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The role of mapping in memory formation of children with autism spectrum disorder: through the lens of a bilingual environment

Роль картографування для формування пам’яті у дітей із розладами аутистичного спектру: через призму білінгвального середовища

Summary. *In the era of digitalization, society is witnessing the emergence of unique conditions for the development of educational environments across all levels. Digital technologies play a pivotal role in contemporary educational processes, particularly in the instruction of children with special educational needs, including those with Autism Spectrum Disorder (ASD). This article focuses on analyzing how the usage of mind maps – created with the aid of digital tools – can enhance cognitive processes, especially in terms of memorization and the reproduction of linguistic material, while also supporting the adaptation of children with ASD to bilingual environments. The study explores the potential for integrating digital technologies into the mapping process and their impact on improving the effectiveness of teaching children with special educational needs. A survey conducted during the 2024 online-seminar “International Experience in Applied Behavior Analysis”, organized in collaboration with credential bodies from the United States, along with a review of relevant scientific literature, allowed the author to conclude that mind mapping can play a significant role in strengthening memory among children with ASD in bilingual settings. However, their effectiveness is contingent upon additional training and consultation for parents, teachers, and other adults involved in the educational process. The study highlights the importance of employing digital tools in combination with structured instructional methods such as audio-supported mapping, repeated verbalization strategies, mnemonic matrices, and others – aimed at facilitating diverse educational goals in bilingual settings. Overall, the findings confirm that mind mapping is a promising strategy for developing memory and language skills in children with ASD and contributes positively to their adaptation in bilingual environments. These insights open up new directions for further research on optimizing teaching methods, particularly through the integration of digital*

technologies, to ensure a more personalized approach to developing children's cognitive and communicative abilities.
Key words: *mind mapping, digital tools, bilingual environment, memory, autism spectrum disorder.*

Анотація. *В епоху цифровізації в суспільстві створюються особливі умови для розвитку освітнього середовища на всіх рівнях. Цифрові технології відіграють важливу роль у сучасному освітньому процесі, особливо коли мова йде про навчання дітей з розладом спектру аутизму. Особлива увага у статті приділяється аналізу того, як використання ментальних карт, які створюються за допомогою цифрових інструментів, сприяє покращенню когнітивних процесів, зокрема запам'ятовуванню та відтворенню мовного матеріалу, а також адаптації дітей з РАС до білінгвального середовища. У дослідженні розглядаються можливості інтеграції цифрових технологій у процес картографування та їх вплив на підвищення ефективності навчання дітей з особливими освітніми потребами. Опитування учасників онлайн-семінару «Міжнародний досвід прикладного аналізу поведінки» з акредитаційними організаціями (США) у 2024 році та аналіз наукової літератури надав можливість зробити висновки, що інтелектуальні карти можуть грати важливу роль для формування пам'яті у дітей з розладами аутистичного спектру в двомовному середовищі за умови додаткового консультування батьків, вчителів та інших дорослих, які беруть участь у навчанні дітей, за умови використання цифрових інструментів щодо створення карт разом з низкою методів заснованих на структурований навчальних схемах, серед них аудіальний супровід картографування, стратегії повторного проговорювання слів, мнемо-матриця та ін. – з подальшим їх застосуванням для різних цілей в контексті навчання дітей в білінгвальному середовищі. Загалом результати дослідження підтверджують, що ментальні карти є перспективною стратегією розвитку пам'яті та мовних навичок у дітей з РАС, вони сприяють їхній адаптації в умовах білінгвального середовища. Ці висновки відкривають перспективи для подальших досліджень, спрямованих на оптимізацію методів навчання – зокрема шляхом інтеграції цифрових технологій для забезпечення більш персоналізованого підходу до розвитку когнітивних та комунікативних здібностей дітей.*
Ключові слова: *картографування, цифрові інструменти, білінгвальне середовище, пам'ять, розлад аутистичного спектру.*

Introduction. In the era of digitalization, specific conditions are required to develop the educational environment at all levels. Information and communication technologies (ICT) play an essential role in the modern educational process, especially when it comes to teaching students with special needs, in particular with autism spectrum disorders (ASD). One of the key aspects of successful inclusive education is the choice of appropriate methods of presentation of the educational material that contributes to the formation and development of cognitive abilities, particularly memory, in children with ASD. The use of adaptive digital tools helps to make the educational process more accessible, organized, and effective.

