Article

Cognitive Learning and Robotics: Innovative Teaching for Inclusivity

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Abstract: We present the interdisciplinary CoWriting Kazakh project in which a social robot acts as a peer in learning the new Kazakh Latin alphabet, to which Kazakhstan is going to shift from the current Kazakh Cyrillic by 2030. We discuss the past literature on cognitive learning and script acquisition in-depth and present a theoretical framing for this study. The results of word and letter analyses from two user studies conducted between 2019 and 2020 are presented. Learning the new alphabet through Kazakh words with two or more syllables and special native letters resulted in significant learning gains. These results suggest that reciprocal Cyrillic-to-Latin script learning results in considerable cognitive benefits due to mental conversion, word choice, and handwriting practices. Overall, this system enables school-age children to practice the new Kazakh Latin script in an engaging learning scenario. The proposed theoretical framework illuminates the understanding of teaching and learning within the multimodal robot-assisted script learning scenario and beyond its scope.

1. Introduction

Over the last three decades, Central Asian countries have undertaken purposive changes in their writing systems as a way to increase the linguistic capital in titular languages and distance themselves from the Russian language influence. When the Soviet Union disintegrated in the 1990s, for independent Central Asian countries, it was an urgent decision to opt for Latinization reforms with the aim to escape from "Soviet identity" and build closer ties with the Western world [1,2]. A similar example of script switchover reforms has occurred in other parts of the Turkic world, from Turkey [3], Turkmenistan [4], the Republic of Tatarstan [5], Azerbaijan [6,7] to the Xinjiang Uyghur Autonomous Republic in China [8,9]. Kazakhstan is about to join the Latinization movement by changing its current Kazakh Cyrillic alphabet to Kazakh Latin. Here, research studies addressing the issue of alphabet switch have mainly covered the acceptance of the proposed shift and the speakers' attitudes toward this phenomenon in different public domains [10–12]. It is evident that people have become more open and familiar with Latinization [10,12], yet literacy development issues and the questions related to educating the population in a new alphabet have not been addressed thoroughly. For example, some scholars from the Central Asian context [3,6], who researched similar alphabet changes, questioned the quality of education during the transition process as it directly affects literacy acquisition. According to Hatcher (2008) [6] and Yılmaz (2011) [3], the main concern in this situation was the existence of multiple competing alphabets representing one language, which was viewed as an obstacle to access to educational materials and resources. Similarly, Kazakhstani researchers highlighted the risk of illiteracy among the population both in the Cyrillic and

the Latin-based alphabets [12,13], arguing on both sides of the Latinization that not only Kazakh speakers can become illiterate in Cyrillic, but the Russian-speaking population is also highly likely to be deprived of access to learning the Kazakh language. However, these challenges remain as mere arguments with no clear evidence as yet.

The education system is an integral part of the Cyrillic-to-Latin transition, dealing with multiple challenges and ramifications. In a school context, teachers as key actors have to adapt to teaching in the new Kazakh Latin alphabet. However, since 2017, three versions of the Latin alphabet have been officially introduced, which signals how unpredictable the language reform is. Ongoing training for Kazakh-language teachers can be costly and a waste of time due to the uncertainty of which version of the alphabet will be implemented. In addition, considering the diversity of classrooms and uneven distribution of students' abilities, teachers most often realize their lack of competence in responding to the academic needs of their students [14,15]. For those in educational settings who are experiencing these significant shifts, understanding how to effectively negotiate the process of teaching and learning is of particular importance. School children who are currently learning Kazakh with Cyrillic letters are now facing an additional process of conceptualizing a new alphabet simultaneously with their previous knowledge. As the transition to the Latin alphabet requires not only the acquisition of the script but also stimulation of various cognitive processes, such as a mental script conversion through handwriting and visual perception, effective strategies and tools are necessary for the process of teaching and learning.

There has been insufficient evidence to determine the most sustainable steps toward effective teaching and learning practices in the acquisition of the new script. While teachers and students have been involved in testing the script [16,17], the results have reported solely on the actions taken to cover the educational institutions, with no empirical evidence on the implementation process whatsoever. Learning a new alphabet from the outset may come with many challenges for learners. Cahill and Karan (2008) ([18] p. 7) stress the educational factor of alphabet reform and warn that "learners experience a higher level of frustration, resulting in possible demotivation or failure and increased learning time". They propose such challenges and obstacles could be directly related to exposure to the new alphabet and its written representation, as opposed to the alphabet students were already familiar with [18]—Cyrillic, in the Kazakhstani context. Additionally, there are major risks to the quality and equity between school systems in the country. Currently, there are two primary systems of education, Russian-medium and Kazakh-medium schools, with a few other options, including Turkish or English-medium teaching. With the latest language reform, there is a risk that could increase the gap between the quality of provided education between Russian-speaking school systems and those in Kazakh-speaking schools. Furthermore, inequities could be heightened between students who attend schools in large cities with more abundant resources versus those who learn in rural areas with limited access to new materials. In addition to the inequities of resources and access, there are greater risks among populations that experience learning difficulties. For example, learning a new alphabet presents heightened issues which can exacerbate challenges faced by students with dyslexic or dysgraphic tendencies [19]. Other challenges include deepening inequalities across the generational spectrum and inadequate resources in the new script. Hence, identifying innovative ways of effective teaching and learning the new Latin-based Kazakh alphabet is fundamental for both the general public and educational stakeholders.

Recognizing the issues stated above, recent research [20–22] has examined the effectiveness of the script conversion task from Cyrillic to Latin scripts and vice versa in experimental studies involving primary school students and the humanoid NAO robot in a learning-by-teaching (LbT) and peer-to-peer learning paradigms. Sandygulova et al. [21], who focused on the conversion of the Kazakh script from Cyrillic to Latin and vice versa in a robot-assisted script learning (RASL) scenario, have found that the learning strategy of performing mental conversion between scripts showed effectiveness even though there were gender-factored differences in the learning gains of girls and boys. As a result, although not significant, the strategy of mental conversion of letters has been found effective

for girls, who performed the conversion themselves, as compared to boys for whom the conversion was performed by a robot. That is, the mental conversion carried out with the help of a non-human agent proves to be useful, albeit with mismatches on the gender basis between girls and boys. Therefore, both mental and technological tools may be at play during the process of letter acquisition, transliteration, and handwriting from one script to another. While this experimental study employed the peer-to-peer scenario for learning purposes, it also suggests that learning scenarios may not be limited to solely one strategy to provide multimodality and inclusion for the letter acquisition in general terms [21].

Drawing from the research data obtained from Sandygulova et al. [21] and Zhexenova et al. [22], which we extend on in Sections 3 and 4, this paper contributes by presenting a theoretical framework to shed light on the processes that take place in the robot-assisted script learning scenario. Derived from an intersection of fields such as cognitive studies, linguistics, and writing systems research, this integrated framework enables the understanding of multimodal and innovative learning methods that can be applicable to alphabet learning using a social robot in a primary school setting.

2. Literature Review

2.1. Challenges and Risks: A Focus on Kazakhstan

This language reform presents multiple challenges and risks within Kazakhstan. Within the scope of our research, we have distinguished three major areas where Latinization becomes challenging and risky. First, this switch encompasses language-related concerns about cross-language orthographic interference between Kazakh and English language, literacy development of Kazakh-Russian bilinguals at school, and writing and reading difficulties with Kazakh Latin. Secondly, Kazakh-language teachers' practices and children's learning can undergo huge changes from an educational perspective. Finally, the whole reform might not achieve immediate positive results as were seen in other Central Asian countries' experiences that pose enormous time and cost issues for the country's economics.

