Cognitive Development in a Bilingual Environment: To Explore the Effect of L1 and L2 use on Early Cognitive Performance in Children

Jingou Feng

The Steinhardt School of Culture, Education, and Human Development, 10012, The United States
Email: fjingou@gmail.com

In China, learning two languages at the same time is becoming more and more common. It's because of real environmental factors, like the fact that the market for English-speaking professionals is growing all the time. Subjective individual factors should also play a role. For example, how well a child can learn a language should have something to do with learning two languages. However, the impact of learning two languages on a child's cognitive growth remains understudied. The purpose of this paper is to talk about bilingual environments and how well kids learn. Learning a second language earlier may alter aspects such as memory, creativity, social and communication skills, academic abilities, and cognitive flexibility. Because their brains are more flexible, children are better able to handle new information, such as learning a second language, than adults. This is due to the way the brain naturally develops. This study summed up the effects on cognitive development using the LLM model. It showed that learning a first or second language as a child was a significant event that could impact a child's cognitive development.
Keywords: Bilingual environment, cognitive development, L1 and L2 learner, LLM, cognitive skill.

1. Introduction

Globalization has accelerated the process of assembling social networks that connect distant places. Globalization has made language crucial as it facilitates communication between people and places, subject to external influences. People who have kids thought that learning

a second language as a child was a beneficial idea because it would help them get ready for school and give them more job options in the future [1].

Getting their kids educated in both Chinese and English is becoming more and more important to Chinese parents these days. The Ministry of Education's 2010 Advancement of National Education on Statistical Bulletin reveals that English training, a significant component of China's education and training market, generated more than 15 billion yuan in revenue in 2009. A number of factors are contributing to this growth. To begin, tourism is growing quickly. Second, there are a lot of people who use the Internet, and English is used 56.4% of the time. Third, English has become more and more important in primary and secondary schooling [2]. This study will be about how learning two languages, like English and Chinese, affects the skills of children.

In China, where the economy is growing quickly, people's cognitive skills are also getting better, especially in cities. For example, studies show that funding for kindergarten and brain development programs has greatly improved the cognitive skills of kids living in cities [3]. Also, improvements in technology have made it easier to share educational materials. This means that more people have access to cognitive training tools and learning possibilities, which helps improve the general cognitive health of the country. Nigeria is trying to improve cognitive abilities, even though there are problems like limited access to excellent healthcare and schooling [4].

Many studies have focused on bilingual education, particularly on the impact of bilingualism on language learning. However, there is a dearth of studies examining the impact of bilingualism on children's cognitive abilities, and those that do exist often lack sufficient depth [5]. Given the previous discussion, it is crucial to expand our understanding of how bilingual education influences the development of children's cognitive skills. We believe that teaching children in two languages is crucial, and when doing so, teachers should prioritize not only their language development but also their overall growth. We place such a high value on preschool education that we are setting higher standards for its quality. This is because bilingual preschool teaching is growing quickly in our country [6]. For a minority, the caliber of instruction primarily reflects the caliber of the students receiving it. The main reason for evaluating a child's schooling quality is to see how they grow. We can help us get a sense of the current school situation and figure out what's wrong by looking at how the kids are growing up [7].

This study examined the effects of learning a first or second language on cognitive development, including memory, innovative thinking, social and interpersonal abilities, academic abilities, flexibility in thinking, and theories of brain growth associated with these areas.

2. Literature review

High an autoregressive effects are used in this work for both word decoding and reading comprehension. L2 learners demonstrated delays in vocabulary, phonological awareness, and RAN in kindergarten [8]. When comparing studies of children from middle-class socioeconomic backgrounds and research from a single lab, a moderator analysis revealed

substantial group differences on EF in favor of bilinguals [9]. Significant multilingual benefits were represented by the EF components of cold inhibition, switching, and monitoring; however, publication bias had an impact on cold inhibition and monitoring [10]. This article examined the ranking values of schemes in English and French bilingual educational environments, as well as the variations in weight and standard deviation [11]. This study offers educators and policymakers a potent tool for decision assistance that allows them to assess various multilingual teaching strategies under various settings and qualities [12]. Youngsters in bilingual preschools scored higher on the reading and numeracy tests than children in regular kindergartens, according to this paper's examination of children in two kindergartens in SH City. This suggests that bilingual environments help children develop their cognitive abilities [13]. According to this article, providing such support over an extended period of time may help to mitigate the detrimental impacts on academic performance that have been linked to students from low socioeconomic backgrounds or those with "migrant backgrounds." [14].

