city school, teachers are also using their smartphones in the classroom. “Sometimes it is difficult to get the

computer, or the internet connection is unstable, so I show them what I need in my cellphone.”

(C3). Another practice is that sometimes they “take photos of the students to make them feel important, and they get excited” (C3). Other teachers also mentioned that they used student pictures to create posters that are displayed on the classroom walls.

While all teachers had smartphones and regularly used email, Google and apps like Facebook and WhatsApp, the older teacher of the sample (C5), was the savviest in education technologies. The other teachers reported her as the one that most uses the computer lab and technology in the classroom. She showed me two apps that she uses on her smartphone. One is to practice the alphabet with animated characters, and the other is one app that allows her to type the student name, and it displays the name in the style of a scrolling LED display. She reported that her students get excited and respond more to her prompts.

Surprisingly, the private school was very poor in terms of technology. They did not use any early literacy digital content in the classrooms, “because this involves costs and the textbooks do not include such kind of content” (P1). The only contact that the students had with technology was during their weekly “computer lab class, where a computer instructor works with them” (P2) and the main teacher only provides assistance. “It is only 50 minutes, so it is a rush. They would like to spend more time there” (P2). Nevertheless, teachers expressed a desire to have technology in the classrooms. It “would be perfect for early literacy if we could combine technology with fun” (P1).

Emerging Categories

At the end of the interviews, I asked if there was any other relevant factor to early literacy that was not covered. The first theme that spontaneously emerged was the family engagement. According to the teachers, there are some families that “do not care about their children” (C1).

Two teachers also mentioned that parents that don't work "usually give less support for their student" (C3) and gave examples such as "in my class I have one boy that is almost alone, his father spends the day drinking around" (C3). Teachers related being very upset when working without the support of the family, and some even said that they go out of the school to confront the parents when they keep neglecting homework (C3).

Another teacher noted that one thing that is very wrong in Brazilian schools is that teachers only call families to complain about their kids. Families also got used to complaining about the school. That teacher suggested that educators should complain when needed, but they also need to show the positive things that the students have done. "There is always something nice to be shown. This can improve the relationship between the school and the families" (C2).

Another issue relating the families was that many of the parents were illiterate. Most of them want to help their students, but they never went to school and didn't know how to read. One teacher said that "I always encourage them to help their children. Even if they don't know how to read, I tell them to sit by their kid, ask them what they have for homework and motivate them to do it. This is a small, but good contribution". (C4). Every Friday, students take one literacy book home, so the teacher suggests that illiterate parents ask their kids to tell them the story while looking at the pictures. She also suggests "reading" stories before the student sleeps, by inventing stories that fit with the drawings of the book.

One additional theme that emerged was a critic over the posture of some teachers from the city schools. According to teacher 5, many teachers are not engaged such as the ones of the studied school. She said that she had met many teachers that taught in private schools in the morning and also at a public school in the afternoon. In the private school, those teachers were engaged and did a good job despite the difficulties. But in the afternoons, when they were in the

public school, everything was a reason for not doing their job. “There is no textbook and the printer is not available, so let’s leave the kids playing during this week.” (C5). According to teacher 5, many bad professionals hide themselves under the argument that kindergarten kids have to play to remain in a comfortable position and not develop meaningful early literacy activities.

Conclusions

The previous research efforts endeavored to understand the current state of instructional strategy, use of assessments, phonological awareness instruction and learning materials in the schools of Fumaça. Considering the exploratory nature and restricting the analysis to the two schools that were studied, the current data can support some claims.

The first characteristic about the instruction in the schools is that there seems to exist a genuine strategy that shares many components of the whole language approach. A good example were the reading activities that were developed by all teachers on a daily basis. The educators also emphasized the importance to provide meaningful and contextual activities in order to engage their students better. They also related how they try to influence the parents so that they can provide literacy experiences at home, even when the parents are illiterates.

The second characteristic was that assessments were totally absent in Kindergarten classes. There was just one test that was administered, but the results were not sent back to the teachers. Student evaluation was said to be constantly done, but there was little evidence that it was used as a systematic process for detecting reading failure early and to improve instruction. Based on the teachers’ answers, it was apparent that they gave little importance to external assessments. They certainly did not think that assessments could help them to improve learning.

The third finding was that while some teachers understand the importance of phonological awareness activities, structured and intentional phonemic training was not present in the sample.

The educators developed some activities when the context allowed them to, but they were not systematic, and there was no measurement of its effects.

As expected, the city school suffered in terms of learning materials. Textbooks were not available for most of the school years, and when the city bought them, their delivery occurred after the fourth month of the school year. While literacy books were available, they were kept away from students for the most part of the school day. Surprisingly, all teachers seemed engaged and explained in detail how they deal with the lack of textbooks by using photocopies of other books and activities that they find on the web. Nevertheless, this process poses a serious threat to student achievement, because it relies totally on the teacher expertise to find, select and develop appropriate activities. In addition, as told by one of the teachers, not all educators are engaged as the ones of the studied schools. When faced with an absence of learning materials, many will immediately direct their kids to play.

Based on the literature and the data gathered in this needs assessment, it is possible to argue that the studied schools could benefit their students if they start to provide structured phonemic awareness training and use diagnostic assessments to detect and prevent reading failure early. A path that seems appropriate for approaching the POP is to design an intervention that deals with those major challenges, taking into consideration the lack of textbooks in the public schools.

Chapter 3. Intervention Literature Review

One of the most relevant challenges faced by Brazilian schools is low student achievement rates (Marchelli, 2010; Neri, 2009). According to the *Avaliação Nacional da Alfabetização* and *Prova Brasil* assessments, 74% of the third-grade students and 71% of fifth-grade students in the public schools of Fumaça city (pseudonym) do not meet the requirements in reading (Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira, 2016a; Qedu, 2015). Within such context lies the intended problem of practice (POP), which focuses on the low levels of student literacy achievement, measured by standardized assessments, among early grade students in Brazil.

Multiple factors affect student achievement in less economically developed countries such as Brazil. Those issues include poverty (Hart & Risley, 2003), malnourishment (Fuller, 1987), and poor visual acuity (Gomes-Neto et al., 1997). Other relevant challenges are the lack of learning materials such as textbooks (Heyneman et al., 1981; Tornroos, 2005) and the low quality of the school facilities (Maxwell, 2016; Uline & Tschannen-Moran, 2008). Low teacher quality (Darling-Hammond, 2000; Harris & Sass, 2011; Stronge, Ward, Tucker, & Hindman, 2007) and the absence of effective instructional strategies (Xue & Meisels, 2004) are also related to learning difficulties.

Nevertheless, Brazil has been reducing the occurrence of many issues that affected student achievement. Poverty and malnourishment, for example, have been declining since 1990 due to economic growth and social welfare programs (Hoffmann, 2002; Kageyama & Hoffmann, 2016; Senna et al., 2007). Access to healthcare has also improved with the expansion and decentralization of the Unified Health System (Paim, Travassos, Almeida, Bahia, & Macinko, 2011). Brazil's federal government made investments to improve existing school facilities, to

build new schools (Neto et al., 2013) and to distribute textbooks to all students from first grade to high school (Fundo Nacional de Desenvolvimento da Educação, 2016; Mantovani, 2009). These advances reduced the challenges stemming from poverty, but the national assessments still indicate serious learning deficits in literacy and math for students in grades five and nine (Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira, 2016a). One area that deserves more attention is preschool, which became mandatory in Brazil by a law passed in 2013. The legislation established that after 2016 the public schools shall accept all four and five-year-old children (Ministério da Educação, 2013). Nevertheless, preschools are still not included in most governmental programs such as the national distribution of textbooks and learning materials.

Prior research established that language and reading skills in kindergarten are strongly correlated to reading achievement in the first and second grades (Catts et al., 2001; Schatschneider et al., 2004). Verbal skills in kindergarten are also significant predictors of reading achievement in fourth-grade students (Kurdek & Sinclair, 2001). These results indicate that improving literacy skills in kindergarten may contribute to students' later reading achievement. Research indicates that using assessments to detect and prevent reading failure early is also an effective instructional practice (Caldwell, 2007; Good et al., 2001). Another essential component of effective kindergarten programs is the development of phonological awareness skills (Chambers et al., 2016; Morais, 2012b; M. J. d. Santos & Maluf, 2010) such as:

- Identifying and replacing words in phrases;
- Identifying longer and smaller words;
- Counting, segmenting, adding, subtracting, synthesizing, and transposing syllables in words;
- Identifying rhymes and alliterations in words;

- Producing new words with rhymes and alliterations;
- Identifying that the same phoneme can occur in multiple words;
- Segmenting, adding, subtracting, synthesizing, and transposing phonemes in words.

To further understand the problem of practice, which is the low levels of student achievement in literacy among early grade students, I conducted a needs assessment in two kindergarten schools of Fumaça. The ecological systems perspective (Bronfenbrenner, 1981) was employed to identify and assess the factors that are hypothesized to be directly associated with the low levels of student achievement in literacy among early grade students of Fumaça. The empirical goal was to evaluate instructional strategies, use of assessments, the teacher-perceived phonological awareness level of students, the existence of learning materials, and the usage of early literacy technologies in kindergarten classrooms.

Using an environmental rating instrument (Sylva et al., 2011) and semi-structured interviews, the needs assessment revealed that the students of Fumaça public schools did not have textbooks. Additionally, although most of the teachers recognized the importance of early literacy digital technologies, few used technologies in their early literacy practice. Teachers reported that they did not use any kind of assessments, which may reduce their capacity to detect reading difficulties. Furthermore, based on the observations and the interviews from the needs assessment, it seems that the educators are failing to provide phonological awareness instruction.

In this context, this review focuses on how technology can assist teachers and students to develop phonological awareness skills surpassing the absence of teacher knowledge about phonological awareness, the lack of assessments and learning materials. Given the limited resources found in the schools of Fumaça, an innovative strategy is needed to support teachers and students. I conceptualized that digital games may be a viable way to engage kindergarten students

in the reading acquisition process and an effective tool for supporting their phonological awareness development. Finally, to fulfill the lack of assessments in the schools, I proposed that digital games can be used to provide cost-effective information about student progress without using traditional standardized tests which are deemed to be particularly stressful for young learners. The review focuses on identifying the required characteristics of an effective tool capable of assisting educators to provide phonological awareness instruction while, at the same time, allowing them to monitor students' progress to refine their instructional strategies.

This review focuses on the effectiveness of phonological awareness interventions on increasing student's phonological awareness, word reading and writing skills. Specifically, it seeks evidence of their effectiveness for kindergarten students. It also evaluates findings found in the Brazilian context. Finally, it seeks indication to support the proposed computer-based instructional program and assist in its design.

Theoretical Background

This literature review is built on the assumption that phonological awareness is a key component of reading development which can benefit four and five-year-old students (Bus & van IJzendoorn, 1999; Chambers et al., 2016; Ehri et al., 2001). The focus is to assess phonological awareness programs which generated effects in other populations, and that could serve as an inspiration for designing a viable intervention to be implemented in the schools of Fumaça and other Brazilian cities. To this end, the review seeks to identify different strategies used, the specific ingredients delivered, and the most effective dosage.

Within this objective, the review adopts a constructivist perspective that understands reading acquisition as an evolutionary process (Ferreiro & Teberosky, 1982). The development starts with the presyllabic stage, in which the children start to build their understanding that words

represent what we speak. Then the process evolves to the syllabic state in which the children understand that syllables form words. The next step occurs when children begin to identify that the syllables are created by more than one sound in the syllabic-alphabetic. Finally, the students reach the alphabetic stage in which they operate at the phoneme level, representing each sound that forms the syllables.

The psychogenesis theory (Ferreiro & Teberosky, 1982) is widely adopted by the Brazilian academia, but it does not give emphasis to phonological awareness. Nevertheless, this research adopts the works of Morais (2006; 2012b) which expands the psychogenesis perspective highlighting the importance of phonological awareness skills. Figure 2 presents a synthesis of the theme and hypothesizes how phonological awareness assists students in moving from one stage to the other.

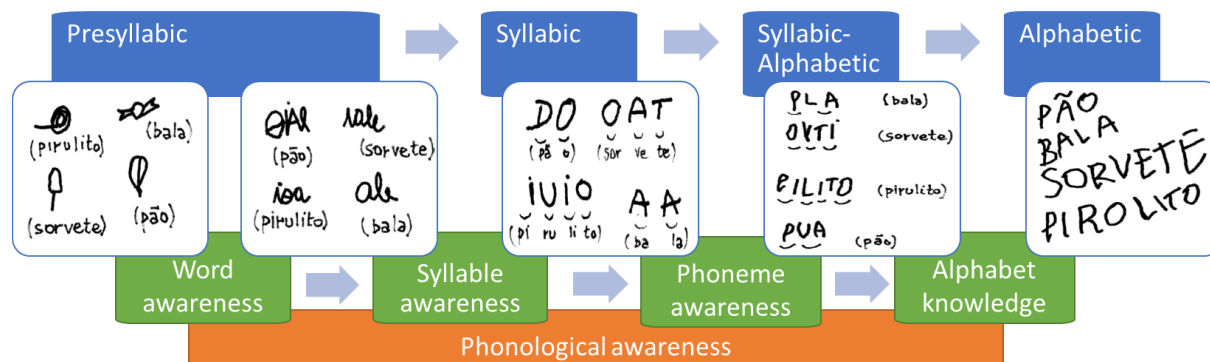


Figure 2. Developmental stages and phonological awareness skills.

Stages in blue, with examples of how the children write in each stage. The individual components of phonological awareness are presented in green and illustrate how they assist student development from one development stage to the other. The writings were adapted from Morais, A. G. (2012). Sistema de escrita alfabética. São Paulo: Melhoramentos.

Phonological Awareness Interventions

The origin of phonological awareness can be traced back to the seminal research of Bruce (1964), who identified that five- and six-year-olds were not able to differentiate phonemes in spoken words. Bruce (1964) discovered that seven-year-old children could answer only a few of his prompts and that by the age of eight, the average respondent scored 50% in his phonemic awareness test. When children reached nine years, they scored approximately 100%. His conclusions indicated that there was a progression in the ability to phonetically analyze speech. Brazilian children learning Portuguese seem to go through the same path, having their phonemic awareness skills evolving from five to nine years (A. G. Capovilla et al., 2007). Further, Liberman, Shankweiler, Fischer, and Carter (1974) found a similar pattern and concluded that children had more difficulty in phonemic segmentation than in syllabic segmentation.

Based on these findings, many researchers started to evaluate the impact of direct phonemic awareness training for the children (Rosner, 1974; Treiman, 1985). Ball and Blachman (1991) found that phoneme awareness training that included sound-letter correspondences significantly enhanced early reading and spelling skills. A meta-analysis of 52 quasi-experimental and controlled experimental studies also indicated that phonemic awareness instruction had a moderate impact on reading ($d = 0.53$) and spelling ($d = 0.59$) skills for students from kindergarten to sixth grade (Ehri et al., 2001). While phonemic awareness was found to be the strongest unique predictor of reading achievement (Høien, Lundberg, Stanovich, & Bjaalid, 1995), phonological awareness also includes syllabic and rhyming skills.