2.2. Language and Literacy Development

Most research on literacy development has been largely focused on English and other Roman alphabetic scripts [23]. Thus, it is important to study different cases of scripts such as Kazakh Cyrillic and Kazakh Latin to understand how people develop such writing skills in the multilingual world. The version of the Latin-based Kazakh alphabet shares common letters with the English Latin alphabet, and this closeness may result in a cross-linguistic orthographic interference between Kazakh and English [24]. Previous research has shown an inevitable influence of L1 orthography on L2 pronunciation [25]. For instance, one can confuse the letter "a", as it is pronounced (ei) in English and in the Kazakh as (a), including other similar instances [24]. Since schoolchildren learn Kazakh and English simultaneously starting from the first grade in Kazakhstan [26], this presumably makes script learning more difficult. In addition, Fazylzhanova (2017) [24] expresses a concern that it may affect the quality of teaching English in Kazakh-medium schools and incorrect pronunciation of native Kazakh sounds.

In most instances, bilingualism has not been well-addressed in terms of writing abilities, with little focus on how young bilinguals learn to use different writing systems. To Kazakhstan's population, Kazakh-Russian bilingualism is a common practice as well as in other post-Soviet countries where Russian is used along with a national language. Therefore, another concern is about bilingual children who speak both Kazakh and Russian in their daily lives. Navigating between Latin-based Kazakh and Russian Cyrillic may add an extra burden to schoolchildren who have to learn two different writing systems. It may pose a risk to language and literacy development both in Kazakh and Russian, bearing in mind that they are taught as a compulsory language subject in either Kazakh or Russian medium of instruction schools. According to Cummins (2000) [27], a bilingual's writing competence develops interdependently, showing the transfer of skills between two

languages. Therefore, learning two languages in two different writing systems may cause uncertainty about language choice and use among learners who are exposed to bilingual script learning.

2.3. Learner Motivation and Perceptions

Moreover, one important concern is the lack of motivation to study in Kazakh due to the change in the alphabet system. This may result in a reduced number of Kazakh speakers, especially in the younger generation. Another risk centers on primary school children who will be required to become fluent in both Cyrillic and Latin versions of Kazakh yet have limited access to materials in the latter. The learning resources offered in schools are still being developed for the new form of writing Kazakh, which means that materials are being supplemented from other locations and languages (e.g., Russian, English, Cyrillic-based Kazakh language).

Following Kuderinova's (2017) [28] research study, which focused on the perceptions of the tertiary education students' at Suleyman Demirel University. The study centered around the difficulties of typewriting in a Latin-based alphabet and handwriting, the time spent on these activities as well as reading. The alphabet version as of September 2017, which included digraphs such as "ae", "us", "sh", and "ng", was used in this experiment-based mixed-method study. The results of the study revealed that although typewriting seemed easier and was performed faster, the reading and handwriting processes took a larger amount of time for students familiar with the alphabet. They tended to make more errors in writing rather than in typing the given text. In addition, students showed putting extra effort into comprehending the text written in the Latin-based alphabet. It is worth mentioning that the recognition of the writing was seen to be slow and the most challenging [28]. Moreover, research on reading ability suggests that "many children who do not acquire sufficient word recognition skills by third grade rarely improve those deficits" [29]. The RAND Reading Study Group identified several major factors, such as the reader, the text, the activity, and the situational text, that act on reading comprehension [29]. They also emphasize the learners' ability to obtain literacy in reading and writing by being bound to instructions that teachers provide. While the instructions and class activities play a key part in literacy development, Pinto, Bigozzi, Gamannossi, and Vezzani (2012) ([30] p. 331) point out the importance of phonological awareness, knowledge of letters, and language skills, to mention but a few types of knowledge that enable children to become literate in reading. Newman (2013) [31] agrees that writing ability requires a deep understanding of the phonological and orthographic (associating letters with the sounds or decoding) conventions of the language. From this, we can assume that poor alphabetic and orthographic awareness and the learners' inability to regulate the mentally stored knowledge may lead to reading deficiencies due to insufficient cognitive functioning. As noted by Worden and Boettcher (1990) [32], even though there is a large body of literature on child acquisition of letter–sound correspondence, there is still a gap in research focusing on the issue regarding children's learning the alphabet knowledge. For instance, students with learning difficulties, such as those who are dyslexic or dysgraphic, present directions for research for language reforms focused on changes in the alphabet. Writing is one of the major skills that directly impact memory, information processing, and organization of thoughts [33] as well as "storing letter names in the memory or retrieving them fluently" [19]. Children with a learning disability such as dysgraphia normally lack these abilities, meanwhile suffering greatly when faced with handwriting and spelling tasks since they are unable to establish links between phonological and orthographic representations of the word. As Hintikka et al. (2005) [19] claim, dyslexic children are the most challenged in "grapheme-phoneme conversion" tasks. Thus, the low pre-reading skills, along with the lack of phonological processing ability, challenge language development in children with dyslexia.

We do not examine how children with learning disabilities such as dysgraphia acquire the alphabet in the current study, but this area certainly deserves attention in future re-

search. Among the available solutions to treat such learning disabilities connected to poor processing of writing or reading, researchers suggest multiple strategies to alleviate the difficulties and allow children alternatives to improve their writing skills [33]. One such alternative is to provide children with word processors, i.e., digital and computer-based interfaces that replace handwriting. Unlike oral language, written language (i.e., differentiating letters and sounds, vocabulary, reading comprehension) is "acquired through explicit education" [31], and it requires a set of mental abilities, such as organizational thinking and processing [33]. Given that, it is of utmost importance to explore the learning aspect of the scheduled alphabet transition as it can potentially allow researchers to come up with solutions that can provide learning facilitation for students in particular and for other learners in general.

2.4. Robot-Assisted Learning and Education

With capitalism, the application of robots was a first step toward building a carefree and less laborious life for humans in and outside the workplace. Although robots are traditionally considered human-controlled machines performing monotonous tasks in industrial settings [34], they now have taken on new roles with some promising social impact. Today, robots are no longer mechanical objects but an assistant and companion to humans in their day-to-day life. With that in mind, the use of robots is multidimensional since they can be applied in search and rescue (Atlas), emotional well-being (BUDDY), cognitive assistance (EMiR), entertainment (WowWee), and other social domains.

The emerging field known as human–robot interaction (HRI) is transforming the ways humans live and learn. In particular, the development of robots has become one of the key drivers for encouraging changes in the education system. It is experiencing a paradigm shift if we consider the challenges with less one-on-one and inclusive tutoring [35] along with inefficient approaches that do not meet the expectations of students with diverse learning styles, motivation, and study skills [36]. One of the possible solutions is that humanoid robots can be given space in the learning and teaching processes. In fact, the interaction between humans and robots enables new opportunities for knowledge and information exchange [37]. Their interaction may happen in two ways: (1) humans can teach robots, learning from demonstration; (2) robots can teach humans using machine teaching, i.e., algorithmic teaching. Taken together, these interactions indicate the assistive and complementary nature of HRI [38], in which both a human and robot can take advantage of knowledge and skills transfer. Given these features of HRI, we can assume that students can cooperate with robots as peers and assistants. In this regard, it is of utmost importance to identify the impact of social robots on a student's learning curve as well as teacher's instruction.