An investigation into the evolution of bilingual schooling in Chinese and English

Jingshi T G was the first institution to offer foreign language instruction; it changed its name to University in Beijing 1912. In 1862, the Qing Dynasty established it. United Protestant missionaries promoted cultural interchange among China and the West and introduced bilingual education to the country in the early 1900s [15]. The contemporary era of multilingual education began with this. Famous Chinese-English bilingual schools started to open as a result. These educational institutions included Shanghai's St. John's University, which established bilingual education in 1910, and Yali Middle School and its related primary and secondary schools, that educated every subject using English excepting Chinese language arts [16]. English has gradually taken the place of Chinese as the official language of numerous events since the Chinese government began a reform program in the late 1970s to become more active in trade between nations and the global economy. Since the end of the World Trade Organization (WTO) era, the English language has become increasingly prominent in China's coastal regions. China's Ministry of instruction (MOE) promoted bilingual instruction in Chinese institutions in 2001 in an effort to keep up with the nation's explosive economic expansion. Over the following three years, it was decided to teach 51 percent of courses in subjects like information technology and biometrics in Chinese, English, or a foreign language [17]. Since then, a lot of work has been done to promote bilingual education. Many colleges feature multilingual courses in biology, chemistry, physics, engineering, finance, law, and other areas in big towns like Beijing, Shanghai, and Guangzhou. Making rules, identifying financing sources both inside and outside the school, and compensating qualified teachers have all benefited from this.

Bilingual education

Around the world, kids from kindergartens to colleges are trying out and adopting bilingual education. In China, bilingual education is becoming more and more common. An expert from the University in Beijing in Education science said, "In Beijing, there used to be a kindergarten with only 12 kids." The area was empty and the gear lay unused [18]. To try to attract more kids, the school put up a kindergarten sign that speaks more than one language.

Chinese and English languages

Preschool English instruction in China still faces significant challenges. To begin, teachers aren't very good. Since there aren't many requirements to become a kindergarten teacher, schools can hire teachers directly from the community. Graduates who aren't kindergarten teachers can also join the school through advertising. It's possible for teachers at some preschools to not have enough schooling. Issues such as insufficient experience with professional training have a direct impact on the methods and quality of teaching English to children. Some English teachers use indoctrination to teach the language, only making the kids remember words and sentences because they haven't had any special training. Little kids lose interest in learning English because of this propaganda. The second factor is the influence of the classroom environment. Children frequently forget the fundamentals of English that they learnt in kindergarten [19]. This is because of things like how their brains are developing and how much they actually learn. The above observation reveals ongoing issues with the dual-language education of young children in China. As a result, people have a lot of different opinions about teaching English in preschool. Some experts are also against bilingual (mostly Chinese and English) education for various reasons. Li says that teaching two languages is not the same as teaching a foreign language. Li also made the strong argument that China can only teach a foreign language and not two languages [20].

 Education in Chinese and other languages

It is well known that China has 56 different racial and cultural groups. Guizhou Province, China, is one place where many Hmong people reside. This is Leishan's area in Guizhou. People in the Leishan area mostly speak the local Chinese dialect and the Hmong tongue. All schools aim to get people to speak Mandarin, and teachers teach in Mandarin. Teachers teach everything in Mandarin, with the exception of the Hmong language. In class, kids read out loud and talk in Mandarin. Kids talk to their parents in Hmong when they're at home. Teaching Mandarin classes is the most common way to teach Hmong and Chinese at the same time. In general, kids from ethnic minorities learn and communicate in school and home at both Mandarin and their own language at school.