Bus and van Ijzendoorn (1999) developed a meta-analysis of 32 phonological awareness training studies that employed quasi-experimental and controlled experimental designs and identified that the impact of phonological awareness on reading achievement was substantial ($d =$

0.70, $r = .33$, $N = 745$). The authors also argued that preschoolers benefit more from phonological awareness programs than kindergarten or primary school students. While the results of this body of research point to the importance of phonological awareness and the effectiveness of instructional programs that foster its development for English-speaking students, it is important to take into consideration that the problem of practice (POP) is focused in the schools of Fumaça, where students are learning Brazilian Portuguese, which presents several linguistic differences in comparison to English.

In Brazil, Capovilla, Gütschow, and Capovilla (2004) designed one of the pioneering investigations examining phonological awareness. These authors identified kindergarten and first-grade students' skills that could forecast their later achievement in reading and writing. They evaluated 54 students in vocabulary, phonological awareness, sequencing, phonological memory, visual memory, figure copying, and arithmetic and writing capabilities. Each student participated in cognitive ability assessments and took reading and writing skill tests ten months later. The authors argued that the correlations between the phonological measures and reading achievement support the phonological deficit hypothesis, meaning that phonological awareness skills are a predictor of reading and writing achievement in the later grades.

Furthermore, Capovilla et al. (2004) identified the reading strategies used by first-grade students and their relation to writing achievement in Brazil. Capovilla et al. (2004) recruited 55 children from a public school that were given reading and writing tests. Statistical procedures using t -tests and multivariate analysis of variance (MANOVA) indicated that the results of writing and reading tests were significantly correlated. The best readers had already mastered logographic and alphabetical strategies, while weak readers had not. The students could be discriminated per their phonological strategies, but not by their lexical strategies. The authors suggested that at the

beginning of literacy development, alphabetic strategies are the most important and should be the focus of phonological awareness interventions. Alphabetic strategies appear to be an important parameter to include in the design of an intervention to the schools of Fumaça because the target population is comprised of kindergarten students.

Phonological Awareness Interventions for Primary Students

Before reviewing studies with kindergarten students, it is important to evaluate how phonological awareness interventions influence student achievement in older students because Brazilian national assessments are developed in primary grades, and the results may reflect specific characteristics of effective interventions. Justino and Barrera (2012) examined late reading failure using a sample of 31 students with serious literacy problems from the fourth to the eighth grades from a public school; their average age was 12 years-old. The authors first conducted a pre-test to separate the children into two groups per the students' skills. Each group received four hours of phonics-based instruction per week, during ten months, a total of 160 hours of instruction. Both groups developed activities described by Capovilla and Capovilla (2004). The beginners group supplemented their activities with phonological awareness games provided by Atica, a local publisher, while the advanced students used an application to improve their grapheme-phoneme correspondence skills (Dias, 2006).

The Wilcoxon non-parametric test was used to compare student results before and after the intervention. Justino and Barrera's (2012) results indicated statistically significant improvements in all skills evaluated for both groups. Although the results were positive, the intervention was intensive, with 160 hours of classes. This amount of time may hinder the application of such intervention in other contexts due to the lack of school time, threatening the fidelity of such endeavors. Another weakness is the absence of a control group, which does not exclude the

possibility that the improvement occurred because of other school activities in which both groups participated.

While Justino and Barrera (2012) studied students with serious reading deficits from fourth to eighth grades, Paula, Mota, and Keske-Soares (2005) aimed to provide phonological awareness improvement to early grade students. They evaluated the influence of phonological awareness instruction with a sample of 46 first-grade students from four public schools. After a pre-test, researchers distributed the children into the experimental group (a) that included only illiterate students ($n = 17$), and the control groups of (b) illiterate students ($n = 12$) and (c) literate children ($n = 17$). Instructional sessions occurred in small groups of two or three students, three times per week, for 30 minutes, and lasted four months, an approximate total time of 18 hours. Paula et al. (2005) concluded that the phonological awareness and grapheme-phoneme training improved measures for over three-quarters of the students. The overall phonological awareness score for the experimental group improved 103% ($p = 0.0001$). The authors noted that many students did not have the previous contact with literate culture (e.g., newspapers, magazines, books, etc.), the intervention, therefore, included a component explaining to the students why learning is important and how they can apply knowledge in their lives.

Additionally, the study found that 23.53% of the experimental group students did not improve and faced clear difficulties accomplishing even simple tasks. The instructors had to reinforce previous sessions when a new class started because those students had trouble memorizing grapheme-phoneme associations. The researchers, therefore, suggested that effective interventions should include syllabic and phoneme analysis, as well as syntheses activities. They also emphasized the importance of working with the relations between grapheme and phoneme (Paula et al., 2005). These are important considerations to take while designing computer-based

phonological awareness programs. While Justino and Barrera (2012) offered 160 hours of instruction to students with serious reading deficits from grades four to eight, Paula et al. (2005) provided only 18 hours to first-grade students with significant outcomes. Nevertheless, their sample was small, preventing generalizations. It is also important to note that the older students' need for more intensive phonological awareness training compared to younger children was also identified in international studies (Ehri et al., 2001).

Another intervention designed to improve the reading achievement of first-grade public school students in Brazil (Dias & Bighetti, 2009) included a sample of 59 children from two classes that became the experimental and control groups. The researchers provided 17 hours of professional development to the classroom teacher in 17 weekly sessions. The teacher implemented the phonological awareness activities described by Capovilla and Capovilla (2004) fostering the correspondence between graphemes and phonemes. During the seven months, the students had 20 minutes of phonological awareness activities every day, a total of 46 hours, followed by the post-test. The scores for each phonological awareness dimension were compared between groups using the *t*-test. Results showed a significant difference between the means of the total score ($p = 0.035$), indicating that the experimental group benefited from the intervention. The experimental group was also more homogeneous in post-test scores than the control group, showing a possibility that achievement gaps between students might have been reduced by the intervention. While many results were statistically significant, the improvement in reading achievement was moderate with $d = 0.56$ (Cohen, 1988). Nevertheless, since pre-tests were not employed, there is a possibility that students in different groups started with different levels of phonological awareness skills.

Despite their weaknesses and differences regarding focus, activities, and duration, the

works of Barreira and Justino (2012), Paula et al. (2005), and Dias and Bighetti (2009) all showed the potential effectiveness of phonological awareness interventions on improving Brazilian primary students' phonological awareness. International research indicated that comprehensive programs including child-initiated activities and phonological awareness instruction also improve early literacy skills in kindergarten students (Chambers et al., 2016). Preschools to four and five-year-old students became compulsory in Brazilian public system recently (Ministério da Educação, 2013) and has not yet received much attention from the national academia, publishers, and governments. It is likely that this lack of attention accounts for the limited number of studies of phonological awareness interventions in Brazilian preschools.

Phonological Awareness Interventions for Kindergarten Students

One randomized controlled trial in the United Kingdom involved 152 four-year-old children that were split into groups of five. Experimental groups received 30 minutes of training in letter-sound knowledge, phoneme awareness with blending and segmenting, and exercises in letter-sound knowledge and phoneme awareness while listening to storybooks (Bowyer-Crane et al., 2008). The intervention also developed 20-minute individual sessions with the teacher assistant where the child read a book and when finished, a second book was read together with the teacher assistant to increase fluency. Students had daily sessions for 20 weeks, a total time of 42 hours of instruction alternating small-group and individual sessions. Control groups received instruction that focused their vocabulary, comprehension, and narrative skills.

While the results showed that the program improved decoding skills, the cost of this program is relatively high given that it employed small groups and individual sessions (Bowyer-Crane et al., 2008). The high-cost of offering small group instruction might be surpassed by computer-based approaches that have the potential to scaffold students' skills with a lower cost.

Another study involved 87 kindergartens split into groups of five and provided with four weekly 20-minute sessions over 16 weeks, a total time of 21 hours (Craig, 2006). The instruction included following a metalinguistic-games program, which included phonemic awareness, rhyming, alliteration, letter, and spelling exercises (Adams, Foorman, Lundberg, & Beeler, 1998). The program was complemented by the segmentation and letter-sound activities described by Ball and Blachman (1991). Results revealed improvements in students' phonological awareness, spelling and reading skills, but the implementation costs of such program might also be prohibitive because it included 21 hours of instruction with small groups (Craig, 2006).

Given that the kindergarten classrooms in Brazil usually have from 15 to 20 students (Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira, 2016b), interventions like those of Bowyer-Crane et al. (2008) and Craig (2006) require that the same instruction shall be provided four times (five students per group). A considerable additional time is also needed to develop the assessments, which makes these interventions less viable for small schools and classrooms where there the teacher works alone, without teacher assistant. These issues might also be surpassed by a computer-based instructional program delivered to pairs of students.

Interventions with Brazilian Kindergarten Students

Pestun, Omote, Barreto, and Matsuo (2010) developed a phonological awareness intervention with 88 kindergarten students in the south of Brazil. The experimental group included two subgroups with 22 students each. Instruction sessions lasted one hour and were provided twice a week for three months, a total of 29 hours. The phonological awareness scores were higher for experimental groups but the differences were not statistically significant. The researchers suggested that the lack of significance might be due to reduced intervention time (29 hours). Another issue might be that the program was delivered by one psychologist and one

undergraduate student that was called in to replace another psychologist who quit the team during the project. Both professionals were experienced in phonological awareness but never had worked with large groups. A school teacher was included in the team and helped to “control” the students during the intervention, but the instructors might not have adequately captured the attention of the students. Such issues with the instructors may have threatened the fidelity of the intervention.

A similar fidelity issue may arise in the schools of Fumaça because the needs assessment revealed that many teachers were not aware of the importance of phonological awareness instruction (Amorim, 2016). The lack of teacher knowledge suggests that the intervention has to provide a strong professional development program. Nevertheless, existing teacher training is probably not sufficient because Brazilian assessments start in the third-grade and there are no forms of assessing learning gains at scale (Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira, 2016a). Due to those characteristics, the schools of Fumaça need an alternative intervention capable of providing assessment data and assuring that the students receive adequate instructions at the optimal dosage. Those are features inherent to computer-based instructional programs. In order to develop an effective computer-based instructional program, it is necessary to first establish the desired instructional components and optimal dosage.

Dambrowski, Martins, Theodoro and Gomes (2008) developed a short-term intervention with ten weekly sessions lasting 30 minutes, a total time of five hours. It included 57 students who received instruction in whole-class groups. Students developed syllabic awareness (segmenting, counting, comparing, adding, subtracting, and transposing), rhyming, alliteration, word awareness, phonemic awareness, and grapheme-phoneme correspondence skills. Results indicated significant differences between the control and experimental groups with 200% improvement in phoneme awareness and 19% improvement in syllabic awareness (Dambrowski et al., 2008).

A. J. Soares and Cárnio (2012) developed an alternative short-term intervention. They also employed speech therapists providing phonological awareness instruction to 49 students. The researchers assessed students' phonemic awareness skills before instruction. Their focus was to establish how the children performed phonemic tasks such as isolation (first and last phonemes), deletion, segmentation, reversal, and blending. According to their standardized scores in the *Consciência fonológica instrumento de avaliação sequencial* (CONFIAS) assessment, students were split into three groups (basic, intermediary and advanced) per their skills ($n = 12$, $n = 21$, $n = 16$). It provided a total time of 4 hours of instruction. The workshops included games for the beginners (letter recognition and alliteration, sound manipulation, rhyming), intermediate (syllabic segmentation, phonemic segmentation, phonemic synthesis, word building) and advanced (all tasks plus phonics).

A. J. Soares and Cárnio (2012) results indicated that the whole group improved their average phonological awareness scores by 56%. The beginner's group improved their score by 89%, the intermediate improved 60%, and the advanced students improved 24%. This study cannot be taken as an example of effect size because it did not employ a control group and it only evaluated phonemic skills, not their effects on reading and writing (A. J. Soares & Cárnio, 2012). One characteristic that may reduce the applicability of this intervention and the previous one (Dambrowski et al., 2008) in the schools of Fumaça is that expert speech therapists implemented it instead of teachers. Public schools in Brazil may not be able to afford this intervention at scale because they often do not have enough budget to hire speech therapists.

Nevertheless, A. J. Soares and Cárnio (2012) employed game-based activities that were adjusted for the students' skills. Balancing aligns with the best practices in level-design for computer games that motivate and engage users. Morais (2012b) also reported that the usage of

phonological awareness instruction with printed games was a successful way to engage students located in Fumaça. It is plausible to say that digital games can also generate high levels of student engagement and may be considered in the design of the intervention program. Nevertheless, one issue which remains open is if short and medium-term interventions can be effective if not delivered by speech therapists.

Santos and Maluf (2010) can help answer the previous concern regarding speech therapists. Their intervention in Brazil to foster metaphonological skills and improve writing involved five and six-year-olds students. The sample included 90 students from five different classes, which were designated to allow monitoring the teacher effects on the experimental and control groups. This design intended to assess if teachers with different levels of experience and know-how in phonological awareness could deliver the phonological awareness program effectively. In the first school, one class was split into two groups (experimental and control), and the intervention was delivered by the school's pedagogical manager. The second school had two classes taught by the same teacher. One became the experimental group and the other the control. The researcher delivered the instruction to the experimental group. The third school included two classes that were taught by different teachers; one became the control and the other the experimental group. The regular teachers delivered the program.

After the pre-tests, the intervention lasted 12 weeks and 32 sessions, a total of 16 hours of instruction. The post-test occurred a week after the intervention ended. The study also included a placebo program applied to the control groups including a set of activities that had no influence on literacy. Statistical analysis using a *t*-test revealed that the students in the experimental groups enhanced their metaphonological skills more than the control groups ($t = 3.03$ and $p = 0.01$, $t = 3.84$ and $p = 0.00$, $t = 2.93$ and $p = 0.01$). The writing abilities increased significantly in the first

and third schools, however, the improvement was not significant for the second school. Nevertheless, additional variance and difference of means tests revealed that the control group started the intervention with better performance than the experimental group.

Overall, Santos and Maluf (2010) confirmed the effects of previous phonological awareness interventions (Dias & Bighetti, 2009; Paula et al., 2005) with kindergarten students, reinforcing the notion that literacy instruction can start earlier than first grade. Additionally, Santos and Maluf (2010) provided an ingenious approach using pre-intervention assessments and control groups allied with statistical procedures to analyze the significance of the data. In their conclusions, Santos and Maluf (2010) emphasized the importance of ludic activities to teach the alphabet and to develop the spoken language. They also found that the intervention was effective regardless of who was the instructor (regular teacher, the pedagogical manager, and researcher) implementing the activities and instructional sequence of the program. This conclusion, together with the difficulties encountered to develop phonological awareness tasks in classes with lots of students (Paula et al., 2005), point to the hypothesis that phonological awareness instruction for Brazilian kindergarten students could be more effective if delivered using computers and mobile devices for individual or pairs of students.