Robots are generally welcome, and students between primary school and tertiary education levels view them as learning partners or companions in an optimistic way [39–42]. Bernstein and Crowley (2008) [43] suggest that children aged four through seven with prior knowledge of robots believed that they are alive and attribute more intelligence and psychological characteristics than those who do not believe in that. In the higher education domain of application, Rosenberg-Kima et al. (2019) [44] found that the physical presence of robots brought positive changes because of the technical functionality, social, and psychological activity. Namely, students pointed out the benefits as follows: "accessible to multiple people", "immediate feedback", "he is not judgmental like human beings", "pleasant and motivating." It is obvious that learners cultivate favorable impressions toward robots as learning companions, and the child–robot interaction may lead to increased self-confidence and better task performance showing creativity [45,46] and problem-solving [47]. The shortage of teachers has become a topic for discussion across many contexts [48,49]. Therefore, the demand for schoolteachers has increased exponentially [50], and it has resulted in a necessity to recruit almost 69 million teachers needed to provide quality education (SDG 4) by 2030. This problem has led to the development of AI in education (AIEd) tools and Intelligent Tutoring Systems (ITS), which are likely to scaffold teachers in flexible and

personalized ways. Hence, within HRI, robots may be embedded into a classroom to serve roles as teacher's assistants (e.g., PaPeRo, IROBI) by helping students to stay engaged and motivated. This characteristic of robots is considered as an asset for human teachers who may focus more on content delivery and assessment. Needless to say that robots cannot replace teachers in classroom settings but rather act as a helpful agent to human teachers to effectively deliver content and instruction.

Unlike other learning aids, such as tablets and laptops, the use of social robots may yield significant benefits in three ways [51]. First, as most learning and teaching processes happen in the classroom, robots seem the feasible option to fit the physical world and thus facilitate classroom engagement. It is explained that the physical embodiment of robots has a huge impact on people seeing them as more human-like, sociable, and creative than a tablet [52–54]. For instance, students exposed to the robot condition perceived the robot as more comfortable for learning compared to the tablet condition [44]. Second, the presence of robots enables more social behaviors from people whose learning is not mere task-based learning. For instance, in a study Kory-Westlund et al. [55] comparing the effectiveness of three sources of information (human, robot, and tablet) with regard to children's rapid word learning, it was revealed that young learners strongly preferred robots despite similar word learning results in the three learning scenarios. Finally, learners are more motivated and interested to learn due to the interactive communication with robots, and it can further result in increased learning gains. Taken together, social robots can be considered more suitable partners and peers in the classroom compared to desktop-based virtual agents. Robots have appeared to be novel, innovative, and smart discoveries that can be used by human beings for learning, social bonding, and interaction in a more efficient way compared to tablets and other learning aids.

2.5. International Research on Handwriting Practice with a Robot

As learning is becoming multimodal, using robots as peers and teaching assistants for language learning purposes has been proven to be a state-of-the-art phenomenon. Particularly, our study focuses on script-learning scenarios where young learners perform script conversion, learn new words with correct spelling, and practice their handwriting with a peer robot. Script conversion, otherwise referred to as transliteration, is guided by the principles of converting the characters of one script to the other script [56]. It is usually performed through mental processes and outputted through handwriting. In specific terms, handwriting is recognized as a major step in cognitive development, which puts forward the idea of making learning easier and stimulating brain activity [57,58]. In the French context, this suggestion is strongly supported by the Ministry of Education, which made a decision to teach cursive writing at the primary level of schooling on the basis of neuroscience evidence. In the Swiss-based study, Hood et al. (2015) [59] found that primary-age French-speaking schoolchildren improved their level of writing by engaging with an educational robot in multiple handwriting interventions. In the Portuguese context, two longitudinal studies revealed tentative evidence about children's learning gains. In this study, children performed two activities of letter selection and letter writing on a tablet with a robot across the personalized, continuous, and non-learning conditions. The unifying conclusion is that the post-test results showed that children in the learning condition improved their writing significantly in view of the suggested variables of motivation and learning activity.

To our knowledge, no previous study has explored whether students experience cognitive benefits in alphabet knowledge construction with a robot. Moreover, most studies [60,61] discussed second language acquisition (SLA) with a robot intervention rather than first language acquisition (FLA). Nevertheless, within the HRI scope, Leyzberg et al. (2012) [62] found that the physical presence of a social robot resulted in significant learning gains in a cognitively demanding task when compared to video/voice learning conditions. Following studies on vocabulary acquisition [61,63], they show differing assigned roles to a robot that cannot give a clear picture of the cognitive learning experiences resulting from child–robot

interaction. Although learning gains in vocabulary have been substantial, research studies on robots' efficacy, either as a peer or tutor, are required to build effective and autonomous robot-aided learning. For instance, comparing personalized and non-personalized long-term robot intervention, Baxter et al. (2017) [64] made a suggestion that children learn more when they interact with personalized robots than non-personalized robots. These results demonstrate that CoWriting Kazakh needs to create personalized learning scenarios germane to learners' language learning preferences.

The original CoWriter experimental research in the context of Switzerland has demonstrated that children engage in learning to write through an interactional teaching scenario [65]. In Switzerland, a predominantly bilingual country where four languages are recognized as official and used on a daily basis [66], children grow up knowing several writing scripts from a very early age while, at the same time, they learn to navigate between the unique orthographies of German, French, Italian, and Romansh [67]. With regard to the interactional teaching scenario involving computer-based agents, there is a consensus among scholars that this learning strategy produces "motivational, meta-cognitive and educational benefits in a range of disciplines" [65,68]. Jacq et al. (2016) [65] tested the hypothesis that had CoWriter been adapted to the educational environment; children could overcome their handwriting deficiencies. Thus, the case study was conducted to investigate the deficit of handwriting skills of a child named Thomas by imposing him on a humanoid robot. According to the results, since the robot accepted only the allographs it recognized as correct, the progress was achieved by means of self-correction on Thomas's part, thus performing better handwriting. As quoted above, it can be assumed that Thomas's continuous efforts incorporated cognitive and meta-cognitive resources. In this instance, the social robot served as remediation.

Another study shed light on developmental coordination disorder (DCD), which includes dysgraphia and related shortages in writing ability in young learners [69]. These authors strongly support the use of social robots in early handwriting development, assuming that handwriting may be challenging and thus be time-consuming to get accustomed to. Thus, the study posed the following three conditions to compare adult learners' performances: (1) handwriting sessions with the CoWriter robot; (2) handwriting sessions with a virtual agent; (3) handwriting sessions with the tablet only, guided by a voice [69]. Following the extant scenarios proposed in the original CoWriter project, Le Denmat et al.'s (2018) [69] study results were appropriated to the four-dimensional questionnaire (Co-Presence, Attentional allocation, Perceived message understanding, and Perceived behavioral interdependence). According to the results, among the three conditions, the CoWriter robot's presence occurred to be significant in comparison to the other two conditions, which mainly caused distractions.

While Jacq et al. (2016) [65] and Le Denmat et al. (2018) [69] provide little or no evidence for the enactment of cognitive abilities in a human–robot learning scenario, Chandra, Dillenbourg and Paiva (2017) [70] expanded on that matter by explaining that complex sensorimotor and cognition skills take part in mastering handwriting. Moreover, once these cognitive skills and handwriting are acquired, they are unlikely to respond to further changes; therefore, much effort should be channeled toward developing the sensorimotor and cognition skills while teaching handwriting [70].

To this end, an interactional learning scenario with a physical robot, which can communicate and is taught, offers further research directions with important considerations of cognitive gains that learners might benefit from during handwriting, letter acquisition, word selection, and language learning as well. As the present research dwells on the multidisciplinary nature of research on learning the Kazakh Latin alphabet alongside the humanoid-robot in learning-by-teaching, peer-learning, and peer-teaching scenarios, we discuss further how the project is related to other fields of inquiry.