Children's cognitive abilities: Different academics have different ideas about what "cognition" means. Figure 1 shows that foreign scholars think of cognitive ability as the ability to see, understand, examine, and judge one's own situation, as well as the connection between the two. Some researchers divide student learning ability into three parts based on cognitive performance theory: "learning," "thinking," and "learning efficacy." In their ability theory, some people also divide human ability levels into four groups: speech ability, memory, intelligence, and problem-solving skills [21]. There are also those who believe that schooling and training, such as reading and thinking training, can enhance an individual's intelligence.
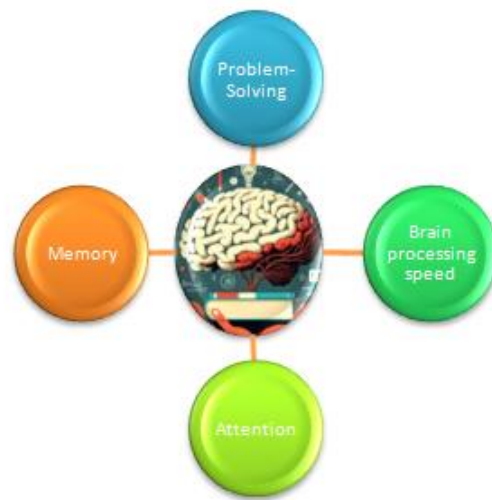
Figure 1: Cognitive ability for children

LLM

To work with bilingual people who speak two languages, LLMs are new developments in deep learning models. The study has demonstrated some excellent applications for LLM. LLM is a lined up in DL model that comprehends and composes text in a human language. A large transformer model performs all tasks in the background. LLM employs transformer models and acquires knowledge from extensive, multilingual datasets, which accounts for their large size. This way, they can read, translate, guess, or make up text or other material. Neural networks (NNs), which are computer systems modeled after the brain, are another name for large language models [22]. These neural networks function by stacking a network of bilingual learning, much like neurons do.

Artificial intelligence (AI) programs can learn two languages at the same time. We can instruct large language models to perform various tasks, including understanding protein structures and writing software code, to gain insight into children's cognitive processes. Similar to the human brain, large language models require initial instruction and subsequent fine-tuning to address tasks such as text recognition, query response, documentation summary, and text generation. Big language models contain a multitude of parameters. These parameters are comparable to the recollection that the system accumulates throughout training. These variables can be viewed as the informational library of the bilingual model.

LLM Architecture

The large language model is mostly made up of many layers of neural networks, such as layers with recurrent, layers with feedforward, layers with embedding, and attention layers in attention. Together, these layers process the text that comes in and make predictions about each child's cognitive growth.

• The embedding layer transforms each word in the incoming text into a high-dimensional vector representation. These embeddings store information about the meaning and form of the words, helping the model understand the situation in a bilingual language (L1).

• Large language models of feedforward layers have many fully linked layers that change the input embeddings in nonlinear ways. These layers assist the model in acquiring broader concepts from the provided text.

• LLMs design their repetitive layers to process information from the text in a specific order. Each time step changes the hidden state these layers maintain. This enables the model to comprehend the connections between words in a sentence.

Another important feature of LLMs in the attention system in bilingual learning enables the model to concentrate on various sections of the input content.