Scientists note the important role of mind maps in teaching – for example, the use of mind maps to improve students' thinking skills (Fajar Bagja Gumilar Winata, Rahmat Rahmat, 2022 [4]), to develop educational resources (Bhattacharya D., & Mohalik R., 2020 [2]), and teaching strategies and lesson plans (Olayinka Theodorio, Mataka Tawanda, Shambare Brian, 2024 [15]), to motivate students to learn (Rui Feng, Haroon N. Alsager, Zeinab Azizi, Leeda Sarabani, 2023 [18]), etc. Given the features of these tools, researchers draw attention to the importance of teachers' use of mind maps for various educational tasks for students with ASD (Drill R.B., Bellini S., 2022 [3]).

Mind mapping as a learning method plays an important role in memory formation, especially in children with ASD, as they often have visual abilities that allow them to better perceive information through diagrams, graphs, and maps [16]. This approach not only helps to organize knowledge and reduce cognitive load but also facilitates the process of memorization. It also stimulates the development of associative thinking, helping to form strong connections between different concepts. In the context of bilingual environment, mapping supports acquiring two languages, ensuring an effective comparison of concepts between them [7].

Hashim H.U., Yunus M.M., Norman H. investigate the challenges faced by students with ASD when learning English as a second language [7]. They identify such problems as limited language skills of children, which complicates the acquisition of a foreign language, difficulties with the perception of the oral language, understanding of context and grammatical structures, and peculiarities of sensory perception. In addition, scientists draw attention to the fact that teachers do not always have special methods and educational resources to adapt lessons to the needs of children with ASD.

Considering this, tools such as mind maps, communication support applications, and interactive methods are effective strategies for offering adaptive learning to children with ASD in a bilingual setting.

The purpose of the article is to identify and justify the role of mapping as an effective tool for memory formation of children with autism spectrum disorder in a bilingual environment.

Methods and material. The research methods include an analysis of pedagogical, methodological, and scientific literature on the use of mental maps for the adaptation of children with autism spectrum disorders in a bilingual environment, a study of pedagogical experience in the use of mapping and the creation of appropriate action matrices for educational purposes; an analysis of the experience of teachers, parents, and tutors in the use of the mental map method in teaching children with autism spectrum disorders; an analysis of the results of the survey conducted

among parents, psychologists, teachers and tutors on the use of mapping in teaching children with autism spectrum disorders in a bilingual environment. which was held within the framework of the seminar "International Experience of Applied Behavior Analysis in Ukraine" with credential organizations` (USA) participation and its follow-up brainstorm meetings in 2024-2025 (appendix 1). We distributed 15 questionnaires, to which we received 7 responses.

Results and discussion. The theory of the learning environment and the formation of its ecosystem has been explored in the research of Moore S. L., & Piety P. J. [10], Nguyen Lan & Tuamsuk Kulthida Nguyen Lan & Tuamsuk Kulthida [13], Norström Livia & Jungselius, Beata & Bradley Linda & Vallo Hult Helena [14] et al. The aspects of bilingual education for children with speech and language capabilities are the focus of studies such as Muelenz-Goli K. [11], Müller H.M. [12] et al.

Particular attention should be paid to the study by Muelenz-Goli, K. (2024), which focuses on language contact, the specific features of language development, and language use in bilingual environments, particularly among German–Japanese adolescents. The author examines the impact of bilingualism on communicative abilities, cognitive processes, and language adaptation in young people growing up in bilingual settings. Muelenz-Goli notes that language contact between German and Japanese in adolescents fosters cross-linguistic influence, which may manifest in mixed utterances, lexical borrowings, and hybrid grammatical constructions. The study demonstrates that the dominance of one language determines the nature of language contact: when both languages are equally developed, code-switching is more flexible and fluent, whereas when one language is dominant, the other may remain less developed.

Mind maps can be an effective tool for visualizing interlingual connections, particularly in bilingual education for children with Autism Spectrum Disorder (ASD), as such learning imposes additional cognitive load and requires clear information structuring. The visual elements of mind maps help children with ASD to better perceive, memorize, and compare linguistic units in two languages, fostering conceptual awareness, the development of associative thinking, and the enhancement of language competence. Moreover, the use of mind maps contributes to reducing anxiety levels by providing a comprehensible, structured framework for learning and facilitating gradual adaptation to a bilingual environment.