3. Addressing Inclusivity and Access: CoWriting Kazakh

Research is becoming more inclusive and multidisciplinary. The three-fold challenges delineated above (i.e., cross-linguistic interference, teachers' competencies, and time and cost issues) can determine the further development of research on Latinization and attract perspectives from interdisciplinary areas such as human–robot interaction. In this respect, CoWriting Kazakh extends its research scope beyond human–robot interaction to various interrelated fields, chiefly education, linguistics, and cognitive science. By bringing these fields together, this project has the potential to grow into a promising area that provides a solution to the problem of script learning from different perspectives. Equally important is the practice of drawing attention to this problem within a broader research context. The current study discusses the framework in connection with cognitive science, and here we focus on the educational and linguistic bases of the study.

Recognizing the importance of education, CoWriting Kazakh is guided by the principles of peer-assisted learning (PAL) and learning-by-teaching (LbT) that account for how script learning takes place between a learner and a robot. Generally, PAL comprises different forms of peer-teaching, peer-learning, and peer mentoring [71]. With some distinctions, they also share similarities, such as collaborative interaction and non-professional teaching roles between learners [72]. Starting from the mid-1970s, reciprocal peer teaching (RPT) has continued to thrive as an educational practice across fields, including medicine, IT, teacher education, and language learning. Its main idea is that individuals are paired up with alternating tutor-tutee roles for different learning activities [73]. In our study, one of the forms of PAL, an RPT fits into the learning scenario.

For example, Liu and Devitt (2014) [74] found that beginners in Chinese language classes increased their motivation and self-responsibility for learning due to the active use of RPT. Going beyond this classical human-to-human RPT, our study leverages it in learning the new Kazakh Latin alphabet. That is, the learning scenario is designed to engage both a learner and a robot to teach one another for two-fold purposes: (1) a student practices the new script; (2) a robot learns Kazakh words. In the meantime, there emerges another educational practice—learning by teaching (LbT)—social learning built on an individual's ability to tutor another and then learn as much as the tutee [68,75]. Central to our study, is a novel approach used for handwriting intervention by Lemaignan et al. (2016) [76] who embedded the LbT paradigm into the original CoWriter project. This paradigm goes hand in hand with the so-called protégé effect; it gets learners to teach handwriting to a teachable agent (i.e., a robot) that eventually turns out to be a subconscious learning experience for the learners themselves [77]. In the present study, children are introduced to the peer robot wanting to learn Kazakh, without noticing that they also learn the Kazakh Latin script by practicing it with a humanoid robot and reflecting on the correct spelling. Our project also proposes to use a free learning approach so that children can enjoy the learning process to the fullest extent. For instance, Habgood and Ainsworth (2011) [78] confirm that user engagement is higher when children are exposed to educational games in free situations. Taken together, these educational practices and models reinforce the learning process within CoWriting Kazakh in view of the peer-based approach that might advantage learners' commitment to collaborative learning.

From a linguistic point of view, CoWriting Kazakh integrates graphitization as a form of corpus planning and script learning, which are essential to illustrate a shift to a Latin-based Kazakh alphabet. With the deliberate reasons for the change in orthography, the role of corpus planning is instrumental for its representation of the internal structure of a language [79,80] and change of script and spelling reforms [81]. According to Ferguson (1968) [82], one of the manifestations of corpus planning is graphitization—a way to build and refine the orthography of a certain language. Graphitization generally encompasses the script and writing system that represent the spoken language in a visible way (Taylor and Olson, 1995) [83]. In essence, the terms of a writing system, an orthography, and a script are synonymous; therefore, they can be used interchangeably [84,85]. However, orthography, as only one part of literacy, is a broader system that includes the individual

characters of the alphabet (i.e., graphemes), diacritic marks and other alphabetic and writing conventions such as word breaks, capitalization, and splitting and hyphenating words at line endings [86]. As reported in the pioneering work by Frost and Katz (1989) [87], writing systems are generally classified as shallow and deep. In shallow (transparent) orthographies, such as Kazakh, there is a one-to-one correspondence between sound and spelling. In contrast, deep (opaque) writing systems, such as English, have no direct letter-phoneme relationship. However, this orthographic depth hypothesis is relative rather than absolute [88,89]. For instance, Chinese is deeper than English in light of even less letter-sound association.

Within the present study, we investigate the switch from Kazakh Cyrillic to Kazakh Latin, which sets an example for biscriptal practices of young learners. This means that children are biliterate in two different scripts, and research shows that bilingualism in writing systems can change the understanding of "bilingual" in relation to the writing dimension [90]. For many years, most researchers [91–93] have identified bilinguals as individuals who speak two or more languages. However, this definition of bilingualism on account of spoken language has been challenged, which no longer places written language in a subordinate role by giving priority to the ability to speak. At this point, the CoWriting Kazakh project presents a new outlook on the growing field of bilingualism, and the research into learning a new writing system in the same language shows the importance of writing ability, which unequivocally pervades every part of our lives.

To date, the Kazakhstani context has not seen any research studies on the learning aspects of the Kazakh Latin alphabet in a way that is discussed in the aforementioned studies from international contexts. Neither the Central Asian nor post-Soviet states have addressed the same issue. Although educational researchers and linguists attempted to research the learning aspects of the new script from the sociolinguistic, sociocultural, and psycholinguistic perspectives, presenting numerous evidence theoretically [11,12,24], the practical teaching and learning issues of the Kazakh Latin alphabet are under-researched. The only empirical study that the present article draws on as the major referencing source is [21], a multiple case study research, which we attempt to frame theoretically.

4. Materials and Methods

4.1. Child–Robot Interaction Scenario

The scenario involves a robot that plays the role of a peer. The humanoid social robot, NAO, is introduced to a child as a native English speaker of approximately his or her age who wants to learn Kazakh. The robot behaves as a curious learner who asks the child to demonstrate how to write Kazakh words using the new Latin-based alphabet because it is convenient for the robot to read. In a control condition, the robot does not ask to write explicitly in Latin script, allowing the child to write words in their preferred script (i.e., Cyrillic script, as that is what they are accustomed to). The interaction takes around 20–30 min depending on the children's writing pace. Moreover, the robot is programmed to produce certain speech utterances to interact with the child.

4.2. Software and Hardware Components

The hardware components of the system include the Wacom Cintiq Pro tablet, its pen, and a humanoid robot NAO. The tablet serves as the second monitor when connected to a laptop. Its pen has 8,192 levels of pressure sensitivity and tilt recognition. This allows not only the trajectory of the handwriting, but also the pressure and tilt at every point to be acquired. A humanoid robot, NAO, is a programmable autonomous robot developed by SoftBank Robotics. It is widely used in human–robot interaction research, in particular, educational and robot-assisted therapy applications. The humanoid robot's height is 58 cm which makes it comfortable to transport. Also its appearance is appealing to children. Furthermore, it has 25 degrees of freedom and 7 tactile sensors. CoWriting Kazakh is an extension of the original CoWriter system. In contrast to the original CoWriter's Learning by Teaching paradigm, where the robot's handwriting improved gradually via

several demonstrations by the child, the CoWriting Kazakh does not have a handwriting improvement component. In the presented system, the robot and a child engage in co-operative learning where the robot learns from the child the new vocabulary in Kazakh, while the child learns from the robot the spelling in the new script. Thus, they take turns in writing words in Kazakh. In addition, the CoWriting Kazakh system integrates handwriting recognition of Latin and Cyrillic Kazakh that was trained on over 120,000 samples of the Cyrillic-MNIST dataset [94].