Computer-based Early Literacy Interventions

Some computer-based literacy instruction studies were developed to measure the outcome of using computers and tablets to develop phonological awareness skills (Chera & Wood, 2003; Pokorni, Worthington, & Jamison, 2004; Segers & Verhoeven, 2004). Segers and Verhoeven (2005) created one of the most relevant works, which assessed the long-term effects of a computer-based comprehensive phonological awareness training program. Their sample included 100 five-year-old children in three kindergarten schools. The experimental group included 42

students from one school, and the control group consisted of 58 students from two other schools. The intervention consisted of rhyming, phonemic segmentation, auditory blending, and grapheme knowledge activities in the form of computer games. To achieve higher levels of motivation, students were allowed to choose the games they wanted to play. Five options were provided, offering the same activities with different graphics (Segers & Verhoeven, 2005).

During the first 35 weeks of the intervention, children used the computer games once a week for 15 minutes (Segers & Verhoeven, 2005) and during the last ten weeks, children completed three sessions per week. Multivariate analysis indicated that the intervention group did not show increased auditory blending or phonemic segmentation capability, but the rhyming test displayed positive outcomes for immigrant children. There was also a positive effect on grapheme knowledge. The amount of time spent on the computer also correlated with learning gains, which suggests that the computer software influenced early literacy development. The lack of significant results for auditory blending and phonemic segmentation might be due to the reduced intervention time, which was less than 15 hours (Segers & Verhoeven, 2005).

While international research on computer-based phonological awareness interventions revealed promising outcomes, Brazilian-Portuguese interventions are still at an earlier stage. Pereira, Brancalioni, and Keske-Soares (2013) did a case study with four children who exhibited poor phonological skills. Two students received traditional speech therapy, and two used the instruction software for ten sessions of 35 minutes, a total time of six hours. Statistical analysis comparing pre-test and post-test revealed that the children that studied with the computer had greater gains than the ones in the traditional group. These promising results, however, were obtained with a small sample, which prevents further generalizations. Nevertheless, this study can be used as a basis for establishing the activities that shall be developed in the intervention.

In another study, 12 four and five-year-old Brazilian children received ten sessions of 20 minutes for one month using a computer software to develop phonological awareness skills (Farias, Costa, & Santos, 2013). Students were randomly assigned to the control and experimental groups, and the procedure included pre-testing and post-testing. Statistical analysis indicated a significant improvement among the students that participated in the experimental group using the software. The main weakness of this study, however, is that the control group did not receive a placebo intervention. The lack of a placebo raises the possibility that the novelty factor of the intervention for the experimental group may have increased the effect size of the program. Another issue is that the experimental group had a speech therapist acting as the group mediator (Farias et al., 2013), so it would be important to evaluate if the improvement in learning came from the software, from the interactions with the mediator or both. While the Brazilian computer-based phonological awareness interventions were promising, they were small-scale projects with few students; a larger study was not found. This gap provides an interesting opportunity for large-scale research and educational practice development.

An additional potential benefit of adopting a computer-based intervention is that it can fulfill the lack of early literacy assessments that was revealed in the needs assessment in the schools of Fumaça. Software applications that have the capability to generate learning data about their users automatically provide a cost-effective way of assessing students (Shute, 2011). Assessments are important because they assist teachers in identifying students' strengths and weaknesses and then taking instructional decisions to support them (Caldwell, 2007).

The proposition of having students playing phonological awareness games that would not only be delivering instruction but also be assessing student progress in real time seems promising. Such stealth-assessments are not far-fetched, they exist and are deemed to be a cost-effective way

for implementing assessments in schools that do not have a culture of developing formal evaluations or standardized tests (Carson, Gillon, & Boustead, 2011), such as the kindergarten schools of Fumaça.

Intervention Characteristics

According to the previous literature, a computer-based intervention can be used to address the various components of phonological awareness (Segers & Verhoeven, 2005). Applications can develop (a) syllabic and phonemic synthesis, (b) rhyming, (c) alliteration, (d) syllabic and phonemic segmentation, (e) syllabic and phonemic manipulation, and (f) syllabic and phonemic transposition (A. G. Capovilla, Dias, & Capovilla, 2014). Regarding the instructional strategies, interventions that combine phonological awareness with letter-sound correspondence instruction were found to be more effective than interventions that only delivered phonological awareness without presenting letters and printed texts during instruction (Bus & van IJzendoorn, 1999).

Another aspect of computer-based phonological awareness interventions regards the pitch, speed, and transitions of the speech that is used for training. Segers and Verhoeven (2004) examined the issue and found no significant results in an experiment that employed instruction with reduced speech rate and enhanced transitions. One practical implication of this research is that computer-based instruction may require a human narrator to produce speech or high-quality text-to-speech technologies that automatically synthesize near-human sounds without reducing the speech rate.

Cheung and Slavin (2013) evaluated the outcomes of 20 randomized ($n = 13$) and quasi-experimental ($n = 7$) studies that involved 7,000 children. Their results indicated that the overall adoption of technology revealed a small beneficial effect size ($ES = .14$) compared with traditional interventions. Nevertheless, small-group interventions generated the strongest benefits

(ES = .32) and the authors also found evidence that individual instructional programs were more effective for struggling students. Studies that focused on primary grade students had larger effects (ES = .36) than those targeted to upper elementary grades (ES = .07), which reinforces the focus on providing phonological awareness instruction to younger students such as those in the kindergarten schools of Fumaça.

The intensity of the phonological awareness instructional program is still a matter of debate. While some Brazilian studies revealed gains in short-term interventions with less than 10 hours (Dambrowski et al., 2008; Pereira, Brancalioni, & Keske-Soares, 2013), more rigorous experiments with randomized controlled trials employed from 14 to 160 hours of instruction, most staying within the 15 to 40 hours range (A. G. Capovilla et al., 2007; Paula et al., 2005; M. J. d. Santos & Maluf, 2010). Regarding computer-based interventions, Cheung and Slavin (2013) meta-analysis found that high-intensity programs that included more than 75 minutes of instruction per week (ES = .19) yielded larger benefits than low-intensity programs (ES = .08). This finding was not statistically significant due to low statistical power ($Q_B = 1.20$, $p < .27$), but suggests that computer-based interventions shall be intense.

Implementation Procedures

The idealized computer-based early literacy intervention presents itself as an attractive way to improve early literacy skills among Fumaça students. To maximize its reach and effects, it is necessary to consider challenges that relate to any computer-based intervention:

- Teachers may not use the technology-based intervention due to their lack of self-efficacy (Holden & Rada, 2011) and feelings of being replaced (Li, 2007);
- Educators and parents may oppose such intervention due to a belief that young children should not use technology because it can cause harm (Osiceanu, 2015).

To effectively mitigate such barriers, I needed to gain the support from multiple stakeholders such as the parents, principals, teachers, and investors, a process that was facilitated as I adopted a leadership perspective that fostered trust and commitment in the face of a new educational approach. This challenge aligned with principles of transformational leadership, which requires high levels of idealized influence to motivate the team involved in the intervention, inspirational motivation to drive the change process highlighting the potential benefits for all stakeholders, intellectual stimulation by providing feedback and challenging activities to the intervention team and individual consideration to each member's needs and aspirations (Blomme, Kodden, & Beasley-Suffolk, 2015). Considering that self-efficacy seems to be the strongest motivational indicator of teacher learning and teaching activities (Thoonen, Slegers, Oort, Peetsma, & Geijssel, 2011), the professional development program emphasized not just the usage of the computer games but also how teachers could become authors, modifying and expanding existing games.

Conclusions

This review provided evidence that phonological awareness interventions can provide learning gains for students with serious reading disabilities (Barrera & Justino, 2012), for students in the first grade (Capovilla et al., 2004; Catts et al., 2001; Dias & Bighetti, 2009; Paula et al., 2005), and for children in kindergarten classes (Catts et al., 2001; Chambers et al., 2016; Kurdek & Sinclair, 2001; Pestun et al., 2010; Santos & Maluf, 2010). It also suggested that computers can be used to deliver phonological awareness instruction (Farias et al., 2013; Pereira et al., 2013; Segers & Verhoeven, 2005) while at the same time providing real-time data about student progress that can serve as a cost-effective assessment (Carson et al., 2011; Shute, 2011).

Previous studies suggested that computer-based phonological awareness interventions

should target young students, should be intense (more than 75 minutes/week), should employ letter-sound correspondence instruction, and should use regular speech during the instruction (Bus & van IJzendoorn, 1999; Cheung & Slavin, 2013; Segers & Verhoeven, 2004).

Chapter 4. Intervention Procedure and Evaluation Methodology

According to the Brazilian assessments, in the public schools of Fumaça (pseudonym), 74% of the third-grade students and 71% of fifth-grade students did not meet the national requirements in reading (Qedu, 2015). The needs assessment revealed that the schools of Fumaça are not providing adequate phonological awareness instruction, do not use assessments to detect and prevent reading failure and public schools lack learning materials. Further, it established that some teachers do not have an adequate knowledge about the importance and operationalization of phonological awareness instruction and usage of assessments to measure students' skills.

The reviewed literature established that phonological awareness instruction can be an effective way of increasing phonological awareness, reading and writing skills for primary and kindergarten students. In the Brazilian context, some interventions were developed with kindergarten students with promising results, but with some methodological limitations. The current study focused on measuring the effectiveness of a phonological awareness program designed to fulfill some limitations found in the schools of Fumaça:

- Professional development to increase teacher knowledge and preparedness;
- Digital games that can be used to scaffold students' phonological awareness skills;
- Assessment data generated automatically by the games.

This research aimed to determine the impact of the proposed phonological awareness program on the literacy achievement with the following research questions:

1. To what extent did the computer-based program differentiate the intervention group students' phonological awareness, word reading, and writing skills from students in the control group?
2. To what degree did the time spent using the games affect the measures of phonological

- awareness, word reading, and writing skills?
3. To what degree did the student performance in the games predict student achievement according to standardized measures?
 4. To what degree did the teacher's instructional strategies differentiate the experimental group students' phonological awareness, reading, and writing skills from students in the control group?
 5. To what degree did the computer-based phonological awareness program engage students?
 - 5.1. In what ways were students engaged in reading while using the program?
 6. What were the teachers' perceptions about the method, content, and delivery of the intervention?
 7. Which factors hindered or facilitated teachers' ability to deliver the intervention?

Research Design

The intervention consisted of a randomized controlled trial within an embedded mixed methods design (Creswell & Clark, 2011) to evaluate the phonological awareness program. The mixed methods study employed standardized quantitative measures to develop a cluster randomized controlled trial. The quantitative strand sought to determine the effect size of the intervention in measures of phonological awareness, word reading, and writing. It also sought to evaluate the dosage of the program and if the student performance in the games could be used to predict their scores on standardized measures. The qualitative strand of the study was employed to identify teachers' existing instructional strategies which might or might not include phonological awareness instruction, and their perceptions about the intervention. Figure 3 displays the overall design of the study, including the pre-tests, intervention and control classes, post-tests and follow-

ups. The scope of this dissertation is limited to the pre-tests, intervention phase, and post-test. I will seek external funding to conduct the follow-up assessments using the findings from the current study.

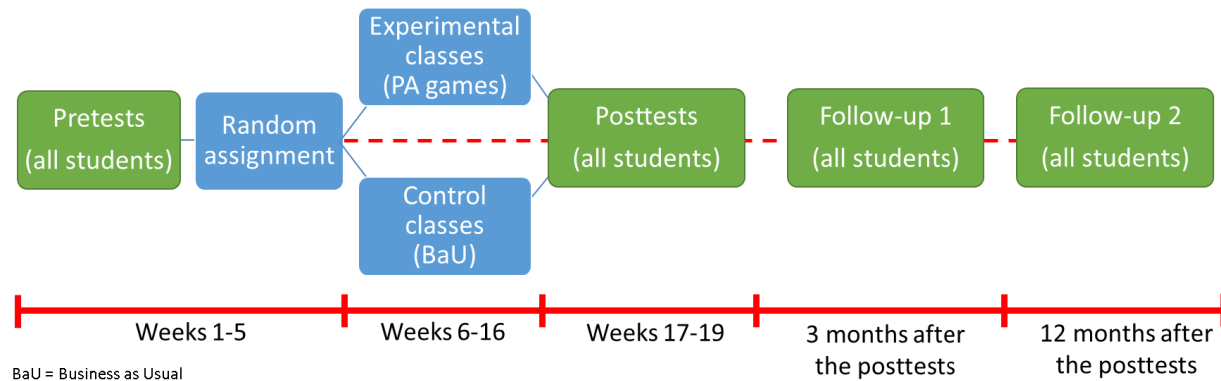


Figure 3. Study design.

Process Evaluation

The process evaluation sought to answer research questions four to seven, identifying implementation issues and stakeholders' perceptions about the delivery of the computer-based phonological awareness program. The process evaluation also needed to determine if the program provided the minimum of 20 hours of computer-based phonological awareness instruction for the students. The process evaluation sought to identify the efficacy of the phonological awareness program (O'Donnell, 2008). Fidelity of implementation occurred when the teachers implemented the phonological awareness program according to the protocol. In this study, fidelity of implementation was achieved when:

- Learners had the opportunity to receive all treatment ingredients through computer-based instruction, which included: syllable awareness, rhyming, alliteration and phoneme awareness;
- Students received at least the minimum dosage expected to generate gains for the treatment ingredients. Each ingredient (e.g., phoneme awareness) was delivered by one

or more games that develop one or more skills (e.g., segmenting phonemes).

A high fidelity implementation consisted of a classroom that allowed its students to play all games in 20 sessions of 20 minutes each, within the 12-week period.

Outcome Evaluation

The outcome evaluation sought to determine the effect size of the intervention, how differences in the dosage affected students' skills and if the student's performance in the games predicted their scores on standardized measures.

Expected effect size. I reviewed previous phonological awareness instruction studies to establish an estimate for the effect size of the intervention. Bus & van IJzendoorn's (1999) meta-analysis of phonological awareness training programs for American and European students revealed gains in phonological awareness ($d = 0.73$, $N = 739$) and word reading ($d = 0.7$, $N = 745$). Ehri et al. (2001) meta-analysis of 52 phonemic awareness training studies detected a large effect in phonological awareness ($d = 0.86$), and moderate effects in reading ($d = 0.53$) and spelling ($d = 0.59$). Based on these results from non-Brazilian studies, I concluded that an effect size of 0.60 is reasonable for this kind of intervention and these types of outcome measures.

Brazilian interventions did not provide effect sizes, so they were calculated. In one study, gains in phonological awareness were very high with $d = 3.35$ (Pestun et al., 2010) but the difference between the experimental and control group means was not statistically significant according to the Mann-Whitney test. Santos and Maluf (2010) reported a more reliable gain in phonological awareness ($d = 0.919$) and word reading ($d = 1.076$). Training in phonological awareness also resulted in word-reading gains ($d = 0.56$) according to Dias and Bighetti (2009). Given the previous studies, it seems reasonable to expect an effect size of at least $d = 0.4$.