It is important to highlight the article by Müller, H.M. (2024), "Mehrsprachigkeit und neurokognitive Störungen der Sprachentwicklung" (Eng. "Multilingualism and Neurocognitive Disorders of Language

Development"), which examines the impact of multilingual settings on language development in children with neurocognitive disorders, particularly ASD. The author analyses how bilingualism can both complicate and support language development in children with speech and language impairments, considering neuroplasticity and the brain's adaptive mechanisms. The study draws on neurophysiological data obtained through Functional Magnetic Resonance Imaging (FMRI) and Electroencephalography (EEG), which reveal distinct patterns of neural activity in children learning in bilingual environments. Müller H.M. emphasizes that while bilingualism may increase cognitive demands, it also promotes greater cognitive flexibility and the development of explicit language control, which are crucial for children with speech and language disorders. The article also discusses the role of linguistic environments and pedagogical strategies in supporting bilingual development in children with special educational needs. The author stresses the importance of adapting educational methodologies, such as visual support tools, structured learning schemes, and mind maps, to help children with ASD acquire linguistic structures and develop communicative skills more effectively.

This study supports the necessity of applying mind-mapping strategies in memory development in bilingual children with ASD, as it confirms the neurocognitive characteristics of the learners that influence their ability to acquire two languages. It also substantiates the need for a structured approach to education, which can be implemented by utilizing mind maps to organize knowledge and reduce cognitive load through visual strategies. Thus, the findings presented by Müller (2024) strengthen our argument that mind maps may serve as a key instrument in supporting bilingual education for children with ASD, helping them to structure information and enhance their language development.

Huang Y.C., Lee I.J. [8] studied how the use of augmented reality (AR) and concept mapping can promote the development of social skills in children with ASD. Scientists conducted research among children aged 7–12 years. Special augmented reality programs that simulated social situations and the concept mapping method were used, which helped to structure the acquired knowledge. Children interacted with animated characters and virtual objects that responded to their actions, helping them practice social skills in a safe environment. Teachers created visual social situations diagrams showing the relationships between actions, words, and emotions. For example, if a child was learning how to respond to a greeting, the concept map would include:

– the central node, i.e., a specific social scenario? such as "Meeting a friend";

– primary branches extend from this node to depict appropriate responses, including possible responses: “Hello! How are you?” or “Good afternoon!”;

– secondary branches further elaborate on expected non-verbal and verbal behaviors that typically accompany or follow the initial response. These may predict the expected reactions (e.g. “smile”, “responses to greetings”, reciprocal “follow-up questions”, etc.).

Such maps helped children structure knowledge and remember the sequence of social interactions. The learning outcomes of children who used AR and mind maps were compared with those who studied using traditional methods. Notably, most children retained and used the acquired social skills after the experiment ended.

Previous research by Beauchamp M.L.H., Rezzonico S., Bennett T. et al. [1], Gilhuber C.S., Raulston T.J., Galley K. [6], Garrido D., López B., Carballo G. [5] have demonstrated that multilingual children with ASD exhibit comparable level of speech development to their monolingual peers with ASD, the impact of a multilingual environment on language skills does not appear to have detrimental effect on language acquisition. On the contrary, some cases indicate that there is an improvement in social interaction among them. Multilingualism has not been shown to impose additional challenges for children with ASD in the development of communication skills. Such an environment may foster enhanced development, contribute to improving social development and greater speech flexibility in language use.

It is worth noting the study by Jimenez-Gomez C., Pichardo J., & Ryan V. [9] on the study and analysis of the effectiveness of using instructive feedback to expand listening skills in children with ASD during second language learning. Scientists sought to determine how this technique could help improve the understanding of new vocabulary and instructions in children with ASD. Their methodology included the use of instructional feedback in the form of prompts and repetitions, the inclusion of learning situations in which children were asked to listen to new words and respond to instructions, and the analysis of the impact of learning strategies on the development of second language perception and recognition skills. The authors base their methodology on the fact that children can learn new information through direct instruction, observation, and listening while performing other learning tasks. This is like implicit learning, where a child receives secondary information during primary learning. In learning basic skills (such as picture identification or word repetition), the child is provided with additional linguistic information that is not required for the task but is still perceived by the child. In addition, children acquire knowledge

without active participation, for example, by hearing additional words or linguistic structures during the main learning task.

The researchers conducted training sessions where children were given listening and language comprehension tasks. For example, in response to the correct performance of the task, the adult provided not only positive reinforcement ("Great! It's a dog.") but also additional linguistic information ("A dog is an animal that lives with people."). Although this additional information was not part of the mandatory task, the children later began to utilize it in their speech and responses.