5. HRI Experiments and Results Overview

Prior to the word and letter analyses that will be presented shortly below, it is necessary to briefly overview the previous two experimental studies by [21,22], each involving word categories with linguistic differences purposefully selected for identifying the effects of words in terms of learning gains. We consider it worthwhile to analyze the words to determine the effects of chosen words on the children's cognitive gains. Thus, in Experiment 1, the following categories of words were used:

- Easy Kazakh words. This category included Kazakh words that are made of one or two syllables and thus easy for memorization. Despite the ease, the selection of the words was based on the criterion of inclusion of unique Kazakh letters. Examples are provided in Table 1.
- Complicated Kazakh words. This category of words included Kazakh words with their unique letters. The words in this category were longer and considerably more difficult in their writing than the words used in the Easy Kazakh words category.
- Loan words. This category of words included Russian loan words with specific letters of the Russian Cyrillic alphabet, which are used in Kazakh with the same spelling.

Table 1. Words and letters used in Experiment 1.

	Experiment 1		
	Easy Kazakh	**Complicated Kazakh**	**Loan Words**
Words	qys, jaz, úi, qus, aǵash	sálem, kóktem, teńiz, rahmet	fýtbol, velosiped, chemodan, tsirk
Letters	q, y, s, j, a, z, ú, i, u, ǵ, sh	s, á, l, e, m, k, ó, t, ń, i, z, r, h	f, ý, t, b, o, l, v, e, s, p, d, ch, m, a, n, ts, i, r, k
Number of Letters	11	13	19

Meanwhile, the word categories used in Experiment 2 were as follows:

- Kazakh words. This category of words included both short and longer words of the Kazakh language that children are supposed to be familiar with from school. The majority of the words contained Kazakh unique letters. Examples are illustrated in Table 2.
- Cognates. This category of words included English words that are directly borrowed and identical in their use and spelling in the Kazakh language.
- Nonsense words. This category of words included English-like and Russian-like pseudo-words that are morphologically and phonologically plausible but have no meanings in either English or Russian whatsoever.

To elicit results from the analysis of words and letters, we counted the total number of letters in each group and assigned points to rate the frequency of each letter.

Table 2. Words and letters used in Experiment 2.

	Experiment 2		
	Kazakh	**Cognates**	**Nonsense Words**
Words	sálem, aǵa, kók, oń, qalam, rahmet	robot, mango, banan, bank, park	nao, dako, vano, afo
Letters	s, á, l, e, m, a, ǵ, k, ó, o, ń, q, r, h, t	r, o, b, t, m, a, n, g, k, p	n, a, o, d, k, v, f
Number of Letters	15	10	7

5.1. Experiment 1: Comparison of Two Learning Conditions

The main study [21] engaged 67 children (32 girls) aged 8–11 years old in paper-based pre- and post-tests, including the conversion of 42 letters. Drawing on the study design and interaction scenario described above, children interacted with a robot in the following two experimental conditions:

- Latin-to-Latin: the child does the conversion mentally and writes directly in Latin.
- Cyrillic-to-Latin: the robot does the conversion. The child writes in Cyrillic and observes the Latin writing provided by the robot.

As a measurement of learning gains, Sandygulova et al. [21] used pre- and post-tests to calculate the difference between the number of learned letters and known letters. During the execution of the pre-/post-tests, it was critical that children were not shown the correct answers in cases of mistakes and hesitations. The main study results revealed that, in general, children improved their knowledge of the Latin alphabet during the experiment. The average number of new learned letters was 4.35 (SD = 3.7, Max = 18, Min = 0).

5.2. Experiment 2: Comparison of Learning Aids Study

Following the experiment conducted by Sandygulova et al. [21], Zhexenova et al. [22] carried out a study employing the Latin-to-Latin version of the experiment, with the procedures of a survey, a pre-/post-test, a learning activity, and an interview to compare which learning aid would result in greater learning gains across three different conditions:

- Robot condition: the child hears the word to be written pronounced by the robot in English and has to translate it to Kazakh and write it directly in Latin on the Wacom tablet using its stylus. Then, the robot simulates the writing while the letters are written on the tablet in Latin as corrective feedback.
- Tablet condition: the child is presented with a pop-up window on the tablet with instructions to first translate and then write the words in Latin-based Kazakh. The vocabulary is the same, and the 13 words are in the same order as in the Robot condition. When it is time for corrective feedback, the correct spelling of the words appears in the same way on the tablet as in the Robot condition.
- Teacher condition: the teacher speaks the Kazakh language and asks children to write the words in Latin-based Kazakh. The vocabulary is the same, and the 13 words are in the same order as in the other conditions. When it is time for corrective feedback, the teacher then shows a correctly written spelling in Latin-based Kazakh.

These conditions were distinguished to test a line of hypotheses underlying the effectiveness of performing a mental conversion of a linguistically diverse set of Kazakh words with the robot in the CoWriting Kazakh scenario (see [22] for details).

The study recruited 62 primary school-age children. The results demonstrated that the average number of learned letters was 3.67 (SD = 2.37, max = 9, min = 0). The results of the pre-/post tests revealed no statistically significant improvement in the number of learned letters in the three conditions. Children learned slightly more letters in the Teacher

condition (4.58 ± 2.19), followed by the Robot (3.58 ± 1.89), and Tablet conditions (2.9 ± 2.71), though without significance. As regards the comparison of learning aids, the paired *t*-tests and TOST equivalence analysis revealed no statistically significant difference and equivalence across the chosen conditions, and each learning aid provided more or less the same facilitation for learning gains.

6. Word and Letter Analysis

Using the data from these two experimental studies, we decided to further analyze if there were differences in cognitive gains depending on the specific linguistic characteristics of chosen words. Both studies presented words belonging to various categories and containing letters, some of which tended to appear repeatedly whereas others uniquely. To grasp a meaningful insight into the learning gains, we conducted a comparative analysis of pre-test and post-test results obtained from two experiments. The word and letter analyses are completely new and developed by the researchers taking into account the linguistic characteristics of Kazakh words. Prior to the statistical analyses, the words used in each experiment were written out in separate tables so that the letters' ratios could be counted. The obtained ratios were then used to run statistical tests such as the Friedman test, tests of normality, and post-hoc Wilcoxon tests. There was a statistically significant difference in learning gains between the three word groups of Experiment 1, $X^2(2) = 18.260$, $p < 0.001$. A post hoc Wilcoxon signed-rank test showed that the Easy Kazakh word category did not elicit a statistically significant change in learning gains ($z = -0.356$, $p = 0.722$) as compared to the Loan word category (see Figure 1). Median learning gain levels for the Easy Kazakh, Complicated Kazakh, and Loan words were 0.00, 0.15, and 0.05, respectively. There was no significant difference between the Loan word and Easy Kazakh word ($z = -0.356$, $p = 0.722$). However, there were statistically significant improvements in learning gains in the Complicated Kazakh vs. Easy Kazakh word categories ($z = -4.101$, $p = 0.001$) and Complicated Kazakh vs. Loan word categories ($z = -3.625$, $p = 0.001$). This signifies that the Complicated Kazakh words category resulted in significantly larger learning gains than the Loan Words, and the Easy Kazakh words were the least effective method for acquiring the new Latin-based letters.
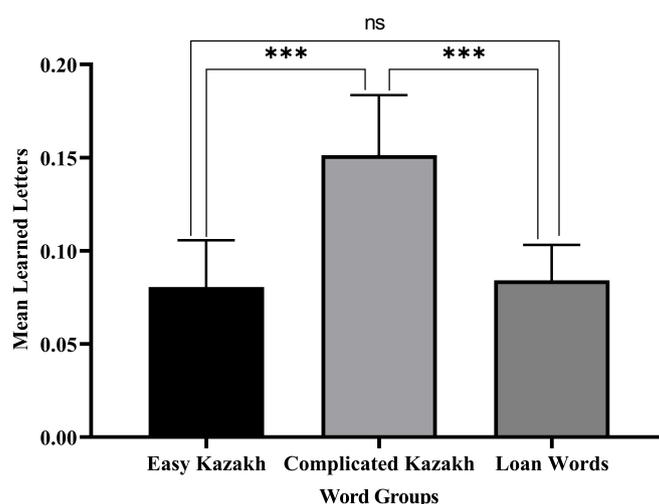