If the design employed random assignment at the individual level and the desired

minimum detectable effect size is defined to be $d = 0.4$, the adequate sample size would be 226 (with $\alpha = 0.01$ and a statistical power of 0.95). Unfortunately, it was not possible to randomize individuals due to operational constraints and to avoid contamination (Shadish, Cook, & Campbell, 2002), so classroom randomization was employed. The initial target was that half of the classrooms would receive the intervention and half would keep doing their business as usual activities. Such cluster random assignment (CRA) design would require at least 28 classrooms with an average of 15 students in each class to assure a minimum detectable effect of $d = 0.4$ (with $\alpha = 0.05$ and a statistical power of 0.8). The alpha and statistical power parameters were reduced so that the design would remain viable with the available resources but would still provide an adequate level of validity. The CRA design would consume more resources to cover 420 students but would allow the analysis to adequately deal with intraclass correlation to avoid making wrong inferences (Torgerson, Torgerson, & Taylor, 2015).

Evaluation design. A randomized experiment was used to evaluate the outcome of the intervention. Randomized experiments are the most powerful design in situations where the researchers want to establish a causal connection between the treatment and its effect (Pierre, 2004). The trial sought to assess how the phonological awareness treatment effects manifested over the time (Shadish et al., 2002). The project employed a design with two kinds of classes (experimental and controls) with pre- and post-tests. Two optional follow-up evaluations were also part of the design and will be developed if funding becomes available.

Gains in phonological awareness were expected to be reliable because the measuring instrument was already age-standardized (A. G. Capovilla et al., 2014). Unfortunately, a reading and writing test standardized to four and five-year-old Brazilian students does not exist yet. Nevertheless, the instrument that is under standardization was used and has shown adequate

psychometric properties with a sample of four-year-old classrooms from private schools located in the southeast of Brazil (Pazeto, 2012).

Regarding the overall design, the first option considered was to use a classic trial design with students as randomization units. Randomizing students was discarded for employing classrooms as clustering units to reduce the risk of contamination (Shadish et al., 2002; Torgerson et al., 2015). If students from the same class were assigned to control and experimental groups, treatment ingredients might spillover (Pierre, 2004) and contaminate control students.

One potential risk that was addressed was attrition due to students changing to another school. Attrition might also occur during the experiment with students dropping out of the study due to disengagement or family concerns. To this end, the research team worked closely with teachers so that operational issues did not hinder the user experience while using the computer-based games. The research team proactively responded to parental concerns and questions manifested to teachers and staff to reduce attrition during all phases. While no parents asked to leave the study, 2.51% of the students were not post tested as they had gone earlier into vacation.

Given that attrition, selection bias, maturation, and contamination were under control, and that past evidence supported the construct validity of the measurement instruments, it was viable to argue that the research had the potential to achieve an adequate level of internal validity. Internal validity would allow to make a causal inference about the impact of the intervention within the limitations of the study (Torgerson et al., 2015). It would be possible to say that the phonological awareness computer-based program would display a similar effect if applied to other private schools of Fumaça. This will be possible if the sample employed analogous educational practices, and their students come from families with similar socioeconomic status (SES) than other local schools.

Method

Participants

The city of Fumaça has 30,591 four- and five-year-old children in 678 schools (Instituto Nacional de Estudos e Pesquisas Educacionais Anísio Teixeira, 2016b). Within this population, the study targets the 448 private schools which have the autonomy to decide which learning materials they use. Based on existing data about 365 private schools provided by a partner company, I identified 139 schools who could afford to have the tablets, internet and support staff for a computer-based intervention.

After the Homewood Institutional Review Board approved this project, the implementation started with the recruitment phase. I sent invitation letters to 25 schools located in the metropolitan area of Fumaça which would probably have the proper technological resources and the autonomy to fit the intervention into their academic plan. The purposive sample goal was to recruit at least ten schools and 30 classrooms (Shadish et al., 2002). I made follow-up calls seeking to meet with each school principal to explain the research goals and procedures. In some of those schools, the meetings were only with the principals, while in others they invited the pedagogic coordinators to participate. During those meetings, the principals informed the number of students that they had in their four and five-year-old classrooms.

A total of 17 schools agreed to participate in the study. Classroom with 4-years old were selected. Together, the 17 schools had 1,089 students in this grade. After participating schools and classrooms were identified, the research team delivered study packets to each school that include an invitation letter and a consent form for each student/parent. The packets were delivered to the schools in the first days of August when the second semester of the Brazilian school year starts. Two weeks after the letters were delivered, the schools were asked to send a friendly reminder

telling the parents about the deadline for their decision. I received a total of 749 signed consent forms after four weeks of recruitment.

From the total of 749 students, 418 (55.8%) were students from the 35 control classrooms which were randomly allocated, and 331 children (44.2%) were from the 27 experimental classrooms. As shown in Figure 8, the mean age for the participants was 56 months (standard deviation [SD] = 3.8) during the pretests. The mean age of 56 months was expected, since the project started in August, with four-year-old classrooms.

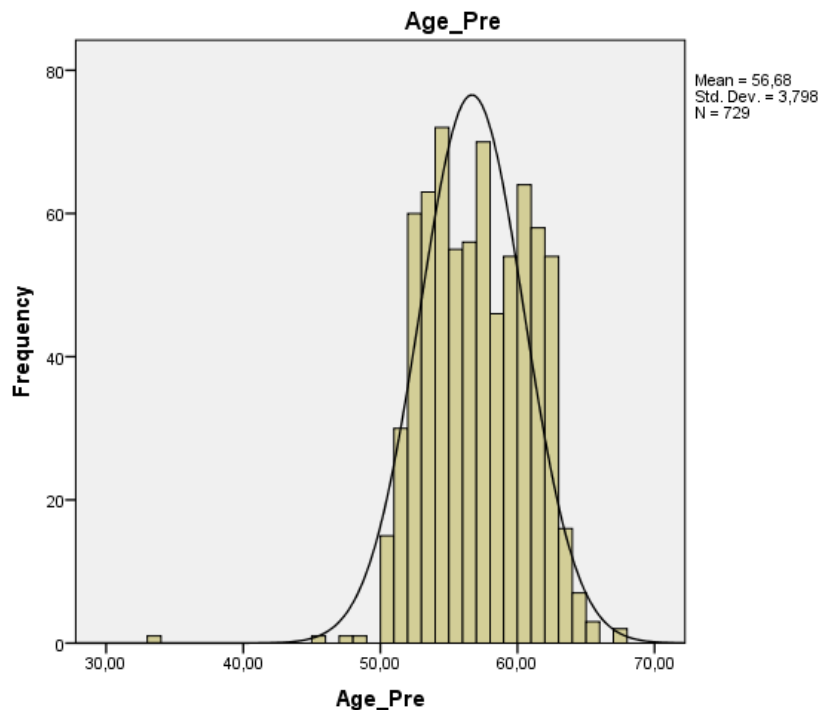


Figure 4. Student's Age Frequency Distribution

Regarding the parental educational attainment, 6.1% of the parents had up to secondary education. Parents that had finished their undergraduate courses accounted for 81.2% of the sample. Some families also had parents with master's (8.4%) and doctoral (4.2%) degrees. These findings indicate that the sample was comprised of families among the highest strata regarding educational attainment. While in Brazil only 15% of the citizens attended higher education

(OECD, 2015), in our sample we had 93.9% falling into this category. This rate was expected as all participants were enrolled in private schools which serve middle and high-income families. Independent samples *t*-tests did not show significant differences between the control and experimental groups for the parental educational attainment ($t(634) = -1.95, p = 0.05$). No association was found between the parental educational attainment and the group allocation ($\chi^2(3) = 4.69, p = 0.20$).

In Brazil, schools usually function in the morning and afternoon, each shift with a different set of students. In our sample, 68.1% of the students attended the school in the morning, while 31.9% attended in the afternoon. This distribution reflected an overall trend observed in the cities of Fumaça, where most families prefer that their children attend in the morning.

The study was open to all four-year-old students of the participating schools. After the intervention was conducted and the posttests were finished, it was established that 12 (1.6%) out of 749 students had some level of learning disability, according to the schools' documents and teachers reports. Although those 12 students participated in the all activities (pretest, intervention, and posttest) because I wanted to give the opportunity for all children which wanted to participate in doing so, they were excluded from the statistical procedures detailed below.

Study Measures

Phonological awareness test by oral production (PAT-OP). The PAT-OP assessment, which was conducted before and after the intervention, was designed to evaluate how children manipulate speech sounds (A. G. Capovilla et al., 2014). It includes ten subtests to the phonological awareness construct; each contains two training and four test items:

- In the syllabic and phonemic synthesis subtest, the researcher speaks separate segments (syllables or phonemes) and the student shall unite them;

- In the rhyme subtest, the evaluator speaks three words, and the student must say the two that finish with the same sound;
- In the alliteration subtest, the evaluator speaks three words and the student must say the two that start with the same sound;
- In the syllabic and phonemic segmentation subtest the evaluator speaks a word that shall be split by the student into the corresponding units;
- The syllabic and phonemic manipulation subtests evaluate student's skills to create new words by adding or removing syllables and phonemes;
- In the syllabic and phonemic transposition subtest, the student ability to create new words by inverting the syllables and phonemes is assessed.

Several studies evaluated the PAT-OP test, including Capovilla (2006), which applied the instrument to 379 students from first to fourth grades. Cronbach's alpha was 0.91, and Spearman-Brown's coefficient was 0.86. In the same study, the test-retest method was applied with 23 students and revealed a Spearman-Brown's coefficient of 0.87. In this study, the PAT-OP had a Cronbach's α of .86 in the pretest and .91 in the posttest, excellent levels of internal consistency.

Ferracini (2005) evaluated 122 preschool children and found that the scores were positively and significantly correlated with the student age with $F(2, 118) = 9.69, p < 0.001$. Capovilla et al. (2014) studied 702 children from three to 14 years using the PAT-OP test and the analysis confirmed previous studies. PAT-OP scores also correlated with other tests such as the word and pseudoword repetition test (A. G. Capovilla et al., 2014) with $r = 0.32, p < 0.001$, and the phonological discrimination test (A. G. Capovilla et al., 2014) with $r = 0.38, p < 0.001$.

Capovilla and Capovilla (2007) compared the PAT-OP scores of 363 children with their grades, finding a moderate correlation between measures. In the first-grade, the correlation

between PAT-OP and grades was very strong ($r = 0.83$; $p < 0.001$), in the second-grade the correlation was strong ($r = 0.68$; $p < 0.001$). The third and fourth grades only presented moderate correlations ($r = 0.51$ and $r = 0.56$, both with $p < 0.001$). Capovilla and Capovilla (2007) suggest that this indicates that phonological awareness is more important to student achievement in early grades. Capovilla et al. (2014) also mention that the PAT-OP test has been successfully used in studies involving children with Williams and Down syndromes. The phonological awareness test was standardized in a sample of 699 three to 14-years-old (A. G. Capovilla et al., 2014). The table 5 presents a sample of the test items.

Table 5. Training Items of the Phonological Awareness Test by Oral Production

Subtest	Item 1	Item 2
Syllabic synthesis	/pa/ - /pel/	/pro/ - /fe/ - /sso/ - /ra/
Phonemic synthesis	/f/ - /o/ - /i/	/l/ - /a/ - /ç/ - /o/
Rhyme	/bolo/, /mala/, /rolo/	/baleia/, /sereia/, /canoa/
Alliteration	/fada/, /face/, /vila/	/escola/, /menino/, /estrada/
Syllabic segmentation	/livro/	/bexiga/
Phonemic segmentation	/nó/	/dia/
Syllabic manipulation	add /rrão/ after /maca/	take /sa/ from /sapato/
Phonemic manipulation	add /r/ after /come/	take /p/ from /punha/
Syllabic transposition	/pata/	/dona/
Phonemic transposition	/és/	/sai/

Note. All elements are in Portuguese. Adapted from Capovilla, A. G., Dias, N. M., & Capovilla, F. C. (2014). *Avaliação neuropsicológica cognitiva: Linguagem oral: Vol. 2*. São Paulo: Memnon.

Word reading and writing test. These variables measured the final goal of the intervention, which was to increase student achievement in word-reading and writing. We conducted this test before and after the intervention. They were operationalized using the reading and writing test, which assesses preschool and kindergarten students' word reading and writing skills (Pazeto et al., 2014). The first part of this assessment consists of eight words and two pseudowords that shall be read by the student. In the second part, the researcher dictates eight words and two pseudowords for the student to write. Each word is more complicated than

previous ones. Words are classified by their regularity and frequency of usage. The test score is calculated by the percentage of the letters that were correctly answered by the student so that the performance ranges from zero to 100% for reading and writing (Pazeto et al., 2014). Table 6 presents the test items.

Table 6. Reading and Writing Test Items

Item	Reading	Writing
1	Oi	Ui
2	Dia	Lua
3	Bala	Bola
4	Macaco	Sapato
5	Talo	Nabo
6	Netuno	Cabide
7	Táxi	Casa
8	Enxame	Chuveiro
9	Tami	Pila
10	Dofule	Butove

Note. All items are in Portuguese. Items one to eight are words, nine and ten are pseudowords. Adapted from Pazeto, T. C. B., Seabra, A. G., & Dias, N. M. (2014). Executive functions, oral language and writing in preschool children: Development and correlations. *Paidéia*, 24, 213-222. doi:10.1590/1982-43272458201409

The reading and writing test is a new instrument that is currently under development by the same research group who created the PDT and PAT-OP tests (A. G. Capovilla et al., 2014). The instrument was used in two studies (Pazeto, 2012; Pazeto et al., 2014) and seems to be displaying adequate psychometric properties. In Pazeto et al. (2014), a sample of 94 kindergarten students went through several tests which revealed robust and significant correlations between the reading and writing test and the PAT-OP scores ($r = .76$ and $.80, p < .01$), knowledge of sounds ($r = .73$ and $.87, p < .01$), knowledge of letters ($r = .49$ and $.57, p < .01$), and between its own reading and writing measures ($r = .81, p < .01$). Per the authors, the preliminary data from their current study examining 300 students from public and private schools also indicates adequate psychometric properties. In this study, the reading assessment had a Cronbach's α of .94 in

pretests and .95 in posttests. The writing assessment had a Cronbach's α of .94 in pretests and .92 in posttests, excellent levels of internal consistency.

To assess if the coding of the tests was reliable between raters, I calculated the intraclass correlation coefficients (ICC) using a one-way random effects model in SPSS 25. For the reading pretest, the ICC was 0.95 ($p = 0.00$), with 20.7% of the subjects being rated by a second rater. The ICC for the writing pretest was 0.97 ($p = 0.00$) and for the PAT-OP was 0.90 ($p = 0.00$). The three ICCs were high, indicating that the PAT-OP, reading and writing pretests ratings were reliable across the raters (Graham, Milanowski, & Miller, 2012).

