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Expert System for Diagnosing Learning Disorders in Children Using the Dempster-Shafer Theory Approach

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Abstract: Learning disorders can occur in children where a child experiences difficulty mastering important skills such as reading, writing, or arithmetic. Learning disorders can have an emotional impact on children, such as low self-confidence, anxiety, or frustration. Therefore, it is important for parents and educators to recognize the signs of learning disorders so that appropriate intervention can be given. The aim of this research is to develop an expert system that can diagnose learning disorders in children using the Dempster-Shafer Theory algorithm to make it easier to diagnose and produce the right diagnosis. The Dempster-Shafer Theory approach has the ability to provide probability values in evidence based on the level of belief and reasoning in accordance with logic and then combine it with information from certain events. This research produces an expert system built on a website that can diagnose based on symptoms and display diagnosis results, definitions of types of learning disorders, and treatment options. The accuracy test results show a value of 92%, which means that the system built using the Dempster-Shafer Theory approach is able to diagnose learning disorders in children well.

Keywords: expert system; Dempster-Shafer theory; learning disorders; level of confidence; probability

INTRODUCTION

Education is an important aspect of children's development, and each child has unique potential to learn and develop. However, not all children experience the learning process smoothly. Some children may have difficulty understanding certain academic concepts, recognizing patterns, or mastering important skills such as reading, writing, or arithmetic. Learning disorders are conditions in which a child has difficulty mastering academic skills or learning skills in general (Farrell, 2021). Learning disorders are not related to factors such as low general intelligence or serious physical or mental health problems. Learning disorders are neurobiological, meaning there are differences in the way the brain works that affect the ability to learn (Peters & Ansari, 2019). Learning disorders can have an emotional impact on children, such as low self-confidence, anxiety, or frustration (Aro, Eklund, Eloranta, Ahonen, & Rescorla, 2022). It can also impact their perception of school and learning overall. It is important for parents and educators to recognize the signs of learning disorders so that appropriate intervention can be provided. Proper diagnosis and treatment can help children overcome their learning difficulties. If it is not recognized and handled appropriately, this will have a negative impact on the child's academic development (Kariyawasam, Nadeeshani, Hamid, Subasinghe, & Ratnayake, 2019). So, it is important for educators and parents to identify learning disorders and provide appropriate support. However, not

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all educators or parents know the symptoms and types of learning disorders in children and how to treat them. In this context, the development of an Expert System can assist in identifying and formulating appropriate intervention steps.

An expert system is a form of technology that combines explicit knowledge from experts with judgment rules to make complex decisions (Gupta & Nagpal, 2020). Additionally, an expert system has the capacity to provide data based on knowledge in a particular field, typically held by people with expertise in that field [6]. Learning disorders in children are one of the most common growth and development disorders in children. Previous research related to the development of expert systems regarding growth and development disorders in children has been carried out by several researchers. The first researcher related to the development of an expert system for diagnosing attention deficit hyperactivity disorder (Andriana, 2022). This research uses the Naïve Bayes algorithm in its inference engine, where this algorithm obtains diagnostic results based on Bayes' theorem with the principle of conditional probability. Another area of research is the development of an expert system to diagnose schizophrenia (Haerani, Candra, & Sari, 2021). In this study, the Certainty Factor algorithm was used for the inference engine, where it works by measuring the level of confidence in a statement based on existing evidence. This research resulted in an accuracy test with a value of 87%. Further research concerns the development of an expert system used to diagnose autism spectrum disorder (Wanti & Puspitasari, 2022). In this research, the Fuzzy Logic algorithm is used to handle uncertainty and ambiguity in systems based on the concept of partial membership in sets. This study resulted in an accuracy value of 90.59%.

In the research conducted, the focus was on developmental disorders in children regarding learning disorders. Apart from that, this research uses the Dempster-Shafer Theory algorithm as its inference engine. This algorithm was chosen because it can determine the level of confidence based on a combination of existing facts in determining probability, so that the problem of uncertainty can be resolved. The Dempster-Shafer Theory approach works by providing probability values in evidence based on the level of confidence and reasoning in accordance with logic to combine information from certain events (Teguh, Fadlil, & Sunardi, 2019). This research also uses a technique for assigning density values, namely expert evaluation, where experts provide an assessment of how strong their belief is in a hypothesis based on their knowledge, experience, and existing information.

Based on the previous explanation, this research aims to develop an expert system that can diagnose learning disorders in children using the Dempster-Shafer Theory algorithm to make it easier to diagnose and produce the right diagnosis. The Dempster-Shafer Theory approach is used as an inference engine by calculating combined factors between facts so that they influence the size of the opportunities that occur. The expert system developed makes a diagnosis by entering the symptoms experienced and is equipped with an explanation of the types of learning disorders and how to treat them. To facilitate access and use of the system, this expert system was developed based on a website. The types of learning disorders used are dysgraphia, dyslexia, and dyscalculia.