Figure 1. Mean values of learned letters by word categories in Experiment 1. *p*-values larger than 0.05 are summarized as "ns" (not significant), while *p*-values less than 0.001 are given three asterisks (***) to denote significance, as shown in the Wilcoxon test.

Similar results were achieved in Experiment 2. The Friedman test, conducted to determine any differences in learning gains, showed a significant statistical difference, $X^2(2) = 24.000$, $p < 0.001$. According to the post hoc Wilcoxon signed-rank test statistics, the comparison between the combination of Cognates and Kazakh words did not elicit

statistical significance ($z = -1.615$, $p = 0.106$) as compared to the value obtained in Friedman's test ($p < 0.001$). However, the remaining two combinations—Nonsense vs. Kazakh words ($z = -4.223$, $p = 0.001$) and Nonsense vs. Cognates ($z = -3.415$, $p = 0.001$), displayed significant differences in the learning gains (see Figure 2). This leads to the conclusion that Kazakh words and Cognate words are more effective in teaching and learning new Latin-based letters. The overall results of the analyses indicate that specific letters can be acquired effectively by employing particular word groups. The most effective way of learning the Latin-based Kazakh script was utilizing longer words made up of two or more syllables and containing a greater number of unique letters, i.e., complicated Kazakh words. When exposed to such long words as "raqmet", "teniz" and "koktem" (Experiment 1), they tended to show better memorization and mental conversion of the Latin letters. A nearly similar effect was achieved with Loan words ("football", etc.), involving letters intrinsic to the Russian language. However, the least effective method was found to be easy Kazakh words, resulting in a much lesser ratio of learning gains.
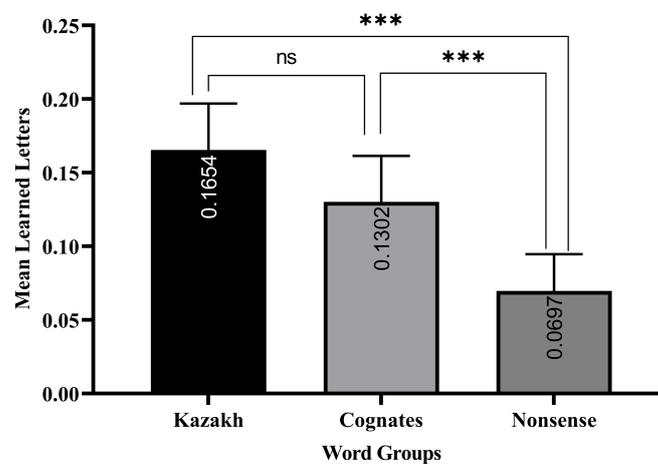

Figure 2. Mean values of learned letters by word categories in Experiment 2. *p*-values larger than 0.05 are summarized as "ns" (not significant), while *p*-values less than 0.001 are given three asterisks (***) to denote significance, as shown in the Wilcoxon test.

While Experiment 1 attempted to find out which groups of Kazakh words would be most effective, Experiment 2 intended to provide an answer to the question if Kazakh words were at all effective alongside completely different categories of words (such as cognates and nonsense words). Notably, the most effective strategy for learning the new script without the intervention of background knowledge was the use of Kazakh words. However, cognate words also played a positive role in the learning gains of the children. It was found that the nonsense words were less beneficial. Furthermore, we conducted a between-subject analysis of two datasets (Experiment 1 against Experiment 2), which totaled nine word combinations. Prior to deciding on performing either One-Way ANOVA or Mann–Whitney U tests, the data were assessed for an assumption of normality of the data distribution. As the data deviated from the normal distribution, we opted for the Mann–Whitney U test in all nine word group combinations to determine if there were differences in learning gains between the word groups of Experiment 1 and Experiment 2. Thus, each word group from Experiment 1 was compared against the word groups in Experiment 2, which resulted in three sets of word group combinations. The learning gain ratios were found to be statistically significantly different between four word group combinations, as the distributions were not similar. For instance, the Mann–Witney U test showed a significant difference between complicated Kazakh and Nonsense ($U = 1185$, $p = 0.001$), Easy Kazakh and Cognates ($U = 2779$, $p = 0.001$), easy Kazakh and Kazakh ($U = 2947$, $p = 0.001$), and Loan words and Kazakh ($U = 2951$, $p = 0.001$) groups (see Figure 3). Meanwhile, distributions of the learning gain ratio for the remaining groups were similar,

as assessed by visual inspection. The ratio for easy Kazakh and nonsense words were not statistically significantly different, U = 1969, z = −0.726, *p* = 0.468. Similarly, no significant differences were found in the ratios between loan words and nonsense words, U = 1752, z = −1.753, *p* = 0.080; cognates and complicated Kazakh words, U = 1966, z = −0.683, *p* = 0.495; loan words and cognates, U = 2333, z = 1.056, *p* = 0.291; complicated Kazakh and Kazakh words, U = 2164, z = 0.251, *p* = 0.802. Similar to the results retained from the separate analysis, word groups such as complicated Kazakh, Cognates, and Kazakh have proven to be the most effective according to the Mann–Whitney U statistics. We can thus conclude that the learning gains vary depending on categories of words containing certain letters. The analyses of linguistic characteristics of words confirm that the learning of new letters is best facilitated by words, where familiar letter shapes appear frequently. In our experiments, such words occurred in the groups of complicated Kazakh words, loan words, and Kazakh words for the most part. These findings have important implications for understanding how the acquisition of a new alphabet can be handled and curated effectively by educators through the focus on a student's cognitive abilities, which trigger the learning gains regardless of prior knowledge.
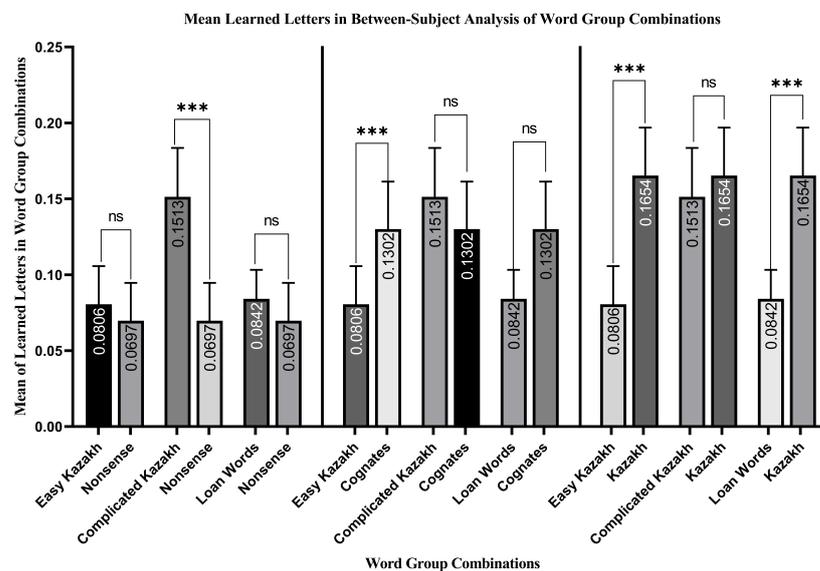

Figure 3. Mean values of learned letters by all word categories in between-subject analysis. *p*-values larger than 0.05 are summarized as "ns" (not significant), while *p*-values less than 0.001 are given three asterisks (***) to denote significance.