For the posttests, the reading assessment ICC was 0.97 ($p = 0.00$), calculated with 20.6% of the subjects being rated by a second rater. The ICC for the writing posttest was 0.94 ($p = 0.00$) and for the PAT-OP posttest was 0.85 ($p = 0.00$). The ICCs for the reading and writing posttests were high. The PAT-OP posttest was above the minimum desired level of 0.75, indicating that ratings were reliable (Graham et al., 2012).

Time using the application. The phonological awareness application automatically collected usage and performance data for all users. The software calculated usage time and the answers that the user gave to each activity, consolidating the data in ten dimensions of the phonological awareness which are also measured by the PAT-OP test (Capovilla et al., 2014).

The time using the application variable consists of the total number of minutes spent by the student using the phonological awareness program application. The app automatically generates the full amount of time spent by each user by summing the duration of each user session (Segers & Verhoeven, 2005). The software computes all sessions, recording the date, originating IP address, starting and ending time.

The reliability of this measure was established by a structured battery of tests which were

developed by the research team. Multiple app usage sessions, occurring at different times and days, were manually registered in a spreadsheet and after the end of the test, the total amount of time was compared to the one presented by the phonological awareness application.

Application scores. This variable includes 10 sub-variables which measured the student performance in the games related to each of ten dimensions of the phonological awareness construct. These dimensions are the same as those of the PAT-OP test (Capovilla et al., 2014) to facilitate the organization of the application games in ten worlds and to make correlational analysis between game usage and PAT-OP measures viable. The app automatically computed each sub-variable by calculating the percentage of the correct answers given by the user in all games that are part of each world, from zero to 100%.

The reliability of this measure was established by a structured battery of tests which was developed by the research team. Multiple app usage sessions, occurring in all the ten phases, were manually registered in a spreadsheet and after the end of the test, the average score was compared to the one presented by the application.

Teacher-perceived effectiveness. Teacher-perceived effectiveness was measured by teachers' responses on a survey presented in each of the 20 lesson plans. The questions were:

1. Do you think your students improved their skills in this session? (No / They improved / They improved a lot)
2. Do you think this session was productive? (No / Yes / a lot)
3. If you have any suggestions for this session, please comment (open question).

Interviews with teachers. Teachers were interviewed to identify their instructional strategies and perceptions about the intervention. Each interview was audio recorded and was expected to last 60 minutes. The first section of the interview protocol presented in the Appendix

included questions to assess the teacher's educational attainment, experience in teaching, professional development opportunities, and workload.

The second set of questions included items which were extracted from the Brazilian national literacy assessment teacher's questionnaire. I selected the items which are related to language, reading and writing development. Each item asked about the frequency that the teacher developed the target activity. For example, one item asked the frequency that "reading of various textual genres for children" activities were developed. Another item assessed the frequency of "exposure of written and non-verbal materials in the classroom". All items were answered by choosing among six options: never, once per year, 3 to 4 times per year, every month, every week, or every day.

The third set of questions were also extracted from the Brazilian national literacy assessment teacher's questionnaire and sought to examine the relationship between the teacher and the principal. Each item presented a managerial practice and asked the teacher the frequency of occurrence. Items included actions such as "the principal promotes discussions with the staff to improve the teaching and learning of the students" and "the principal encourages innovative activities." All items were answered by choosing among four options: never, a few times, frequently, or always.

The fourth set of questions were open prompts to assess the teachers' literacy goals for the four-year-old classroom and the activities that she considered most important to meet these goals. The fifth set of questions were related to assess the teacher's perception about the intervention, the delivery and its impact. It included prompts such as "what are your impressions about the method of delivering instructional content using tablets?" and "what are your perceptions about the scaffolds provided by the games so that students could develop their PA skills?". Also, the process

of implementation was assessed with prompts such as “were the professional development activities helpful for your teaching or implementation of the intervention? Could it be improved?” and “how do you evaluate the intervention? The communication, logistics, and support?”.

Procedure

After the pretests were finished, the cluster trial procedure was conducted to assign its units, the classrooms, to the control and experimental groups (Torgerson et al., 2015). The goal was to allocate half of the classrooms to each group. If a school did not have resources to run multiple experimental classes at the same time, it could contribute with more control classes, which also increases to statistical power (Shadish et al., 2002). The final sample of the study included 62 classrooms. The goal was to have 31 classrooms in each group, but as I had a limited number of research assistants to run the intervention and the classrooms had their schedule already established, four classrooms had to be converted from experimental to control due to agenda incompatibility. The final experimental sample was comprised of 27 classrooms.

Intervention goals. The goal of the intervention was to develop the students’ phonological awareness skills to enhance their reading and writing development with the following learning objectives.

Syllable awareness objectives:

1. Upon hearing a spoken word that was written on the screen, each student would need to separate its syllables correctly.
2. Upon hearing two separate syllables that are written on the screen (e.g. /ga/ and /to/), each student would need to synthesize the word by connecting the syllables (e.g. gato) and clicking on the correct image among four options (e.g. the cat).
3. Upon hearing a word that was written on the screen (e.g. /jaca/), each student

would need to add the correct syllable that transforms the word into another by clicking on one of the four options (e.g. /jaca/ + /re/ = /jacare/).

4. Upon hearing a word that was written on the screen (e.g. /jacare/), each student would need to remove the correct syllable that transforms the word into another by clicking in the correct syllable (e.g. /re/).
5. Upon hearing a word that was written on the screen (e.g. /bolo/), each student would need to invert its syllables, transforming the word into another by moving one of the syllables (e.g. /lobo/).

Rhyming and alliteration awareness

6. Upon listening to a word that was also written on the screen (e.g. /avião/), each student would need to find the word that rhymes by selecting among four others that are spoken and displayed in image form or written (e.g. /balão/).
7. Upon hearing a word that was written on the screen (e.g. /casa/), each student would need to find the word that starts with the same syllable from four options that are spoken and displayed in image form or written (e.g. /cama/).

Phoneme awareness

8. Upon hearing a word that was written on the screen (e.g. /faca/), each student would need to find the word that starts with the same phoneme from four options (e.g. /festa/).
9. Upon hearing a word that was written on the screen (e.g. /barco/), each student would need to find the word that ends with the same phoneme by selecting among four that are presented (e.g. /pato/).
10. Upon hearing up to four phonemes that were written on the screen (e.g. /p/ and /é/),

each student would need to click on the word that is formed by the syntheses of such phonemes by selecting among four words that are read (e.g. /pé/).

11. Upon hearing a word that was written on the screen (e.g. /pato/), each student would need to separate its phonemes correctly (e.g. /p/ /a/ /t/ /o/).
12. Upon hearing a word that was written on the screen (e.g. /pato/), each student would need to add a phoneme to generate a new word from up to four phonemes presented (e.g. /pato/ + /s/ = /patos/).
13. Upon hearing a word that was written on the screen (e.g. /alo/), each student would need to transpose its phonemes to generate a new word (e.g. /ola/).
14. Upon hearing the name of a letter, each student would need to click on the corresponding written letter among four options.

Reading and writing

15. Upon seeing a word (e.g. carro), each student would need to read it correctly by clicking on the image that displays the meaning of the word from five options.
16. Upon hearing a word (e.g. bicicleta), each student would need to write it correctly by filling the missing letters with the correct ones from five alternatives.

Professional development goals

17. Each teacher would need to be aware that phonological awareness is a key component of reading development and how it assists the student's progress through the developmental stages (Ferreiro & Teberosky, 1982).
18. Each teacher would need to understand how digital games were used to assist students' development of phonological awareness skills.
19. Each teacher would need to master how they can assist the students to use the

games during the intervention instructional sessions.

Instructional Strategies. The proposed program adopted the assumption that reading development is a complex process in which learners build, refine, and reconstruct their skills and knowledge about the alphabetic notational system through multiple developmental stages (Ferreiro & Teberosky, 1982).

The syllable awareness objectives were introduced so that the learner could start to understand how the words are created, advancing from presyllabic to the syllabic developmental stage (Ferreiro & Teberosky, 1982). Learners should master how to separate the syllables of a given word and how to connect individual syllables to synthesize new words (Dias & Bighetti, 2009). By adding, removing and inverting syllables, students started to operate with many elements of writing development and consolidated their understanding in the syllabic stage. In this period, if the students were asked to write spoken words, they would usually write the noun of each syllable (Ferreiro & Teberosky, 1982). Rhyming and alliteration contributed to consolidate syllable awareness and to move the student towards the syllabic-alphabetic developmental stage (Barrera & Justino, 2012).

In the syllabic-alphabetic stage, the learners start to understand that syllables are formed by individual sounds (phonemes) and that such phonemes can be manipulated (A. G. Capovilla et al., 2007) to create new syllables. In this phase students still write the nouns for the syllables but some of them are accompanied by the correct consonant (Ferreiro & Teberosky, 1982). Phoneme awareness learning objectives contribute to such process, consolidating the development of the student that progressively moves to the alphabetic stage (Paula et al., 2005; M. J. d. Santos & Maluf, 2010).

The reading and writing learning objectives target the consolidation of the alphabetic

principle among the students by exercising grapheme-phoneme correspondence (Morais, 2012b). Such practice is essential to consolidate ability to write any word spoken in Portuguese and to read any word written in a given text. It is expected that by the end of the instruction students will master reading and writing regular words. Words which employ irregular orthographic structures will not be included in the instruction since they can be learned at later ages according to the Brazilian common core (Ministério da Educação, 2017).

The professional development objectives were established so that teacher can understand the importance of the intervention and feel that they are able to develop it with their students. Objective 17th will be developed in a professional development session in which the teachers will be invited to recall their previous knowledge about phonological awareness skills and share with their peers how they usually develop such activities with their students. Then the most relevant studies will be presented in a logical manner to solidify the importance of phonological awareness instruction. Then the most relevant studies about how digital games were used to develop phonological awareness skills will be presented so that the teachers can reach the 18th objective. After explaining the goals, design and results of such works, the teachers will be invited to understand how the proposed intervention will be developed and to experience one of the games. This experience will be the kick-off of the instructional process to reach the 19th objective, which is to empower the teachers so that they can develop instructional sessions using the games with their students. The instructional process to reach this goal will start in the professional development session and will continue during the intervention, with individual mentoring that will be provided by the research team. The goal is that the teachers will be able to develop the sessions without the assistance of the researchers after session 18th.

Component Skills.

Table 7 synthesizes the prerequisites and component skills for each objective.

Table 7. Program Component Skills

Objective	Prerequisites	Component Skills
1. Segment syllables	Is familiar with the words that will be used and understands that words can be broken into smaller parts.	Splits the syllables of two, three and four-syllable words orally.
2. Synthesize syllables	Understands that words can be formed by connecting syllables.	Orally connects the syllables of two, three and four-syllable words.
3. Add syllable to a word	Synthesizes syllables.	Connects the syllable to the end or the beginning of two, three and four-syllable words.
4. Remove a syllable	Separates syllables.	Removes a syllable from two, three and four-syllable words.
5. Invert the syllables	Separates and synthesizes syllables.	Inverts the syllables of two and three-syllable words.
6. Find words that rhyme	Has a good vocabulary to develop rhymes	Identifies when the ending syllable of two words is the same.
7. Find the alliterate word	Has a good vocabulary to develop alliteration	Identifies when the starting syllable of two words is the same.
8. Identify the first phoneme	Understands that syllables are formed from phonemes.	Identifies when the starting phoneme of two words is the same.
9. Identify the last phoneme	Understands that syllables are formed from phonemes.	Identifies when the last phoneme of two words is the same.
10. Synthesize phonemes	Understands that phonemes can be connected to create words.	Connects the phonemes of two, three and four phoneme words orally.
11. Segment	Understands that words	Splits the phonemes of two, three and four

phonemes	can be broken into their constituent phonemes.	phoneme words orally.
12. Add a phoneme	Synthesize phonemes.	Adds one phoneme to an existing word.
13. Transpose phonemes	Segments and synthesizes phonemes.	Inverts the phonemes of three-phoneme words.
14. Link letters to sounds	Knows the sounds of the letters and how they are written.	Identifies the sound of a letter and recalls how it is written.
15. Reading	Links letters to sounds.	Can produce the phonemes of the written word and comprehend its meaning.
16. Writing	Links letters to sounds.	Upon hearing a word can identify its phonemes and write the corresponding letters.
17. Phonological awareness understanding	Teachers must know the psychogenesis theory.	Teachers can explain the importance of phonological awareness and how each of its component skills affect reading development.
18. Digital games as an instructional tool	Teachers must use apps like WhatsApp and internet browsers.	Teachers can explain how games can help their students to evolve and their own instructional work.
19. Assist the students to use the games	Teachers must see the relevance of PA and instructional games.	Teachers can successfully develop instructional sessions with their students without external assistance.

Instructional sequence. The program started with the professional development session for the teachers, which lasted 1 hour. After this session the instructional sessions with the students started. The student's instructional sequence was created to assist the learners in progressing through the developmental stages (Ferreiro & Teberosky, 1982). Within this constructivist perspective, the program also adopts the findings from multiple studies which identified that the direct instruction of phonological awareness skills is a key component to reading development (Bus & van IJzendoorn, 1999; Catts et al., 2001; Chambers et al., 2016; Ehri et al., 2001; Morais, 2012b). Figure f presents a synthesis of the instructional sequence. Each instructional session

lasted 45 minutes and that at least two sessions would be developed per week.

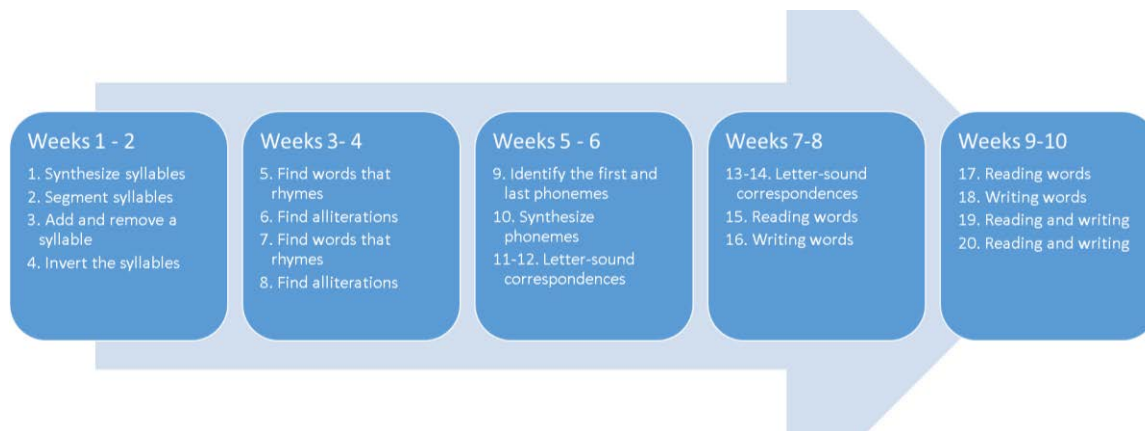


Figure 5. Instructional sequence.