This self-attention aids the model in concentrating on the crucial sections of the provided text, thereby enhancing its predictive accuracy. This process is referred to as autoregressive creation. The large language model operates in this manner: it is a transformer model capable of processing lengthy input texts, a large context vector capable of handling complex concepts, and it incorporates numerous layers in both the encoder and decoder.
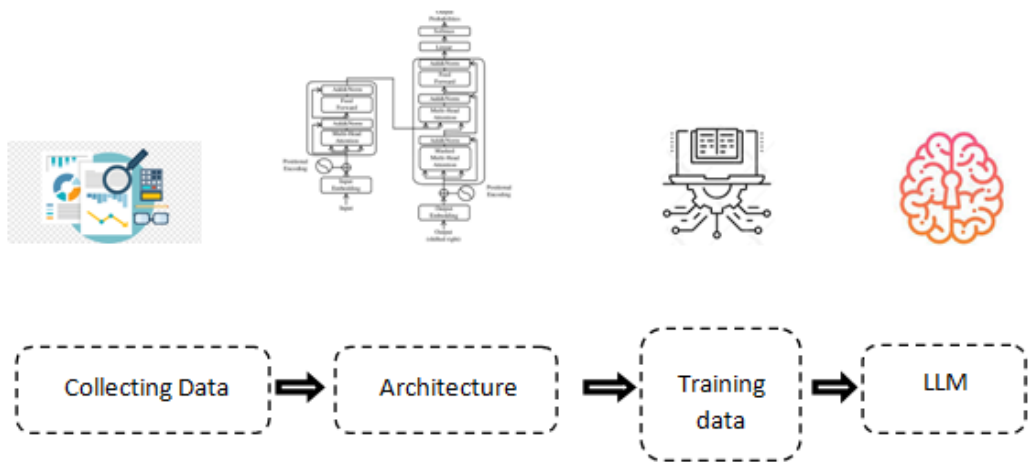

Figure 2: Proposed method

Here is a list of some of the most important ways that LLMs help businesses:
• Textual generation: the ability to come up with language on your own, such as writing emails, blog posts, or other medium- to long-form content in response to prompts that can be improved and polished. A great example of this is retrieval-augmented generation (RAG).
• Document summary: Turn lengthy articles, news stories, research reports, company paperwork, and even customer histories into detailed texts that are the right length for the output format.

• The code generation process aids developers in creating apps, identifying errors in code, and identifying security vulnerabilities in various computer languages, even facilitating "translation" between them.

• Language analysis: look at text to figure out the customer's tone, understand large amounts of customer feedback, and help control a brand's reputation.
• Language translating: offers organizations a wider reach across languages and locations with accurate translations, as well as the ability to work with people who speak more than one language.
LLMs have the potential to change every aspect of bilingual education, from automating self-service for customers to improving accuracy, routing, and gathering intelligent context. They will also speed up response times for a growing number of jobs.

Perplexity

The perplexity of a bilingual language model on a given text corpus is the most common way to assess how well it works. Perplexity is a way to rate how well an LL model can guess what will be in a dataset. The lower the perplexity, the higher the chance the model gives to the dataset. According to math, perplexity is equal to the exponential of the average negative log probability per token:

$$\text{Log(Perplexity)} = \frac{1}{M}\sum_{i=1}^{M} \log(\Pr(\text{token, |context for tokens i}))   \quad (1)$$

Here, M represents the maximum number of tokens in the text collection, and "the context of the for token i" differs for each type of LLM. If the LLM is autoregressive, "the context for token i" is the part of text that comes before token i. In the case of a hidden LLM, equation 1 illustrates that the "context for token i" refers to the text surrounding token i.

To estimate the average effect of bilingual education on processing,

$$\text{ATT} = \text{E}(\text{testscore1} - \text{testscore0}|\text{Di} = 1, \text{P}(x))   \quad (2)$$

Equation 3 illustrates the sequence of probability in L1 phrases.

$$S(w_1, w_{2\ldots} w_{n)}   \quad (3)$$

The probability of words given the words that came before them in equation 4

$$S(w_{n\,|w_1,w_{2\ldots}w_{n-1)}}   \quad (4)$$

Equation 5 shows the chain rule for bilingual learners.

$$S(x_{1,}x_{2\ldots\ldots}x_n) = S(x_1)*S(x_2|x_1)*S(x_3|x_1 \ldots \ldots x_2)*S(x_n|x_{1\ldots\ldots\ldots}x_n - 1)   \quad (5)$$

Can be altered in Equation 6 to match Equation 5.

$$S(w_1, w_{2\ldots} w_{n)} = \prod_{i=0}^{n} S(w_i   \mid w_{i-1}\ldots..w_1)   \quad (6)$$

Markov Assumption of Bilingual performance into equation 7

$$S(w_1, w_{2\ldots} w_{n)} = \prod_{i=0}^{n} S(w_i   \mid w_{i-1}\ldots..w_{i-k})   \quad (7)$$