7. Theoretical Framework

In this section, we provide the grounded theoretical framework developed after exploring the literature on literacy development and robot-assisted education and conducting word and letter analyses. This section serves the purpose of explaining the robot-assisted script learning scenario and how such a learning environment stimulates higher cognitive gains. Having reviewed different concepts and theories, we propose a framework that can help grasp the essence of a child–robot interaction enriched with a range of cutting-edge tools. In particular, we attempt to demonstrate that cognitive processes, such as visual memory, phonological decoding, mental selection, and the conversion of letters, may be influenced by biscriptal practices.

7.1. Writing as a Cognitive Process

Research on Second Language Writing System (L2WS), which intersects with multidisciplinary research areas, accepts that learning the new script requires a set of cognitive processes such as recognition, good visual skills, and metalinguistic awareness [95]. When learning to write, a person may experience recognition and mental selection of a grapheme

corresponding to a sound that the letter represents. The use of familiar and unfamiliar words (i.e., "pseudowords" or "nonwords") is likely to activate those cognitive capabilities [96]. Learning to write, namely, handwriting, takes a considerable amount of time for preschoolers to master. This difficulty depends on the automatization of handwriting, which, in turn, unleashes the working memory, providing much space for higher-order skills [97]. As noted by [98], this working memory, known as a cognitive workbench, usually controls mental activities that allow us to write, read, and do basic arithmetic.

According to (Cook and Bassetti [95] p. 24), "different writing systems have an impact on nonlinguistic aspects of cognition". Those are visual memory, perception of movement (due to the directionality of writing), and perceptual span (in reading). Indeed, the study on transliteration has shown that the shifts between different alphabetic writing systems can assist the development of cognitive abilities in young learners [56]. This finding is consistent with that of Li and James (2016) [99], who demonstrated the active role of handwriting and tracing exercises as a driving mechanism of cognitive assets. One type of such a cognitive process that occurs during the conversion of scripts is "phonological decoding" [100]. Unlike transliteration, in phonological decoding, children should convert the written symbols to the corresponding sounds. The process of script conversion relies on the mental selection of words, which may be possible due to the lexical items (i.e., letters and words) stored in the cognitive system throughout one's lifespan and are accessed easier and quicker when studied at an early age [101,102]. From this, it follows that children, already familiar with several scripts/alphabets, can thus retrieve those words and letters appropriately from their mental lexicon.

7.2. Embodied Learning Scenario

Another significant aspect of cognitive learning is the environment alongside the tools and tasks it provides. Children's learning environments enriched with visual and physical materials seem to activate several cognitive processes, namely selective attention and working memory, involved in the processing of visuospatial information [103]. By and large, learning settings where the cognitive load is incorporated into physical user interfaces are viewed through the embodied learning scenario [104]. Embodied learning scenario, which relies largely on bodily movements, has been recognized to have a positive impact on children's cognitive and academic performance as well as on language development and comprehension [105]. According to Kosmas, Ioannou, and Zaphiris's (2019) [105] study, in the context of investigating Kinect-based educational games, leveraging embodied learning connected physical activities with cognitive ones. As a result, second and third graders displayed high cognitive and academic performance, especially in language and vocabulary acquisition.

7.3. Distributed Cognition Theory

The framework we intend to propose heavily relies upon the constituent of the cognitive learning theory, namely, the distributed cognition (DCog) theory coined by Hutchins [106]. It is believed that the theory of distributed cognition is useful in explaining the cognitive learning processes that result from the synergetic use of various tools in an educational setting. Moreover, this theory is deemed appropriate for the following constituents that distribute cognition through [107,108]:

- **Social distribution**: dynamics of (group) thinking and decision-making
- **Symbolic distribution**: signs and language
- **Physical distribution**: robots, tablets, and other tangible artifacts

Combined, these constituents contribute to the creation of a favorable condition, encompassing learner, artifact, and tool situated in a sociocultural context (see Figure 4). Such an environment, in turn, accelerates cognitive abilities required for the completion of a task through interaction, the success of which relies upon the external driving forces.
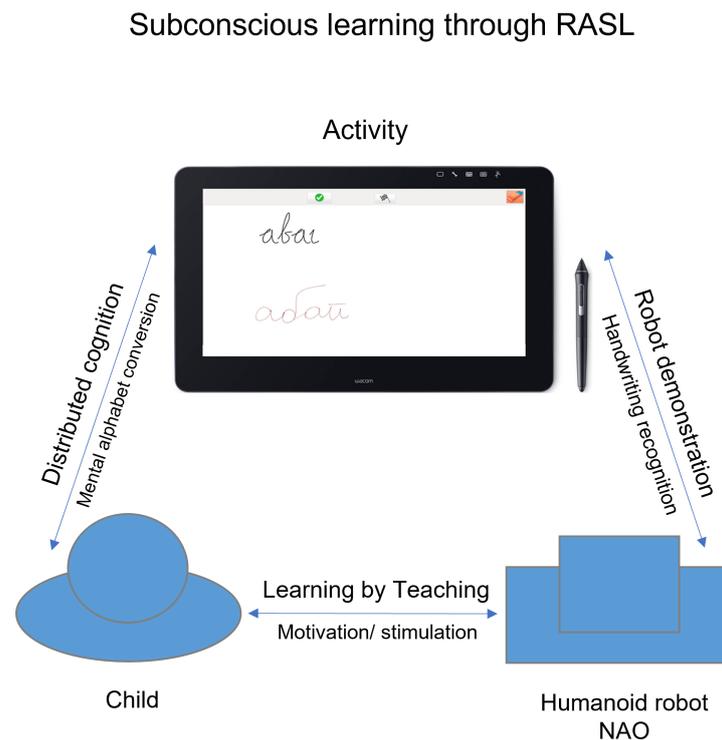
Subconscious learning through RASL

Figure 4. The RASL setup for subconscious learning.

Research on cognitive perspectives of HRI suggests that "educational robotics provides active development of the entire complex of the cognitive processes, like perception, problem-solving, imagination, thinking strategies, memory, and speech in learners" ([109] p. 200). Thus, learners' engagement with educational robots makes the two dimensions explicit: (1) technology-led action; and (2) learner/user-led action. Given the appropriately developed learning activities enforced with cognitive technological tools, learners are believed to achieve higher cognitive skills without causing frustrations. By interacting with the social humanoid robot NAO, children subconsciously retained the new Latin-based alphabet. Our evidence shows how an interaction design with a social robot provides an additional stimulus that affects cognition.