LITERATURE REVIEW

Learning Disorders in Children

Learning disorders are conditions in which children experience difficulty in mastering academic skills or learning skills in general (Farrell, 2021). Some children may have difficulty understanding certain academic concepts, recognizing patterns, or mastering important skills such as reading, writing, or arithmetic (Peters & Ansari, 2019). Learning disorders can have an emotional impact on children, such as low self-confidence, anxiety, or frustration (Aro et al., 2022). The condition of learning disorders is different from the condition of children with intellectual disabilities or slow learners, where children with learning disorders can have normal intelligence potential or IQ tests (Wijaya, 2020). It can also impact their perception of school and learning overall. Interventions for learning disorders can include individualized approaches, such as teaching tailored to the child's learning style, extra support in the form of special guidance or support, and innovative teaching techniques (Raharjo & Wimbarti, 2020).

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Expert System

Expert systems, also known as knowledge-based systems, developed in the 1960s. Expert systems refer to technological applications designed to mimic the knowledge and skills of human experts in a particular field (Kołodziejczyk, Grzegorczyk-Dłuciak, & Kuliga, 2022). Expert systems take advantage of accumulated knowledge from experts and apply it in a computerized manner to provide solutions, recommendations, or diagnoses in complex situations. The main goal of an expert system is to provide assistance in decision-making with a level of accuracy and expertise similar to that of human experts (Yang, Ye, Liu, & Wang, 2023). The essence of an expert system lies in the knowledge stored in a knowledge base. This knowledge base contains structured information about facts, rules, and relationships within a specific domain. In addition, expert systems use inference engines, which are computational algorithms or methods to apply knowledge stored in the knowledge base to draw conclusions or solutions based on the data provided (Marlinda, Widiyawati, Widiastuti, & Indrarti, 2020). Expert systems are structured in two environments, namely, the development environment and the consultation environment (Pasaribu, Sihombing, & Suherman, 2020). The development environment functions to input knowledge from experts into the expert system, while the consultation environment functions to interact with users to gain knowledge or solve problems that require expert knowledge.

Dempster-Shafer Theory Approach

This approach was first popularized by Arthur P. Dempster by modeling solutions to solve uncertainty problems using probability. Then this theory was continued by Glenn Shafer for adjustments in 1976 through its publication in a book entitled "Mathematical Theory of Evidence". Furthermore, this concept is then called the Dempster-Shafer theory approach. The main goal of Dempster-Shafer theory is to address situations where the available information does not always allow accurate probability measurements (Wen, Song, Wu, & Li, 2020). This theory recognizes that in many real-world situations, it is possible to have incomplete or certain information to calculate probabilities (Fernando, Napianto, & Borman, 2022). Therefore, the Dempster-Shafer Theory allows us to describe uncertainty more flexibly.

Specifically, the Dempster-Shafer Theory algorithm is based on proof through levels of trust, or what is called belief, and paying attention to logical thinking patterns, or plausibility. The combination is then used to prove phenomena based on calculations of existing probabilities (Napianto, Rahmanto, Borman, Lestari, & Nugroho, 2021). In the Dempster-Shafer Theory, there is belief (Bel), which refers to the level of belief in a proposition (evidence) when providing support for a condition.(Safitri, Insani, Yanti, & Oktavia, 2023). If belief gets a value of 0, this means that there is no evidence; conversely, if a value of 1 is obtained, it means that there is evidence. So, the belief function can be denoted by equation (1).

$$Bel(X) = \sum_{\subset X} m\,(Y) \qquad (1)$$

where the notation $Bel(X)$ indicates belief in the variable (*X*), while the notation $m(Y)$ refers to the mass function of the variable (*Y*).

To obtain a plausibility value (Pls), a calculation can be performed using equation (2).

$$Pls(X) = 1 - Bel(X') = 1 - \sum_{Y \subset X}^{n} m\,(X') \qquad (2)$$

where the Pls value has a value range of 0 to 1. All possibilities for the Bel and Pls values are presented in Table 1.