Each session followed Gagné’s instructional events (1965). First, the attention of the student was gained when the teacher explained the target skill on the whiteboard. Then the teacher did three exercises with the students using the whiteboard. Then the teacher demonstrated the game to the students, playing the first three levels orally with the whole group. After the demonstration, students were assigned to their peers and received the tablet to play the game. As students finished the game they received a virtual medal (gold, silver, bronze) and were congratulated by the teacher.

Intervention Implementation. Figure 6 presents the timeline for the multiple phases of the program. The timeline required that the researchers developed the program in an iterative process to meet the delivery goals. I used the SCRUM agile methodology to implement the games (Schwaber, 1997). The SCRUM software development process offers flexibility that is required in iterative processes when the design team needs to consider feedback from multiple parties along the several stages of the development process. In this project, I received feedback about the activities, content and the games from researchers and teachers with experience in phonological awareness.

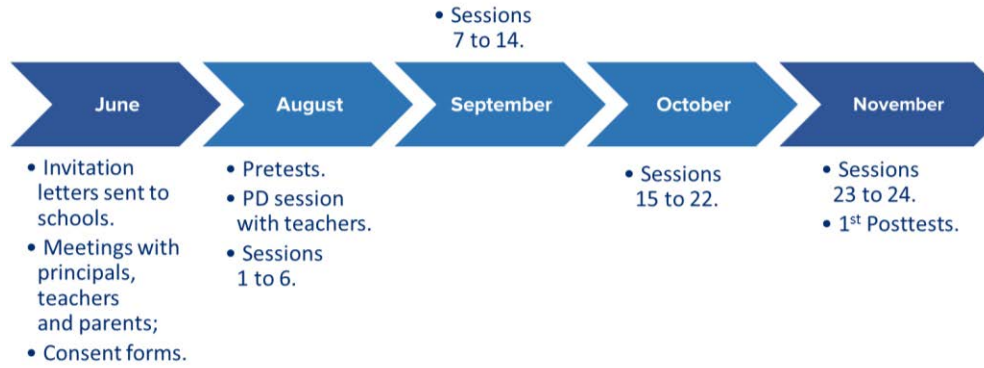


Figure 6. Implementation plan.

Content and game designs were improved based on the experts' feedback before their implementation. Experts included doctoral-level researchers from the fields of education, cognitive psychology, and speech therapy. Once the games were fully functional and tested in the lab, they were deployed with a small group of children in a controlled environment. This alpha test was dedicated to assessing if the students engaged with the games, the user experience, the difficulties that they displayed while using the application, and their learning progress. I decided which issues were relevant, improved them and the games were ready for deployment in the participant schools. Figure 7 presents a schematic view of the development process.

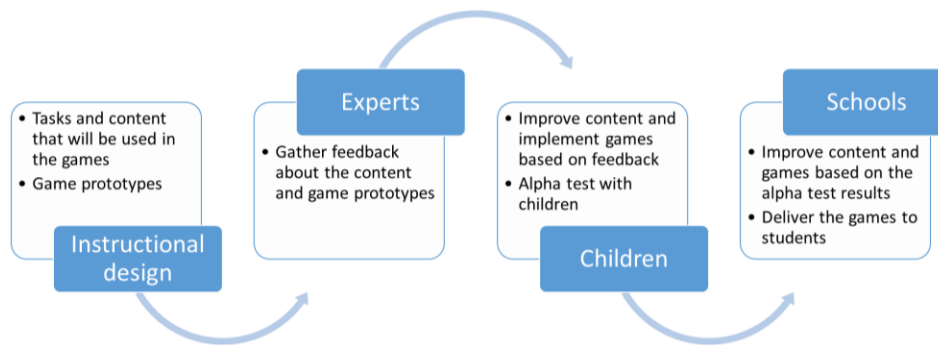


Figure 7. Game development process.

The development process needed to be well structured and coordinated to meet the program goals. To this end, I designed several milestones that guided the development work so that the games were fully tested and improved before their deployment in the schools. According

to the schedule presented in figure 8, the original goal was that each session became ready at least one month before the deployment. I established such deadline as a contingency measure for unexpected problems which are common to occur in software development projects.



Figure 8. Project schedule.

To meet this schedule, I was assisted by:

- One project manager;
- One senior software developer;
- One junior software developer;
- One graphic designer;
- One teacher coach.

Data collection.

Pretests. As the consent forms were being received, I coordinated the research assistants to conduct the pretests. According to the protocol, we obtained oral assent from each student before starting the pretest. Students were assessed individually, in a meeting space provided by the school. Research assistants, blinded to the allocation of classrooms to control or experimental groups, conducted the pre-tests to reduce bias (Torgerson et al., 2015). All assistants were trained by Dr. Dias, one of the authors of the assessments which were used.

Each assessment started with the Phonological Awareness by Oral Production Test PAT-OP (A. G. Capovilla et al., 2014), then was followed by the reading and the writing tests (Pazeto, Seabra, & Dias, 2014). All tests were audio-recorded so that inter-rater reliability could be calculated after the pretests were completed. In average, pretests lasted 30 minutes. The pretests were conducted from August to mid-September, as some families returned the consent forms near the deadline.

Professional development. I promoted a professional development session with the teachers of the experimental classes to assure that they would meet the learning goals. The professional development session was developed by following a strict instructional protocol so that all experimental group teachers received the same content and experienced similar practices prior to starting the instructional sessions with their students. The teachers, together with the researchers, defined the specific days and times for the intervention to be delivered to each classroom, with the target of promoting two sessions of 45 minutes of computer-based instruction for each class per week, for 10 weeks.

Instructional sessions. The initial goal of the intervention was to conduct 24 sessions with students, however, due to the longer than expected recruitment and pre-tests period, I, together with my advisors, adjusted the intervention dosage to 20 instructional sessions. I decided not to use word awareness games with the students, focusing on syllable awareness, rhyming, alliteration, phoneme awareness, and the reading and writing games. This decision was made as I knew that many schools in Brazil develop word awareness activities frequently (M. Soares, 2004).

With the updated scope, I conducted the intervention with four research assistants from September to November in 2017. Due to holidays and school events which took place, some classrooms had to extend the instructional sessions into the first two weeks of December. Even

though the goal was that each classroom holds two instructional sessions per week, some had to develop an extra session in some weeks to finish the program before the students left the school for vacation, which usually happened on December 15th of 2017.

Each session lasted 45 minutes and was divided in three components. The first component, lasting from 10 to 15 minutes, was the teacher explaining the target skill of that session (ex: cutting words into small parts - syllable segmentation) to the whole-group and developing three exercises using the whiteboard or the movable alphabet. The second part, lasting around 5 minutes, started when the teacher explained how to develop the target operation in the game, playing the first three levels together with the whole group.

The third component started when the research assistant randomly assigned the students to their pairs. This strategy was employed because previous studies found that small-group instruction generated higher phonological awareness gains than large-group and individual instruction (Cheung & Slavin, 2013; Ehri et al., 2001). The goal was that each student would play with all peers along the 20 sessions of the intervention. Random allocation was used to minimize the eventual effect that specific students might have in inhibiting or supporting another peer.

While the students were playing, the teacher and the research assistant would rotate, from pair to pair, observing how the children were using the game and scaffolding when needed. When students finished the game before the time was up, the teacher suggested them to play again to make more points or to win a virtual gold medal, when they had gotten silver or bronze. Teachers filled the teacher-perceived effectiveness survey at the end of each instructional session.

To examine the fidelity of the intervention, each instructional session was observed by a research assistant. While the teacher was giving the lecture, explaining the target skills and activities to the students, the research assistants filled a fidelity checklist to assess the adherence

of the lecture to the proposed lesson plan.

During the instruction period, the experimental classes played a sequence of computer games designed to foster multiple phonological awareness skills under the supervision of the teacher and a research assistant. After 20 sessions, the students received the established dosage for each ingredient of the treatment (e.g. rhyming, syllable segmentation, phoneme awareness). During the 10 weeks of the treatment, control classes kept doing their regular activities.

Posttests. Posttests using the same instruments (PAT-OP and the reading and writing assessment) started in the last week of November 2017 for the control classrooms. As the experimental classrooms started and finished the instructional sessions on different days, when a classroom finished the 20th session, we conducted the posttests in the following days. Two additional research assistants were hired at this stage due to the urgent timeline (the winter vacation began on December 15 for most of the schools), and a total of six research assistants conducted the posttests. Students were assessed individually, with the same instruments used in the pretests. Follow-up evaluations, which are outside of the scope for this dissertation, may take place six and twelve months after the end of the post-tests, for all students. Post-tests and follow-ups were also conducted by research assistants who were blinded, not knowing which participants were from the control or intervention groups, to reduce bias (Torgerson et al., 2015).

Teacher interviews. After the end of the posttests in December of 2017, 21 teachers were interviewed according to the protocol in the Appendix. Five teachers could not be interviewed because of conflicting agenda or because they had already gone into vacation.

Chapter 5. Findings and Discussion

Findings

Pretest Findings

Pretests revealed that students in the control group had a very similar mean score in the PAT-OP test 9.3 (SD = 5.2) than the experimental group, which had a mean of 9.4 (SD = 5.1). The reading mean score for the control group was 10.66 (SD = 20.84) while the experimental group had 9.41 (SD = 19.59). Finally, the writing mean score for the control group was 15.06 (SD = 20.36) while the experimental group had 14.95 (SD = 19.76). Independent samples t-tests did not show significant differences between the control and experimental groups for the PAT-OP, reading and writing scores. When controlling for the student shift, the results indicated that students in the morning had better scores in the three tests, but a significant difference was only found in the writing score ($p = 0.044$). The causes of the reduced performance in the afternoon are not clear, but reduced scores may also manifest in posttests.

A correlational analysis with the pretest data indicated that the phonological awareness scores were correlated to the reading test ($r = .40, p < .00$) and with the writing test ($r = .58, p < .00$). Although significant, these correlations were less intense than what was observed by Pazeto, Seabra, and Dias (2014). Their data indicated that phonological awareness was much strongly correlated with reading ($r = .76, p < 0.01$) and writing ($r = .80, p < 0.01$). Regarding the reading and writing tests, they were significantly correlated in our sample ($r = .66, p < 0.00$), but still on a smaller scale than what was found by Pazeto, Seabra and Dias (2014) in their research ($r = .81, p < 0.01$).

Part of those differences may be explained by the fact that Pazeto, Seabra and Dias sample was comprised of students which were, on average, six months older than our sample. Another

difference was that they developed their study in the southeast of Brazil, while my work was done in the Northeast. The way kindergarten schools operate in those regions may be very different.

Intervention Effects (Q1)

The posttests revealed that students in the control group had a mean score in the PAT-OP test of 11.5 (6.2), lower than the experimental group, which had a mean of 12.4 (6.6). The reading mean score for the control group was 19.84 (27.88) while the experimental group had 24.86 (30.94). The writing mean score for the control group was 23.57 (26.47) while the experimental group had 27.55 (26.63). Independent samples t-tests did not show significant differences between the control and experimental groups for the PAT-OP assessment ($p = 0.08$). The t-tests did show a significant difference between the means of the control and experimental students in the reading ($p = 0.02$) and writing tests ($p = 0.05$).

Table 8. Descriptive Statistics for Pre and Posttests

Assessment	Mean	n	Std
Control classrooms			
PAT-OP Pretest	9.3	399	5.2
PAT-OP Posttest	11.5	392	6.2
Reading Pretest	10.66	417	20.84
Reading Posttest	19.84	417	27.88
Writing Pretest	15.06	418	20.36
Writing Posttest	23.57	418	26.47
Experimental classrooms			
PAT-OP Pretest	9.4	318	5.1
PAT-OP Posttest	12.4	306	6.6
Reading Pretest	9.41	331	19.59
Reading Posttest	24.86	331	30.94
Writing Pretest	14.95	331	19.76
Writing Posttest	27.55	331	26.63

A correlational analysis with the posttest data indicated that the correlations between the tests for the experimental group were stronger than the control group, with the higher difference between the reading and writing assessments, as can be seen in Table 9.

Table 9. Correlations Between Posttests for Both Groups

Measure	1	2	3
Control classrooms			
1. PAT-OP	--	.55	.56
2. Reading	.55	--	.72
3. Writing	.56	.72	--
Experimental classrooms			
1. PAT-OP	--	.53	.58
2. Reading	.53	--	.81
3. Writing	.58	.81	--

Note. All correlations were significant at the $p < 0.01$ level.

To compare the growth patterns between the experimental and control groups, I calculated the differences between each students' pretest and posttest mean scores. On average, control classes gained 9.18 points in reading between pretest and posttest. Experimental classes gained 15.45 between pretest and posttest. I subtracted the experimental gain from the control gain ($15.45 - 9.18 = 6.27$) to find the difference in gain. By dividing the difference in gain by the control gain ($6.27/9.18$), I calculated the relative gain. Experimental classes gained 68.3% more in the reading score when compared to the gains of control classrooms. The same procedure was done with the writing score, which revealed that experimental classrooms gained 48% more in the writing assessments when comparing to the control classes gains.

Multilevel Analysis to Determine Intervention Significance (Q1)

Since the randomization procedure that I employed consisted of selecting classrooms to receive the intervention, it is expected that students nested in the classrooms may display similar properties, as they were exposed to the same instruction and interacted during the school year. To adequately account for the hierarchical nature of the data, it is advisable to employ multilevel models (Wears, 2002).

The focus of the multilevel analysis was to determine the effectiveness of the intervention on the student's reading skills while adjusting for the nested data structure. The multilevel

parameters are presented in tables 10 to 12. The analysis revealed a significant relationship between the experimental treatment and the reading posttest when controlling for students' age, parent educational attainment, pretest phonological awareness scores, and pretest reading scores.

Table 10. Multivariate Final Model Information Criteria (Reading)

Information Criteria	
-2 Log Likelihood	4998.85
Akaike's Information Criterion (AIC)	5014.85
Hurvich and Tsai's Criterion (AICC)	5015.11
Bozdogan's Criterion (CAIC)	5057.47
Schwarz's Bayesian Criterion (BIC)	5049.47

Note. The information criteria are displayed in smaller-is-better form.
Dependent Variable: Reading Posttest

Table 11. Multivariate Estimates of Fixed Effects (Reading)

Parameter	Estimate	Std. Error	df	t	Sig.
Intercept	-28.20	13.41	556.63	-2.10	0.04
Parent Edu. Attainment	2.68	1.63	557.16	1.64	0.10
Experimental group	4.11	1.84	53.27	2.23	0.03
Age in Pretest	0.36	0.24	551.71	1.53	0.13
Reading Pretest score	0.82	0.05	536.88	16.90	0.00
PAT-OP Pretest score	1.44	0.20	443.64	7.31	0.00

Note. Dependent Variable: Reading Posttest.

Table 12. Multilevel Estimates of Covariance Parameters (Reading)

Parameter	Estimate	Std. Error	Wald Z	Sig.
Residual	438.21	27.61	15.86	0.00
Intercept	2.68	9.27	0.28	0.77

Note. Dependent Variable: Reading Posttest. Intercept subject = Classroom.

A second multilevel analysis revealed a significant relationship between the experimental treatment and the writing posttest when controlling for students' age, pretest reading and writing scores. The multilevel parameters for the writing posttest scores are presented in tables 13 to 15.