Unigram model is illustrated in equation 8

$$S(w_1, w_{2\ldots} w_{n)} = \prod_{i=0}^{n} S(w_i)   \quad (8)$$

Equation 9 shows the maximum likelihood estimate for the bilingual Bigram optimization model.

$$S(w_i| w_{i-1}) = \frac{Count(w_{i,}w_{i-1})}{Count(w_{i-1})} \quad (9)$$

Bilingual language models might fit their data used for training too well, so they are generally judged by how well they do on a test set of data they haven't seen before. This makes it challenging to evaluate big language models in a certain way. Models, trained on increasingly large text collections mostly scraped from the web, are more likely to accidentally include parts of any given test set in their training data.

Fine-Tuning LLM

In this paper, we use a more parameter-efficient method. The task-specific parameter increment increment $\Delta\phi = \Delta\phi(\theta)$ is represented by a much smaller set of parameters θ with $|\theta| << |\phi_0|$. This task of $\Delta\phi$ finding turns into optimizing over θ:

$$\max_\theta \sum_{(x,y)\in Z} \sum_{t=1}^{|y|} \left(\log(P\phi_0 + \Delta\phi(\theta)(y_t|x, y_{<t}))\right) \quad (10)$$

In the subsequent sections, we proposed to use LLM bilingual representation to encode $\Delta\phi$ that is both compute and memory efficiency in L1 and L2.

3. Results and Discussion

Because of their cognitive nature, children exhibit a high degree of open to new experiences. They are more likely to believe that they can simply adapt new ideas into their own thinking in accordance with the game's new rules. Its nerves' suppleness is largely responsible for its open thinking. As they grow older, youngsters will more depend on targeted motivation and methodical learning, as well as on previously learned habits and life experiences. It is evident that kids are more likely to study a second language and are more engaged in doing so. Furthermore, because of their imperfect cognitive development and their L2 learning process, children experience comparatively less psychological pressure. Consequently, children can develop stronger speech abilities during this delicate stage if parents and preschool teachers provide phonetic, vocabulary, and grammar incentives at the appropriate times based on the language cognitive level of the kid. For kids these days, learning two languages has obvious advantages. First of all, learning L1 and L2 at the same time might benefit one another because they share a lot of similarities.

Table 1: Kindergarten development process in cognitive level

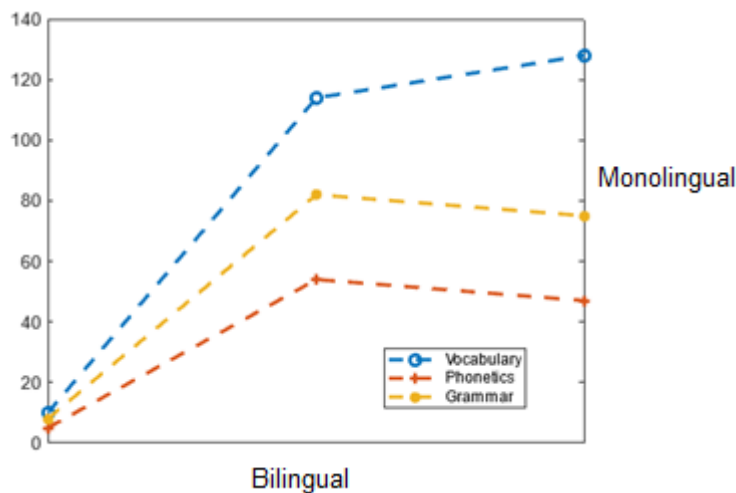|	Vocabulary	Phonetics	Grammar	Sample data
Monolingual	114	47	75	250
Bilingual	128	54	82	250