The experience of scientists in using instructional feedback can be effectively used in our research on mapping as a means of teaching children with ASD in a bilingual environment.

Thus, like instructive feedback, mind maps allow children to passively absorb information by observing the connections between words, categories, and concepts. For example, if a child uses a map to learn the words "dog", "cat" and "rabbit" they may additionally receive indirect linguistic cues (e.g., images of the habitats of these animals or their characteristics).

Concept mapping serves as an effective tool to support the adaptation of children to new learning environments. It enables the organization and systematization of educational content, supports the structuring of information, and facilitates the planning and execution of learning activities. It helps in managing and balancing the workload among teachers, parents, and tutors. Importantly, this method also provides a clear framework for monitoring and summarizing the child's progress and achievements over time. The creation of mind maps for educational purposes requires careful consideration by teachers, parents, and tutors. It is essential to select material that aligns with the child's individual needs and personal interests. Moreover, the choice of digital tools or software should prioritize accessibility and ease of use, both for the educator and the child, ensuring that the learning experience remains engaging and adaptable.

For instance, when introducing the concept of colors, the central node of the mind map could represent the theme "Colors." From this core, primary branches may depict individual colors, each of which leads to secondary branches illustrating real-life objects associated with those colors (e.g., red – pomegranate (always red); yellow – yolk (always yellow), etc.). Tertiary branches may then include simple phrases or short sentences combining the object and color (e.g., "Look at the red pomegranate", etc.). Additionally, audio elements may be integrated into the map. When selecting visual and auditory content, it is crucial to avoid stimuli that may confuse the child, cause misunderstanding.

Fig. 1. Conceptual Mind Map for facilitating the Study of Colors Associated with Specific Objects (Original Design Created Using Canva)

Another example of adapting in a bilingual environment (Fig. 2) could be a bilingual map that displays words in the child's native language and the language of the country where the child is located.

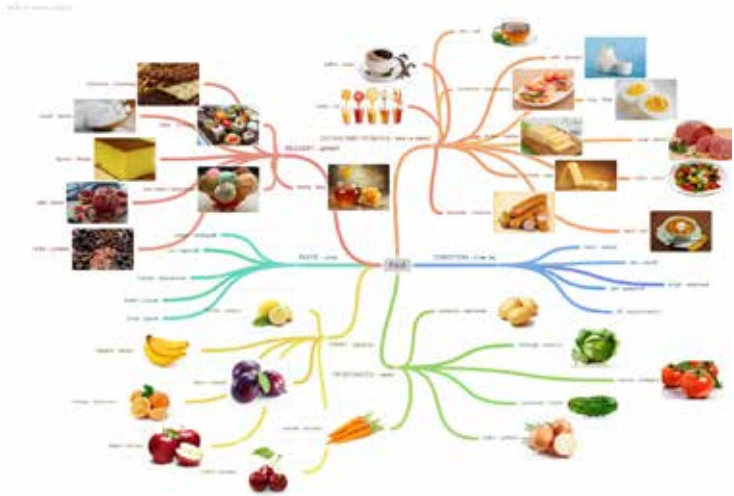

Fig. 2. Bilingual Mind Map for Learning Food Vocabulary (pre-designed map available at https://static.coggle.it/diagram/WFbUKvcXCnAKekyO/t/food)

As mentioned above, each child should have an extraordinary approach to presenting the material. This can be sequentially opening pictures or words, having the child search for correspondences, etc. Mind maps provide such opportunities that make the learning process interactive and allow you to control the presentation of information to children, unlike paper media.

Given the above, it should be noted that in addition to mind maps that reflect the clarity of tasks, it is recommended (Tarbox C.M., Silverman E.A., Chastain A.N. et al., 2021 [19]) to create an Activity Matrix that will help to conduct children's education consistently. Such an Activity Matrix can be built for the teacher and separately for each child.

For example, a matrix can be created for the teacher in Figure 1 according to the lesson stage, teacher activities, and expected results (Table 1).