Table 1. Value of Belief and Plausibility

Certainty	Information
[1, 1]	All true
[0, 0]	All wrong
[0, 1]	Uncertainty
$[Bel, 1]$; 0< Bel <1	There is support
$[0, Pls]$; 0< Pls <1	There is resistance
$[Bel, Pls]$; 0< $Bel \leq Pls$ <1	There is resistance and support

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Table 1 shows that the belief and plausibility values will have high confidence if they are close to 1. However, in reality, in expert system development, there are elements that create all possibilities in the user's answers. However, the fact is that in the development of an expert system, there are elements that create all possibilities in the user's answers. This possibility in the Dempster-Shafer theory is known as the power set, whose symbol is $P(\theta)$. So, to get the value, it is calculated using equation (3).

$$m = P(\theta) \qquad (3)$$

where m denotes the mass function value, while $P(\theta)$ denotes the power set value.

The implementation of Dempster-Shafer in an expert system in its development will use several pieces of evidence on the uncertainty variable in solving problems. So, to solve problems with a large amount of evidence, a procedure called Dempster's rule of combination is used. This procedure combines evidence, namely m_1 and m_2, through equation (4).

$$m_1 \oplus m_2(Z) = \sum_{X \cap Y = Z} m_1(X) m_2(Y) \qquad (4)$$

where $m_1 \oplus m_2(Z)$ refers to the mass function in evidence, $m_1(X)$ refers to the mass function value in evidence (X), $m_2(Y)$ refers to the mass function value in evidence (Y), and $\oplus$ refers to the direct sum operator.

Furthermore, in order to obtain Dempster's rule of combination value, equation (5) is used.

$$m_1 \oplus m_2(Z) = \frac{\sum_{X \cap Y = Z} m_1(X) m_2(Y)}{1-k} \qquad (5)$$

Based on equation (5), k refers to the number of evidential conflicts. The total value of k can be calculated via equation (6).

$$k = \sum_{X \cap Y = \theta} m_1(X) m_2(Y) \qquad (6)$$

Based on Equation (6), to simplify it in order to obtain a combination value between evidence using the m_3 value, Equation (7) is used.

$$m_3(Z) = \frac{\sum_{X \cap Y = Z} m_1(X) m_2(Y)}{1-\sum_{X \cap Y = \theta} m_1(X) m_2(Y)} \qquad (7)$$

METHOD

A planned research phase is necessary in order for the research to be structured and organized systematically (Ahmad et al., 2022). The goals of the research guided the structuring of this research phase. The flow of the research steps is depicted in Fig 1.

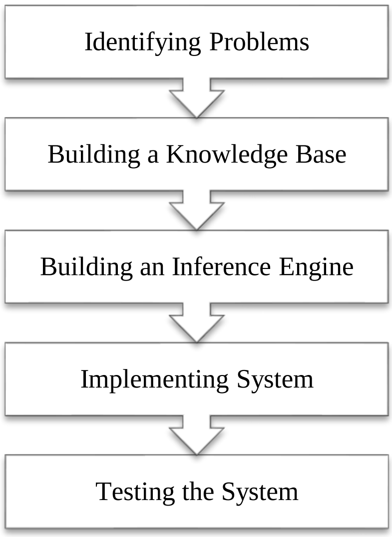

Fig 1. Research Phase

Based on Fig 1, a detailed explanation for each stage can be explained in the explanation below.

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Identifying Problems

This is the phase where problems will be explored and resolved so that the right solution can be obtained. After the problem has been determined, a statement of needs is prepared to solve it. Based on the results of observations and interviews, learning disorders can have an emotional impact on children, such as low self-confidence, anxiety, or frustration. It is important for parents and educators to recognize the signs of learning disorders so that appropriate interventions can be provided. Proper diagnosis and treatment can help children overcome their learning difficulties. If it is not known and handled properly, this will have a negative impact on the child's academic development. Thus, it is important for educators and parents to identify learning disorders and provide appropriate support.

Building a Knowledge Base

Expert systems are also known as knowledge-based software, and knowledge collection is an important aspect. So, the next phase is to collect knowledge obtained from experts and other sources of knowledge. To get knowledge into a knowledge base, it begins with the process of acquiring knowledge. In this acquisition process, the knowledge needed will be collected, organized, recorded, and then become a knowledge base.

Building an Inference Engine

To be able to carry out expert system reasoning requires an inference engine. The main responsibility of the inference engine is to search for connections and correlations between existing rules in the knowledge base in order to make decisions or offer recommendations based on user input (Harjanti, 2022). Through this inference process, the inference engine plays an important role in applying the knowledge of human experts contained in the knowledge base so that expert systems can function effectively in solving various complicated and complex problems in certain domains. In this research, the inference engine was built based on the Dempster-Shafer theory approach. Dempster-Shafer theory. The Dempster-Shafer Theory is based on proof through a level of trust, or so-called belief, and pays attention to a logical mindset, known as plausibility. The combination is then used to prove phenomena based on existing probabilities.