Figure 2: children language in cognitive level

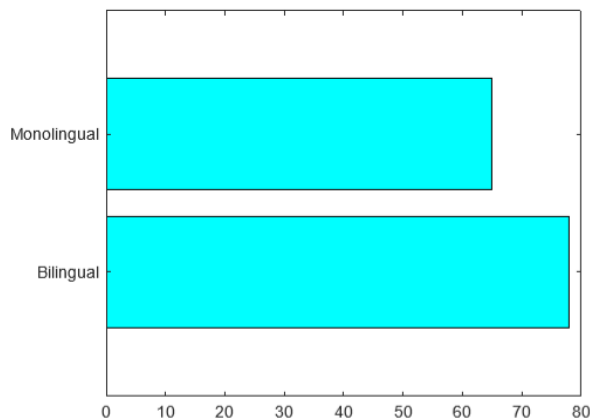Learners of Bilingual and monolingual

Figure 3: Evaluation of bilingual and monolingual learner

L1 and L2 learners

Variations between L1 and L2 learners in terms of literacy measures:

L1 and L2 learners in terms of language and cognitive development, decoding with word development, and understanding of text development in kindergarten. First, we looked into whether kindergarten assessments of vocabulary, knowledge of graphemes to phonemes, first separation of phonemes, segmentation in phoneme, fast naming, and verbal and visual short-term memory differed between L2 and L1 learners.This indicates that the home environment had no bearing on the Group's (L1 or L2) effect on the kindergarten metrics. In terms of vocabulary, phoneme segmentation, and quick naming, the L2 learners performed worse than the L1 learners (Table 2). For the univariate tests, no interaction effects were discovered, which is consistent with the findings from the total multivariate analyses. This

indicates that the educational level had no moderating effect on the group differences observed for vocabulary, phoneme segmentation, and quick naming.

Table 2: Statistical analysis of L1 and L2 learner

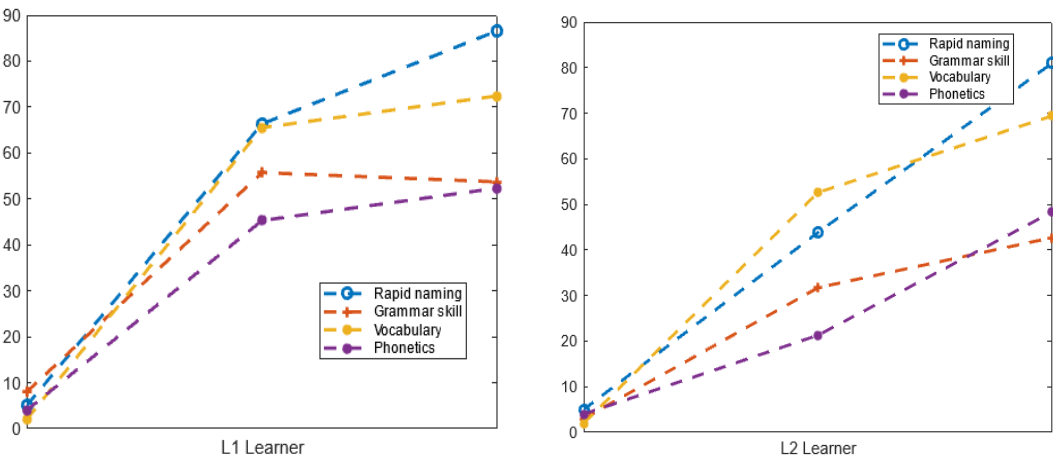| Measurement	Group L1 and L2	Mean	Standard Deviation
Rapid naming	L1 learner	66.34	86.62
	L2 learner	43.84	81.03
Grammar skill	L1 learner	55.73	53.71
	L2 learner	31.36	42.23
Vocabulary	L1 learner	65.52	72.43
	L2 learner	52.61	69.02
Phonetics	L1 learner	45.3	52.36
	L2 learner	21.29	48.10

Figure 4:Outcome of L1 and L2

Years spent learning English and attitudes regarding bilingual education Out of a total of Sixty perceptions, the mean was 42.23 (SD 6.72), indicating that, students in average had good opinions. The results of the correlational analysis showed a significant association between the number of years of English learning and students' perceptions of bilingual education, indicating that the more years of learning in English, the more favorable the students' judgments were of bilingual teaching. Regarding attitudes toward bilingual education, there was no discernible gender difference, $F(1, 141)$ 0.321, p 0.572.