Table 1

Enchanced Activity Matrix for the teacher according to Figure 1 "Mind map for studying colors under specific objects"

Lesson Stage	Teacher Activities	Expected Results
1. Familiarization	Show the mind map and ask: "What colors do you see?" Encourage identification of multiple color examples.	Children identify and name known colors.
2. Association	Help children connect each color with various objects (e.g., red – apple, pomegranate, ball). Use matrix format: vary both colors and object types.	Children begin to generalize color-object associations (early matrix training) and find and circle a particular object.
3. Word Repetition	Repeat color-object pairs (e.g., "green cucumber", "yellow yolk"). Present combinations in a varied order.	Improves memorization and begins to support flexible use of learned vocabulary across combinations.
4. Game: "What's Missing (Disappear)?"	Hide an item or part of the mind map; ask: "What was here?" "What object was this color?" Vary both rows (colors) and columns (objects).	Enhances memory and attention and supports generalization through matrix-style variable prompts.
5. Practical Task	Students draw and label new object-color pairs and add them to the mind map. Prompt variations across both dimensions (e.g., new color + new object).	Consolidates knowledge and promotes spontaneous generalization, the core goal of matrix training.

Additional questions may be incorporated into Table 1 to further stimulate engagement, such as: What other objects can be green? (e.g., grass, tree); What objects can be black? (e.g., cat, night); Which of these objects is food? (e.g., cucumber); What objects can vary in color? (e.g., car), among others. A promising approach involves combining a Combined Activity Matrix with a Matrix Training Table 2, as illustrated in the following example. This method is grounded in the principle of teaching specific, trained combinations during the learning phase, while subsequently introducing untrained combinations to promote generalization (e.g., "Touch the red car," "Point to the green grass").

Table 2

Matrix-Training Grid for Learners as follow-up to Table 1

Instructions (Actions)	Choose colors: blue (блакитний), green (зелений), yellow (жовтий), black (чорний), red (червоний), brown (коричневий), orange (оранжевий)		
Point to… Вкажи на ...	Sky (Небо)		
Touch (with your palm) … Доторкнись до ... (долонею)		Pomegranate (Гранат)	
Circle … Обведи (коло)...			Cucumber (Огірок)
Underline … Підкресли...	Car (Машина)		

Bilingual Matrix-Training Grid (Table 2) can be developed by educators to support personalized learning, specifically tailored to the unique needs of each learner. By systematically organizing instructional targets across multiple dimensions – such as vocabulary categories or language structures – these matrices establish a structured framework for memory-driven instruction and communication. Their functions (1) promote generalization across untrained combinations, facilitating broader skill transfer; (2) serve as an ongoing communication tool within bilingual educator teams, ensuring collaboration; and (3) function as a dynamic mechanism for tracking learning progress over time. Moreover, online platforms for creating mind maps should support the integration of interactive activities – such as the game "What Disappeared?" – by incorporating features like a dedicated button that temporarily conceals selected elements and restores them upon user interaction. The matrix will look different for learner and for teacher, but it is more of a task

guide for the teacher and can be provided to the child depending on her/his condition (Table 3).

Table 3

Activity Matrix for Learners according to Figure 1 "Mind map for studying colors under specific objects"

Task	What needs to be done?
1. Look at the picture	Find all the colors on the map. Use your finger to point out which objects have the same color
2. Say the colors out loud	Repeat after the teacher: Red, Yellow, Green, Black, Blue, Brown, Orange.
3. Find a pair	Match the color and the object: What is red? – Pomegranate.
4. Answer the question	- What color is a cucumber? – Green! - What color is a cocoa? – Brown!
5. Remember!	Try drawing your mind map and adding new colors and objects.
6. Tell a friend	Show the picture and tell me what colors you know!

In addition to Table 3, you can offer the child additional tasks, such as drawing own colorful picture and signing or naming its colors in second language (used in a foreign language environment).

In 2024, we took part in the seminar "International Experience of Applied Behavior Analysis" with ABA credential organizations (USA) and offered those present a questionnaire regarding the use of mind maps in working with children for the purpose of adaptation to a bilingual environment and memory training (appendix 1). The important issues that we paid particular attention to in drawing conclusions in our study were: 1. "Do you use mind maps in the education and adaptation of the child with ASD?". 2. "If yes, for what purposes?". 3. "Which programs or tools do you use to create mind maps?". 4) "How would you rate the effectiveness of mind maps in the child's learning process?". 5. "Have you noticed any improvements in the child's learning or communication after using mind maps?".

The respondents' answers to the questionnaire showed that the main purpose of using mind maps is to organize a child's daily schedule – 100% of respondents chose this answer, learning new words was indicated by 46% of respondents, improving social interaction – 56%, and creating step-by-step instructions for conducting classes – 15%.