Table 13. Multivariate Final Model Information Criteria (Writing)

Information Criteria	
-2 Log Likelihood	5024.20
Akaike's Information Criterion (AIC)	5038.20
Hurvich and Tsai's Criterion (AICC)	5038.40
Bozdogan's Criterion (CAIC)	5075.71
Schwarz's Bayesian Criterion (BIC)	5068.71

Note. The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Writing Posttest.

Table 14. Multivariate Estimates of Fixed Effects (Writing)

Parameter	Estimate	Std. Error	df	t	Sig.
Intercept	-23.62	11.76	570.71	-2.00	0.04
Experimental	3.86	1.66	52.17	2.31	0.02
Age in Pretest	0.60	0.20	566.69	2.87	0.00
Writing Pretest score	0.60	0.05	457.40	11.54	0.00
Reading Pretest score	0.39	0.05	533.52	7.48	0.00

Note. Dependent Variable: Writing Posttest.

Table 15. Multilevel Estimates of Covariance Parameters (Writing)

Parameter	Estimate	Std. Error	Wald Z	Sig.
Residual	349.94	21.73	16.10	0.00
Intercept	4.40	7.75	0.56	0.57

Note. Dependent Variable: Writing Posttest. Intercept subject = Classroom.

A third multilevel analysis did not reveal a significant relationship between the experimental treatment and posttest phonological awareness scores, even when controlling for students' age, pretest phonological awareness scores, and pretest reading scores. The multilevel parameters for the phonological awareness posttest are presented in tables 16 to 18.

Table 16. Multivariate Final Model Information Criteria (Phonological Awareness)

Information Criteria	
-2 Log Likelihood	3420.77
Akaike's Information Criterion (AIC)	3434.77
Hurvich and Tsai's Criterion (AICC)	3434.96
Bozdogan's Criterion (CAIC)	3472.48

Schwarz's Bayesian Criterion (BIC)	3465.48
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Note. The information criteria are displayed in smaller-is-better form.

a. Dependent Variable: Phonological Awareness Posttest.

Table 17. Multivariate Estimates of Fixed Effects (Phonological Awareness)

Parameter	Estimate	Std. Error	df	t	Sig.
Intercept	1.63	2.58	576.47	0.63	0.52
Experimental	0.48	0.60	62.99	0.79	0.42
Age in Pretest	0.04	0.04	557.27	0.94	0.34
Reading Pretest score	0.05	0.00	580.77	5.65	0.00
PAT-OP Pretest score	0.75	0.04	593.10	18.66	0.00

Note. Dependent Variable: Phonological Awareness Posttest.

Table 18. Multilevel Estimates of Covariance Parameters (Phonological Awareness)

Parameter	Estimate	Std. Error	Wald Z	Sig.
Residual	16.52	1.00	16.38	0.00
Intercept	3.72	0.98	3.77	0.00

Note. Dependent Variable: Phonological Awareness. Intercept subject = Classroom.

Predictive Power of Learning Analytics (Q2, Q3)

Multiple regression techniques were employed to establish the degree that the time spent using the games affected the student gains in the phonological awareness, word reading, and writing assessments. The models explained only 31.9% of the variance in gains of reading and 25.7% of the variance in gains of writing. I further explored whether the number of sessions that the student attended was correlated with their gains in the reading, and writing assessments and found weak but significant correlations ($r = .17$ for both reading and writing, $p < .01$). Thus, it seems that the dosage of the intervention was not the strong driver of change in student skills.

A regression analysis was also conducted to evaluate if performance data collected by the digital games could be used to predict student performance in the reading and writing assessments. The first step employed was to calculate the net number of hits each subject had in

each game. The net hits were calculated by subtracting the total wrong answers from the total hits that the children had in each game. This procedure was employed because students used each game multiple times to improve their performance. We expected that the net correct answers would be a meaningful measure of student achievement.

After calculating the net hits for each of the 20 games we employed SPSS 25's stepwise regression analysis to check if a viable predictive model could be generated. The analysis revealed a viable model, presented in table 19, which employed the student's net hits in the last two games of the intervention to predict their reading score. This model explained 99% of the variance in reading scores.

Table 19. Regression Coefficients for Learning Analytics

Model	Unstandardized Coefficients		Standardized Coefficients		t	Sig.
	B	Std. Error	Beta			
1	(Constant)	-2.12	3.14		-.67	.52
	Game_19	4.26	.36	.98	11.83	.00
2	(Constant)	2.81	1.94		1.44	.22
	Game_19	3.77	.21	.87	17.88	.00
	Game_20	.41	.10	.20	4.13	.01

Note. Dependent Variable: Reading_Score

To assess if any of the games could be used to predict the student's writing performance, a similar stepwise regression analysis was developed. The analysis revealed a viable model, displayed in table 20, which employed the student's net hits in the 16th game of the intervention to predict their writing score. The model adjusted R Square indicates that it explains 90% of the writing assessment variance. The 16th game shown in figure 9 starts by prompting students to complete the first letter of a word. Then it progresses to complete the first and the last letters. In the last level it prompts students to write the first and a medial letter. This game, then, measures student initial, medial and final phoneme identification skills. It also requires an adequate level of

letter-sound knowledge to select the correct letters that need to fill the spaces.



Figure 9. Image of the Escaladão das Palavras Game

The two regression models suggest that the net hits, measured by their specific games, can be used as adequate predictors to reading and writing achievement. By employing such games as an assessment tool, schools can gather a reliable estimate about their students' skills, allowing teachers and administrators to keep track of their children's progress. One important note is that the game performance data was collected when two students were playing together, collaboratively. If the games are played individually, the predictive power of such games may be increased, as they will reflect the individual game and will not be affected by the pair effect.

Table 20. Writing Regression Coefficients

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
1 (Constant)	36.94	4.37		8.44	.00
Game_16	1.84	.24	.95	7.45	.00

Note. Dependent Variable: Writing_Score

Existing Instructional Strategies and Intervention Effectiveness (Q4)

Seeking to understand how contextual factors influenced the effectiveness of the intervention, I calculated the effect size (Morris, 2008) of each experimental classroom. The effect for each classroom was calculated by contrasting the classroom mean the difference between the pretest and posttests with the mean difference of the whole sample of the control classrooms. The lowest effect size was $d = -0.42$, the mean was $d = 0.32$ while the highest was $d = 1.08$. The histogram below presents the distribution of the effect sizes.

To assess the influence of contextual factors, a regression model was built. Data from the teachers' interviews were coded into quantitative variables. The frequency that the teacher reported each activity was used to transform a qualitative answer into a score. For example, an activity that the teacher said that she implemented daily received a score of 200 as this is the total number of school days per academic year.

I used the SPSS 25 Automatic Linear Modeling feature with the scores of the 34 items from the teachers' interviews trying to predict the reading effect size of each classroom. The software built a regression model which explains 79.8% of the variance. The model suggested that the intervention was more effective in the classrooms that the teachers most frequently updated the text displays on the walls. This may be caused because such students might become more familiar with the printed text. High levels of letter-name knowledge may be a prerequisite knowledge for some of the activities developed by the intervention.

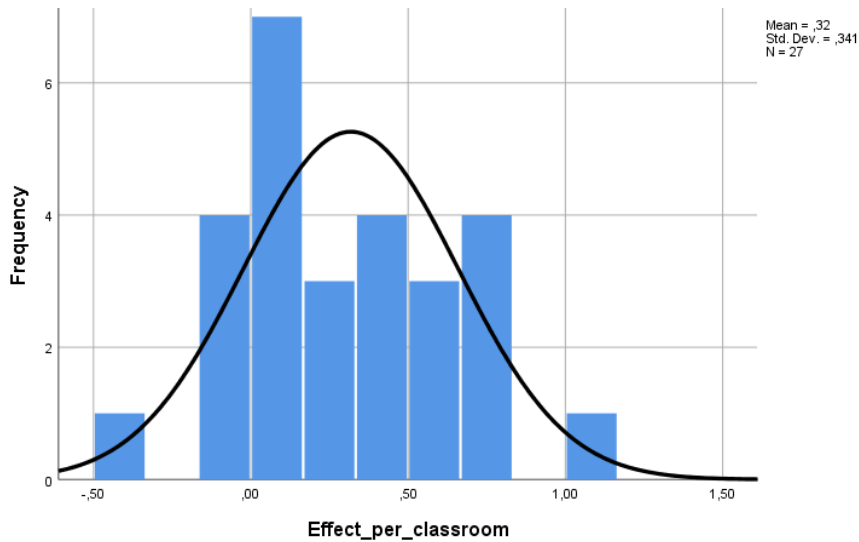


Figure 10. Distribution of classroom effect sizes

The second most relevant predictor was the frequency that the principal talked to the teacher about how to improve learning. The less the principal discussed with the teachers about how to improve learning, the more effective was the intervention. This finding might indicate that more engaged principals might infuse more effective instructional strategies, thus reducing the intervention effectiveness.

Two other factors were related to higher intervention effects but were not statistically significant. There were two additional factors, which were kept in the model displayed in table 21 to explain the variance, but were not significantly related to the intervention effects: teachers' experience in the current grade-level, and a degree of teacher-reported trust in the principal.

Table 21. Regression Coefficients Predicting Reading Effect Sizes

Model Term	Coefficient	Std.Error	t	Sig.
Intercept	-0.00	0.07	-0.06	.94
Text displays	0.00	0.00	5.44	.00
Principal learning	-0.72	0.15	-4.55	.00
Experience in grade	0.02	0.01	1.82	.10
I trust the principal	-0.17	0.14	-1.24	.25

The influence of contextual factors in the effectiveness of the intervention was examined

only for the reading effect size. This decision was made because the intervention did not develop writing activities with pencil and paper. As the writing games were played in the tablet, student's handwriting skills were not stimulated. As the writing scores were assessed using a pencil and paper assessment, it was expected that the writing gains would be lower than the reading gains, thus more difficult to detect and relate to contextual factors.

Teachers Perceptions about Engagement and the Intervention (Q5, Q6, Q7)

During the intervention, after each instructional session finished, teachers answered three questions in the back of the lesson plan asking about student progress and their perceived benefits for that lesson. At the end of the intervention, we received 466 lesson plans filled by the teachers, representing 86.29% of the 540 lessons which were developed with the experimental classes. The first question assessed teacher's perceptions about the evolution of the students towards the learning objective of that specific session. The teachers found that in 59.9% of the sessions the students evolved "a lot" while in 35% of the sessions they evolved a little. Only in 5.2% of the sessions, the teachers did not notice evolution towards the learning objectives established in the lesson plans.

The second question, which was presented in the lesson plan, was if that specific instructional session was productive. Teachers informed that 78.4% of the sessions were very productive while 19.8% of the sessions were a little productive. Only 1.7% of the sessions were perceived as unproductive by the teachers.

Beyond their answers in the lesson plans, I also gathered perceptual data about the method, content, and delivery of the intervention during the teacher interviews. All teachers expressed that the project was relevant to their professional practice. In all interviews, teachers expressed appreciation for the professional development that was provided, with one accelerated meeting

with Americo Amorim followed by the delivery of the lesson plans and mentoring by the research assistants during the instructional sessions.

Many teachers expressed that they were anxious before the intervention began because they were dealing with two new factors: phonological awareness activities and digital games. They reported that after the first two instructional sessions they perceived that they could handle the challenge. A fundamental feature of the intervention, which was reported by the teachers, was the presence of the research assistant to support them during the instructional sessions. The research assistants gave them confidence and helped them in operational tasks such as organizing the tablets, headphones and other hardware equipment. To scale the intervention, it will be necessary to examine the optimal number of sessions in which the research assistant needs to be present. For example, it might be possible that after the session 10 the teachers might already feel comfortable with working with the technology alone, and such measure would reduce the implementation cost by approximately 30%.

Some teachers expressed that they were afraid that their students might break the tablets while playing. This fear was alleviated as they noted that the lesson plans emphasized the procedures that the students were guided to follow. The teachers were instructed to highlight that the tablets were in the classroom for a fun learning activity, but that it was still an activity, not entertainment. Students were instructed to take good care of such learning tools. The guidance and the tablet cases were effective, as no tablet was damaged during the 540 instructional sessions.

Another behavior which was developed during the sessions was teaching students how to develop a leaning activity using the technology. This was needed as most of the students were familiar to using tablets for entertainment purposes, and they tended to consume small pieces of content. For example, they usually started the game and, after a few screens, wanted to change to

another game, or to watch a movie online. Teachers explained that when we are using the technology for learning, we must keep our focus in what we need to accomplish, which was finishing the game and receiving a gold or silver virtual medal. Teachers' behavior management was an important aspect of the study –future studies may incorporate professional development on behavior management to help teachers effectively utilize the intervention.

Beyond learning how to use the tablets for an instructional activity, the lesson plans also emphasized that the teachers must instruct the students to work cooperatively. In every instructional session, prior to distributing the tablets for the students, teachers emphasized that by speaking with each other, discussing the prompts presented by the games before answering, the students had more chances to win stars and the gold medal at the end of each game. The teachers were also instructed to intervene when they noticed that a pair of students were not playing cooperatively. By approaching the pairs and reminding them of the importance of playing together (learn more and get better medals), most students started to cooperate. This indicates that although the intervention was developed to promote students' literacy skills, the intervention might also foster their social skills. Future studies may investigate the effectiveness of the intervention on students' social-emotional development.

In the teacher's perceptions, the students were engaged with the intervention. After the first classes, the children usually started to ask them when they would "play with the tablets" again. Two teachers from schools which serve lower-income families expressed that they were "amazed by what their students were achieving". One of those teachers said that she "thought it was impossible for a four-year-old student to finish the academic year reading words," but with the intervention, she saw that happening. All teachers expressed that the games were fundamental to increase student engagement and motivation.

The teachers also expressed concern about the intensity of the intervention. While the original plan was to develop two instructional sessions per week per classroom, due to holidays and school events, some classrooms had to do three or four sessions in some weeks. In teacher's view, this was excessive and reduced the motivation of the students, as it was "becoming a regular school practice, losing the novelty factor." Most of the teachers said that one or two times per week is the ideal intensity.

Regarding the games, the teachers made several comments on how they could be improved. The most important and recurring theme, however, was the repetition of mechanics. For example, the intervention employed three games which used a soccer mechanics. The teachers perceived that "student motivation was lower when they saw the same visual design" and game mechanic that they had played before.

The final question of the interview asked the teachers if they would like to use the games again with their next students if the school had the tablets and games. All teachers informed that they would use this instructional tool again. When asked if they could use it alone, without the research assistant, all teachers expressed that yes, that they had mastered the process of using this kind of technology with their students.

Discussion

The findings show that the intervention had a significant gain in the experimental classrooms reading and writing scores when compared to the gains of the control classrooms. The effect of phonological awareness instruction in reading and writing development that was detected in this research is in line with international (Bus & van IJzendoorn, 1999; Chambers et al., 2016; Ehri et al., 2001) and previous Brazilian research (A. G. Capovilla et al., 2007; Morais, 2015; Paula et al., 2005; M. J. d. Santos & Maluf, 2010).