Accuracy

To explore the effect of L1 and L2 using cognitive performance is analyzed by accuracy in Table 3,4 and Figure 5 show the accuracy's outcome. Our suggested approach had a higher LLM (96.30%) prediction than the current methods, which are PSM (88.21%), OLS (91.62%). When compared to existing approaches, the proposed approach, LLM, has significantly improved bilingual teaching environment.

Table 3:Grouping L1 and L2 with three models

Age(years)	Group L1 and L2	PSM	OLS	LLM[Proposed]
1-2	L1 learner	65.34	87.72	92.65
	L2 learner	52.73	71.03	79.41
2-3	L1 learner	56.53	78.01	83.06
	L2 learner	43.21	59.23	71.64
3-4	L1 learner	85.41	91.19	95.52
	L2 learner	69.11	89.02	90.02
4-5	L1 learner	88.33	92.34	97.42
	L2 learner	61.29	88.10	89.99

Academic achievement of students is positively connected with the teaching environment of a school. According to these study findings, multilingual instruction using LLM has a higher effect on kids' cognitive development. Additionally, using L1 and L2 combined in kindergarten is preferable than using L1 alone, and the promoting effects of each module of children's individual cognitive development vary, with a higher benefit to word ability and a lesser benefit to mathematics. Additionally, bilingual teaching environments can actively forecast children's cognitive growth and have a more pronounced promotion effect on word performance, as demonstrated by Chinese researchers, which has a good impact on children's learning. The chart also shows that other variables associated with people's cognitive development have a significant impact on people's cognitive growth.

Table 4: Outcome value of Accuracy

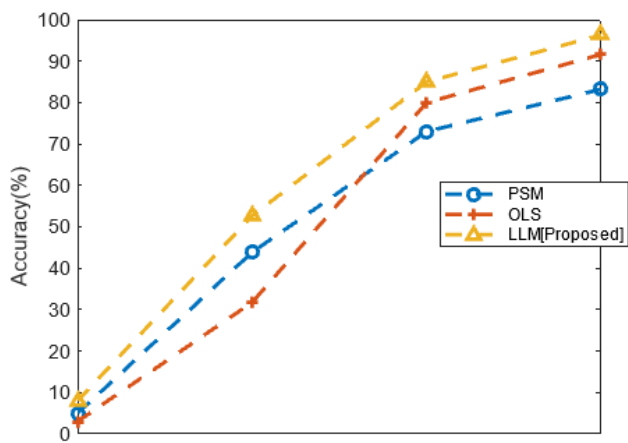| Models	Accuracy(%)
PSM	88.21
OLS	91.62
LLM[Proposed]	96.30

Figure 5: Outcome of accuracy

4. Conclusion

This study's main focus is on how bilingual environments affect kids' cognitive development. The literature from earlier times suggests that children's cognitive ability develops gradually. Despite the growing popularity of bilingual education—primarily in Chinese and English—

in China, the country's prosperity conceals certain drawbacks, and experts' perspectives on this topic remain divided. Based on the reported findings, we offer recommendations to academics and practitioners. Future research ought to adopt a more detailed categorization of bilingual environments, according to academics. In conclusion, kindergarten bilingual students have a higher cognitive level. Providing bilingual education to students at an early age can enhance their language proficiency through the use of L1 and L2. Additionally, bilingual environments encourage children to think critically, which helps to develop their inhibitory processing skills and alters how the brain functions. To ensure the ecological validity of future studies on bilingual learning in China, it is crucial to clearly define and clarify the type of bilingual education under investigation. China's bilingual education differs from that of other nations in some aspects, necessitating the use of special terminology to express these distinctions and individuality (Y. Feng, 2005). However, given China's growing involvement in international politics and the global economy, we anticipate it to be a valid and ultimately fruitful educational approach that complements the discussion of topic context of developing China. Future research might therefore set a longer time span, incorporate additional studies, and include articles in different languages. The LLM proposed model continues to grow and improve its ability to communicate in natural language. It's obvious that LLM will have the capacity to demonstrate effectiveness in a bilingual setting.

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