This attitude of respondents towards the use of intellectual maps is explained by their answers to the question "What challenges have you faced when using mind maps?".

All respondents noted that difficulties in using maps to work with children arise due to the lack of experience and skills in their use, and additional training of parents and teachers is necessary.

Among the tools that were proposed for creating mind maps (MindMeister, Xmind, SimpleMind, Canva) were chosen by respondents: MindMeister – 10%; Xmind – 20%, SimpleMind – no one has chosen, Canva and MindMup – 100%. In addition, 2 respondents suggested using Mindomo.

A study conducted as part of follow-ups of the "International Experience of Applied Behavior Analysis" seminar in 2024 demonstrated the significant role of visual support in the learning and adaptation process of children with ASD in a bilingual environment. The results obtained confirm the potential of mind maps in the education and socialization of children with ASD, and also indicate the need to increase awareness and practical skills in their application among educators and parents.

Conclusions. The study`s results confirm the important role of mapping, in particular the use of mind maps, in the formation of memory in children with autism spectrum disorders in a bilingual environment. The main purpose of mind maps is to help organize the child's daily schedule, which contributes to reducing cognitive load and developing self-organization skills. At the same time, their use for learning new vocabulary and improving social interaction indicates the significant potential of this method to support bilingual learning. An important conclusion is that mind maps can serve as an effective tool not only for memorizing individual concepts, but also for forming associative connections between languages, which is critically important for children with ASD, who often have difficulties with generalization. At the same time, among the challenges, respondents noted a lack of skills in creating and using mind maps, which indicates the need for additional training for parents and teachers. Overall, the study confirms that mapping through mind maps is a promising strategy for developing memory and language skills in children with ASD, as well as contributing to their adaptation in a bilingual environment. This opens opportunities for further research in the direction of optimizing teaching methods, in particular by integrating digital technologies for a personalized approach to the development of children's cognitive and communicative abilities.

The prospects for further research lie in developing a comprehensive methodology for utilizing mapping techniques to support the formation and development of memory in students with Autism Spectrum Disorder across different age groups within bilingual environment.

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Appendix 1

Questionnaire on the Usage of Mind Maps in Bilingual Education of Children with Autism Spectrum Disorder (ASD)

Form Description:

Dear participants,

This questionnaire is intended for parents, teachers, speech therapists, and other professionals working with children with Autism Spectrum Disorder (ASD). Its goal is to explore the role of mind maps in the education and adaptation of children with ASD to a bilingual environment. Your responses will help us better understand the needs of children, the effectiveness of this method, and provide suggestions for addressing the issue. **Thank you for your participation!**

Section 1: General Information

1. What is your role in the education and care of a child with ASD? (Select one or more options)

Parent
Teacher
Speech Therapist
Special Education Teacher
Psychologist
Other (please specify): _____

2. Child's age:

3. At what age did the child enter a bilingual environment?

4. Does the child speak two languages?

Yes

No

Partially (understands but does not speak)

5. Which languages does the child use in daily life?

Native language: _____

Second language: _____

Section 2: Use of Mind Maps

6. Do you use mind maps in the education and adaptation of the child with ASD?

Yes

No

I want to try

7. If yes, for which purposes? (Select all that apply)

Learning new words

Improving social interaction

Organizing daily routines

Structuring information

Step-by-step task instructions

Other (please specify): _____

8. Which programs or tools do you use to create mind maps?

MindMup

MindMeister

XMind

SimpleMind

Canva

Others (please specify): _____

I do not use any

Section 3: Effectiveness of Mind Maps

9. How would you rate the effectiveness of mind maps in the child's learning process?

Linear scale (1 to 5):

1 – Not effective at all

5 – Very effective

10. Have you noticed any improvements in the child's learning or communication after using mind maps?

Yes, significant improvement

Yes, partial improvement

No noticeable changes

Difficult to say

11. Which challenges have you faced when using mind maps? (Select all that apply)

Difficulty in creating maps

Lack of appropriate software

Hard to engage the child with mind maps

Adults need additional training

Other (please specify): _____

Section 4: Additional Comments

12. What other methods or tools do you use to support bilingual education for children with ASD?

13. What language-learning difficulties has the child faced, and how did you address them?

(This may include issues with speech development, reading, vocabulary acquisition, answering or asking questions, understanding others' conversations, group communication, etc.)

14. Do you use mind maps when planning activities with children? If yes, for what purposes?

15. Your suggestions on how to improve the use of mind maps in the education of children with ASD: _____