The different aspect of this research, when compared to previous studies, is that it employed digital games to scaffold students' skills and to increase motivation. In the interviews with the teachers, they indicated that the games were effective both for fostering student skill building and their motivation. The quantitative data from pre and post assessments revealed that experimental classes gained 68% more in their reading scores than the gains of the control classrooms. This suggests that the games and the instructional strategies using technology were beneficial for students' reading achievement. This finding is in line with previous research which had detected beneficial effects of using technology to scaffold reading and increasing motivation (Cheung & Slavin, 2013; Dias, 2006; Piquette, Savage, & Abrami, 2014).

The findings also indicate that two of the games used in the intervention can be employed as a cost-effective and reliable indicator to measure and follow-up student's progress. The regression model which uses the scores of the two games to predict the assessment scores explains 99% of the variance in the reading assessment and 90% in the writing assessment. Such indicator is important as PreK schools usually do not want to employ tests with young children and individual application of diagnostic instruments is not viable due to budgetary restrictions. This finding is in line with previous research on stealth assessment and computer-based testing (Carson et al., 2011; Shute, 2011).

Based on the data collected from the teacher's interviews, I note that the implementation strategy that was devised (accelerated meeting, lesson plans, and mentoring altogether) worked to empower PreK teachers to develop phonological awareness instruction supported by digital games. Schools seeking to implement a similar program may experiment reducing the number of sessions in which the research assistant (mentor) is present, as in the study they were with the teachers for 20 sessions. For most of the teachers, 8 to 10 sessions may be sufficient. Also it is

possible to implement an intervention without mentoring and examine whether the games itself are effective.

Another relevant finding for practice is that the game-enhanced intervention was delivered using very inexpensive hardware. The games were played in Amazon Fire tablets which can cost as low as USD 50 each. As the students played in pairs, ten tablets were enough as the majority of the classroom had up to 20 students. A single kit with ten tablets is probably enough for most of the schools, as they can be rotated from classroom to classroom. The tablet battery duration is a key component of such process, and Amazon tablets ran for the full day of classes and were recharged at night. In schools that shut down the power grid at night, it would be advisable to charge the tablets during the morning, lunch and afternoon breaks.

Limitations

The main limitation of this study regards the sample composition. The sample included 17 schools from five cities in the metropolitan area of Fumaça. While this sample presents an adequate composition when considering the private school sector that serves 30% of the students of Fumaça, it did not include public schools. As Brazilian public schools display reduced student achievement levels than private schools, the implementation of the intervention in public schools may display different results and the current findings cannot be generalized to students in public schools.

For example, in public schools, students might not have the prerequisite skills for the intervention to be effective, such as existing letter-name knowledge. The degree of teacher and principal commitment may also affect the feasibility of developing two instructional sessions per week with each classroom. Finally, infrastructural issues such as schools located in communities which suffer from high rates of criminal activity may pose a threat to technology-enhanced

interventions, as robbers may be interested in breaking into the school to get the tablets.

Since low-income families have less access to technology goods than the families of the private schools, public school students may need an increased level of mediation during the first instructional sessions. This lack of familiarity probably will occur more in schools located in extremely poor areas and rural communities. Nevertheless, it is expected that such students would learn how to use the tablet quickly, as the user interfaces are very intuitive today, and the games employed in the intervention do not require complex commands or procedures. Finally, it is important to note that the demographic characteristics of our sample, with a higher than the national average level of parental educational attainment, may also be influencing the effectiveness of the intervention.

Future Research

A clear avenue for future research is trying to replicate the current intervention in public schools. Instead of directly replicating the research, a more cost-effective approach might include developing a needs assessment to determine the current level of instruction and student skills in public schools. Depending on the outcome of this phase, changes in the learning objectives, instructional strategies and games may be needed to maximize the intervention effectiveness potential in public schools.

Based on the findings, multiple research directions can be developed. Due to variation in the effect sizes of the classrooms, one clear path is to seek more evidence about how the process of the intervention works in different circumstances. How the existing student's skills are related to the intervention effectiveness and how the technology mediation process influences the reading and writing development are two interesting questions for future research.

Another aspect of the intervention effectiveness differences regards the relationship

between principals and teachers. The finding that the intervention was more effective for contexts in which principals discuss less with the teachers about how to improve learning may open several questions. Those principals may not be discussing how to improve learning with all teachers of their schools or are they may be discussing less with some teachers because they might perceive those teachers already having better capacity. Also, it would be appropriate to investigate, listening to the principal's view, how their behavior might affect the intervention.

Conclusions

In the first steps of this dissertation I sought to understand why we have a high percentage of Brazilian students failing to learn how to read and write. After identifying societal and family factors which contribute to reading failure, I focused on understanding classroom practices which were identified in previous research with increased reading achievement. The international literature demonstrated that children learn how to read more consistently when teachers have quality learning materials, when they develop phonological awareness activities systematically, and when they use assessments to detect students at risk of reading failure early. We also identified that the teachers in my context did not provide phonological awareness instruction. Schools also did not provide means of assessing students.

Previous intervention studies indicated that phonological awareness instruction for small-groups was more effective than whole-group instruction. Also, research demonstrated that phonological awareness activities could be developed in a fun way with oral and card games. Thinking about ways in which teachers could gather information about their students' phonological awareness, reading and writing skills, we imagined that computer-based assessments, which are an established tool in secondary and higher education settings, could be adapted to be used by PreK classrooms.

Based on such findings we designed an intervention which sought to empower the teachers to develop phonological awareness activities and, at the same time, provide them with reliable assessment data to track students at risk of reading failure. Such intervention would use digital games to increase student motivation and engagement. Also, the games could assist the teachers as they could be used as a way of developing small-group instruction using student peers working with the game. Finally, the games would collect usage data to track student performance and development.

Our findings demonstrated that the proposed game-enhanced reading program was feasible and developed accordingly. The large scale randomized trial which was developed with 749 students from 62 classrooms in 17 schools located in five cities revealed that the teachers learned how to use the game-enhanced technology to improve student learning. Students enjoyed the experience of learning while playing. The children that participated in the instructional sessions using the games gained 68% in reading and 48% more in writing than the children which did not participate. The analysis also revealed that student performance data collected by the games is a reliable predictor of student achievement in the standardized assessments.

Based on the evaluation study findings, we can argue that the game-enhanced reading intervention has the potential to generate long-term gains in reading and writing development. Schools and districts may benefit from implementing such program, as it can be an affordable project. Beyond increasing student achievement in early reading and writing, since the project employs peer-study and mediation tactics to develop collaboration and the proper use of technologies, the program has the potential to generate significant benefits in children's socioemotional and digital literacy development.

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Appendix. Teacher's Interview Protocol

School: _____ Teacher: _____

Classroom: _____ Date: _____ Interviewer: _____

Hi! My name is Americo, and I am a doctoral student at Johns Hopkins University [If an interviewer is a research assistant: My name is XXX and I am a research assistant, working with the student investigator, Americo, at Johns Hopkins University]. First of all, I would like to thank you for agreeing to participate in this interview. To save your time, I would like to record our conversation. All recordings will remain confidential, and I am not going to release them to anyone outside our research team.

As you may know, our research is about early literacy. I am trying to evaluate if computer games can be used to assist teachers and students in developing phonological awareness skills. I would like to ask you several questions. This interview shall last less than one hour, and you are not obligated to answer any question. If you want to stop the interview at any time, just raise your hand.

You can speak freely since I will treat the data confidentially. Please tell me what you think and feel without being afraid. All respondents will be safe when the study report becomes available to the public. Do you have any questions? Do you agree to participate? Great! Thank you. Let us start.

Q1. What is the highest level of education you have completed? _____

Q2. When did you graduate? _____

Q3. During the past two years, have you participated in any Professional Development activity?

- ☐ Yes
- ☐ No

Q4. If yes in D3, what is the hourly load of the most relevant activity in which you participated?

- ☐ Less than 20 hours.
- ☐ From 20 to 40 hours.
- ☐ From 40 to 80 hours.
- ☐ More than 80 hours.

Q5. Have you attended or attend specific literacy courses?

- ☐ Yes, the training for PNAIC teachers (National Pact for Literacy in the Right Age).
- ☐ Yes, course offered by the Secretary of Education.
- ☐ Yes, course promoted by the school.
- ☐ Another literacy course, on its own initiative.
- ☐ I did not take any specific literacy courses.

Q6. Do you use the knowledge gained in the training activities that you participated?

- ☐ Often.
- ☐ Eventually.
- ☐ Almost never.
- ☐ Never.

Q7. How many years have you been working in education? _____ years

Q8. How many schools do you work in?

- ☐ Only at this school.
- ☐ In 2 schools.
- ☐ In 3 schools.
- ☐ In 4 or more schools.

Q9. How many hours per week, outside of school, do you dedicate to activities related to teaching work (lesson planning, proofreading and work, etc.)? _____ hour(s) [note: if it is less than 1 hour, record minutes]

Q10. IN THIS SCHOOL, what is your weekly workload? (Consider contractual working hours: class hours plus hours for activities, if any.) Do not consider private lessons.

- ☐ More than 40 hours.
- ☐ 40 hours.
- ☐ From 20 to 39 hours.
- ☐ Less than 20 hours.

Q11. In this institution, is there a portion of the weekly workload of teachers' professionals to perform activities outside the classroom (excluding direct student assistance)?

- ☐ Yes.
- ☐ No.

Q12. Please tell us the frequency that you develop the activities below: [Note: Show a participant a copy of the list of the activities below]

	never	Once per year	3 to 4 times per year	Every month	Every week	Every day
Ask students to copy texts and activities from the textbook or blackboard.						
Encourage students to express their opinions and develop arguments for diverse topics.						
Propose learning situations that are familiar or of interest to the students.						
I work with groups and doubles.						
Curricular rehearsal classes for students experiencing difficulties						
Establishment of pedagogical routines (permanent activities), such as reading wheel, calendar marking, choice of helper (s), games, etc.						
Reading of various textual genres for children.						
Reading and discussion of non-verbal texts, such as plaques, labels, comic strips, posters, among others.						
Reading of genres of cultural heritage of childhood, such as parlendas, languages lock, among others.						
Spelling training activities.						
Reading of texts from the textbook.						
Individual or group production of texts of different genres.						
Exposure of written and non-verbal materials in the classroom.						
Realization of dictation of words or phrases.						
Use of games and games for appropriation of the Alphabetical Writing System.						

Writing and reading of syllabic families.						
Syllable awareness activities.						
Rhyming awareness activities.						
Alliteration awareness activities.						
Phoneme awareness activities.						

Q13. Now tell me a little about the principal (or coordinator):

	never	A few times	Frequently	Always
Does the principal discuss educational goals with teachers at meetings?				
The principal promotes discussions with the staff to improve the teaching and learning of the students.				
The director gives special attention to aspects related to administrative rules.				
The director gives special attention to aspects related to school maintenance.				
The director informs the teachers about the possibilities of professional improvement.				
The director promotes integration with the community.				
The director encourages me and motivates me to work.				
The director encourages innovative activities.				
I feel respected by the director.				
I have confidence in the director as a professional.				
I participate in decisions related to my work.				
The team of teachers takes my ideas into consideration.				
The principal establishes clear rules of school conduct.				
The principal supports me when necessary.				

Now let's move to the final questions:

Q14. Which grade(s) are you teaching this year? _____

Q15. How long have you been teaching at this level? _____

Q16. What are your literacy goals for your students when they finish this grade?

Q17. In your view, what are the most important literacy-related activities that you develop with your students?

Q18. What is the frequency of each of those activities? Daily? Weekly? Monthly?

Q19. What are your impressions about the method of delivering instructional content using tablets?

Q20. What are your impressions about the PA games included in the program?

Q21. What are your perceptions about scaffolds provided by the games so that students could develop their PA skills? In which ways do you think they could be improved?

Q22. How do you evaluate the intervention? The communication, logistics, and support?

Q23. Do you believe that this intervention could be carried by the school staff without the assistance of the research team next year? Why?

Q24. What were your feelings towards this intervention? Were you at ease with the app and the research team? Did anything cause frustration?

Q25. Were the professional development activities helpful for your teaching or implementation of the intervention? Could it be improved?

Q26. Do you have any suggestion to improve this intervention?

We are finishing the interview. Would you like to add any additional information regarding early literacy and the intervention that took place?

Great. We are done. Thank you for participating in this interview.

AMERICO NOBRE G. F. AMORIM

Birth date: November 11, 1981.

Birth location: Recife, Pernambuco, Brazil.

Americo Amorim is a Brazilian leader in the education technology arena. Son of a university professor and an entrepreneur, he started to work when he was 15 years old. His first education startup became nationally awarded when he was 20 years-old. He received his bachelor and master's degrees from the Federal University of Pernambuco. He received his Doctor of Education degree from Johns Hopkins University.

His first research work was done during his undergraduate course and received the best paper award in a national conference held by the prestigious Fundacao Getulio Vargas (FGV). His findings were published in journals, books, and chapters. His works were presented in Brazil, Europe and in the United States, where he received the Best Student paper award in an international conference held in San Francisco.

During the years he matured as a professor and specialized in research and development of digital media for learning, receiving several grants and contracts for his projects. His works include instructional content for social networks, games, and apps used by millions of Brazilian students. Today Americo is a prestigious influencer in the Brazilian education technology sector. He is frequently invited to speak in private conferences for decision makers and his innovative projects frequently appear in national Brazilian media outlets.

HONORS AND AWARDS

- | | |
|--|------|
| • Best Paper Award - 14th CONTECSI - International Conference on Information Systems | 2017 |
| • International Development Bank – Escribo in the TOP 12 Latin American Creative Startups | 2016 |
| • Jabuti Award (Brazilian Pulitzer) – Turma do Som among the TOP 10 e-books of the year | 2015 |
| • Best Educational App – Hypertext Award – Turma do Som | 2012 |
| • FINEP Innovation Award – Daccord S.A. - Most Innovative SME of Northeast of Brazil | 2012 |
| • FINEP Innovation Award – Daccord S.A. - Most Innovative SME of Northeast of Brazil | 2009 |
| • International Young Interactive Entrepreneur - Brazilian Winner – British Council. | 2008 |
| • Approved with distinction by the review board of the Master's in Business Administration | 2007 |
| • Honors praise by the University Council of the Federal University of Pernambuco | 2006 |
| • Santander Entrepreneurship, Innovation and Research Award | 2006 |
| • Best Undergraduate Student Paper, International Academy of E-Business | 2005 |
| • Young Entrepreneurship Award by the Federal University of Campina Grande | 2005 |
| • Best business Paper of the Annual Congress of Information Technology (FGV - EAESP) | 2004 |
| • Top 10 Website - iBest Award - sombrasil.com | 2002 |
| • Best Manager and Best Website – iBest Award - sombrasil.com | 2001 |
| • Best Webmaster and Best Website – iBest Award - sombrasil.com | 2000 |