As Hollan et al. (2000) ([110] p. 178) asserted, "from the perspective of distributed cognition, the organization of mind—both in development and in operation—is an emergent property of interactions among internal and external resources". By internal resources, the authors imply the intellectual and cognitive processes, while the external ones are here represented in the face of agents, which accelerate and trigger those processes. Indeed, the joint involvement of symbolic and physical means can diversify the learning activities to enhance cognitive powers, enabling fast information processing, high-level thinking, problem-solving, and decision-making [111]. The framework of distributed cognition provides insights into the role and function of multimodalities used to mediate activities requiring interaction and occurs in many intersecting fields, such as HCI and distance learning [110]. Research on cognitive perspectives of HRI suggests that "educational robotics provides active development of the entire complex of the cognitive processes, like perception, problem-solving, imagination, thinking strategies, memory, and speech in learners" ([109] p. 200). Thus, learners' engagement with educational robots makes explicit the two dimensions: (1) technology-led action; and (2) learner/user-led action [109]. Given the appropriately developed learning activities enforced with cognitive technological tools, learners will be able to achieve higher cognitive skills without causing frustrations.

Overall, combining various learning strategies with an emphasis on multiple mediators could serve as catalysts for the development of cognitive assets. The framework of distributed cognition covers the dimensions of language and literacy learning in human-to-

human, human–agent and human–robot interaction scenarios accompanied by cognitive tools. It can thus be applied to a wider area of HRI and HAI research intersecting with other fields.

Figure 5 illustrates the framework developed based on concepts and theories discussed in this section. Through integrating an interdisciplinary theoretical research framework, as Sandygulova et al. [20] explain, researchers are better positioned to understand complex topics. We believe that child–robot interaction in the scope of our study enables children to acquire a script followed by positive cognitive processes in their minds. Our theoretical framework focusing on RASL encompasses four pillars—teaching, learning, language, and distributed cognition. This framework integrates all multifaceted learning processes that shape alphabet acquisition in multimodal ways. The language component includes script learning, handwriting exercise, and word representation both in Kazakh and English. The cognition component encompasses mental selection, phonological decoding, and recognition of words as key cognitive processes children experience in the script acquisition environment. Combined, the given framework helps guide our understanding of the major concepts and theories in the field of literacy development and cognitive learning context.
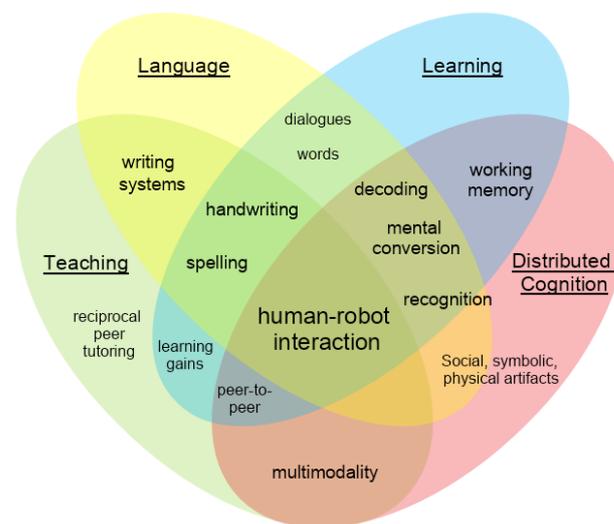

Figure 5. Visual representation of the theoretical framework for RASL.

8. Discussion

The findings of the two previous studies reported in this paper show consistency with the literature. The proposed CoWriting Kazakh learning scenario enabled students to practice and learn new Kazakh Latin letters with the peer robot. It is observable that the scenario involving multimodal human–robot interaction, peer-to-peer, and learning-by-teaching strategies can contribute to building an effective alphabet learning environment. The multifaceted theoretical framework could be used to make sense of the complex learning and teaching events and provide support in choosing suitable instructional approaches in the RASL scenario. Thus, combining various learning strategies with an emphasis on multiple mediators could serve as a catalyst for the development of cognitive assets. The framework of distributed cognition covers the dimensions of language and literacy learning in human-to-human, human–agent, and human–robot interaction scenarios accompanied by cognitive tools. It can thus be applied to a broader area of HRI and HAI research intersecting with other disciplines. Moreover, there is an important instructional implication for educators to consider such multimodal and interactional design for the effective teaching of the Latin-based alphabet.

The results from word and letter analyses provide supporting evidence for our framing as an essential part of the robot-assisted alphabet learning scenario. As proposed in Section 7.3, our study relies on distributed cognition theory underlying subconscious learning between a learner and a robot during the script conversion task from Kazakh

Cyrillic to Kazakh Latin. In Experiment 1, although it was straightforward that children would learn letters through simple words chosen for the category of Easy Kazakh, we found that this set of words was the least effective for mastering the new alphabet. By contrast, children learned better when they were mentally challenged to write long words with unique Kazakh letters. In Experiment 2, the results showed that mastering Kazakh words containing unique letters was the most significantly effective strategy compared to English cognates and other nonsense words. This finding aligns with the results from Experiment 1, as both found significant cognitive gains for Kazakh words, including their special marks. Learning those Kazakh-specific letters could stimulate cognitive processes and thus facilitate memory retention, though in the short term.

The ability to write in different scripts or commonly referred to as biscriptality, is an example of a neglected understanding of bilingualism that is believed to be cognitively rewarding for multilingual learners [112]. We thereby suggest that writing in different scripts brings an added value to becoming bilingual and improving metalinguistic skills across one's linguistic repertoire. In addition to acquiring different scripts, the handwriting practice in itself involves a complex set of sensorimotor and cognition skills [70]. These mental and writing activities form a lasting relationship that benefits learners in mastering both the new alphabet and its handwriting. The recent study from our project [113] showed that the quality of both Cyrillic and Latin writing increased across primary grades depending on the amount of writing experience children had at the time. While the improvement in Cyrillic writing was attributed to more practice, the improvement in Latin script was most likely due to the transfer of fine motor control skills from Cyrillic to Latin, especially as both scripts are written in the same direction (from left to right). In this regard, the importance of exploring cross-cultural literacy acquisition becomes more evident for under-studied speech communities and their native scripts [23]. Future works should focus on how handwriting in different scripts evolves from word to sentence level, which may expand our understanding of how children build meaningful communication in a complex way through writing and cognition.

9. Conclusions

In this paper, we aim to present a theoretical base for cognitive learning within the CoWriting Kazakh project. The framework we propose based on the previous research data and word and letter analyses shows the feasibility and importance of creating and implementing various learning scenarios for CoWriting Kazakh that aim to discover the cognitive aspects of a novel co-writing project through interactive learning with the robot. In this regard, we drew on Hutchins' (1991) [106] Distributed Cognition theory, which is fundamental in understanding the subconscious learning between a learner and a robot reinforced with cognitively demanding tasks. Drawing on the existing knowledge on HRI and tech-based educational tools and activities studied in relation to language and literacy acquisition (L1 and L2), their facilitative nature can be confirmed for children at the primary level of education. Since there are two functioning scripts used for the written Kazakh language (e.g., Cyrillic and Latin) and, considering the benefits of biscriptal practices, the CoWriting Kazakh project can deploy both scripts for improving children's cognitive and linguistic development through human–robot interaction and using the handwriting, tracing, and spelling exercises. In the longer term, the system can be applied to the types of remote learning administered either by parents or teachers in the home settings. Such steps offer opportunities for both reducing obstacles in learning a new script while integrating teaching that can enhance equitable, inclusive, and accessible learning. Depending on the cognitive demand that learners encounter and their varying cognitive development levels, learning scenarios should acknowledge these and distribute the cognitive load in a meaningful way compared to the conventional instructional settings.

Abbreviations

The following abbreviations are used in this manuscript:

RASL	Robot-assisted script learning
RAAL	Robot-assisted alphabet learning
HRI	Human–robot interaction
HAI	Human–agent interaction

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