Implementing System

The system implementation stage, commonly known as coding, aims to translate the system analysis and design into software (Gunawan, Napianto, Borman, & Hanifah, 2019). The system was developed based on a website, so a code editor was used, namely Brackets with a MySQL database.

Testing the System

The system that has been developed is tested in this step to make sure it complies with the established specifications (Ahmad, Rahmanto, Pratama, & Borman, 2021). Additionally, this phase seeks to evaluate how well the model under development performs (Borman, Fernando, & Yudoutomo, 2022). To test the system, an accuracy test is used. Comparing the system's results with the findings of the expert diagnosis yields the accuracy value. Then the results of the comparison are calculated for the level of accuracy through equation (8).

$$Accuracy = \frac{\text{Total Correct}}{\text{Total Test}} \times 100\% \qquad (8)$$

RESULT

To develop an expert system for diagnosing learning disorders in children using the Dempster-Shafer Theory algorithm, it begins with collecting the required knowledge through a knowledge acquisition process. The knowledge acquisition process is the process of collecting, understanding, and recording explicit and implicit knowledge from human sources or other knowledge sources in a particular domain. This knowledge acquisition process will produce a collection of knowledge that will later be used as a

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knowledge base. In this research, the knowledge collected relates to symptoms, diseases, and treatment methods obtained from psychologists. In this case study, three types of learning disorders in children were found. A list of types of learning disorders in children can be seen in Table 2.

Table 2. Types of Learning Disorders in Children

Code Types of Learning Disorders	**Types of Learning Disorders**
P01	Dysgraphia
P02	Dyslexia
P03	Dyscalculia

Based on Table 2, from the three types of learning disorders, 30 symptoms were obtained, and a density value was obtained for each symptom. The technique used to obtain density values uses expert evaluation techniques. Where domain experts can provide input regarding the extent to which evidence or information supports a particular hypothesis. The mass density value can be determined based on an expert's assessment of how strong the evidence is. The value in PS has a range of values from 0 to 1, where if the expert's level of confidence is close to 1, then the symptom is close to certain. Symptom data and density values are presented in Table 3.

Table 3. Symptom Data and Density Values

Code	**Symptom Name**	**Type of Disorder**			**Density Value**
		P1	**P2**	**P3**	
G1	The writing is bad, disorganized, or difficult to read.	X			0.8
G2	Difficulty in maintaining a consistent font size.	X			0.8
G3	Difficulty in keeping space between words and letters.	X			0.8
G4	Disturbance in coordinating hand and eye movements when writing.	X			0.7
G5	Disturbance in following a predetermined line.	X			0.6
G6	Difficulty in copying writing into a book on paper.	X			0.7
G7	Writing is slow and requires greater effort than peers.	X			0.6
G8	It's hard to hold the writing utensil.	X			0.7
G9	Often confused and forget the order of letters and numbers.	X		X	0.8
G10	Difficulty in expressing something and writing it back.	X	X		0.7
G11	Difficulty in connecting letters into meaningful words.	X	X		0.6
G12	Difficulty recognizing and remembering letters and phonemic sounds.		X		0.8
G13	Reads slowly and tends to misread or substitute words.		X		0.7
G14	Difficulty in understanding the text read.		X		0.8
G15	Difficulty in spelling words.		X		0.7
G16	When reading often swaps letters, repeats words, or ignores words.		X		0.8
G17	Difficulty in understanding sentence structure and text.		X		06
G18	Forgetting certain words while reading.		X		0.6
G19	Stammers while reading.		X		0.7
G20	Have poor short-term memory.	X	X	X	0.6
G21	Easily tired of reading that involves a lot of numbers.		X	X	0.7
G22	Nervous when it comes to letters and numbers.	X		X	0.6
G23	Difficulty in recognizing and understanding numbers.			X	0.8

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Code	Symptom Name	Type of Disorder			Density Value
		P1	P2	P3	
G24	Difficulty understanding measurement concepts such as length, weight, and volume.			X	0.8
G25	Difficulty in performing basic arithmetic operations such as addition, subtraction, multiplication, and division.			X	0.8
G26	Disturbance in identifying mathematical patterns and relationships.			X	0.7
G27	Difficulty in understanding the concept of time and measuring time.			X	0.7
G28	Difficulty in solving math problems.			X	0.6
G29	Difficulty in recognizing nominal money and calculations.			X	0.8
G30	Difficulty in arranging the sequence of what will be done.			X	0.6

Table 3 shows the symptom data obtained in the knowledge acquisition process. The data on symptoms and diseases that has been obtained is used as a knowledge base. Next, so that the system can carry out diagnoses, an inference engine is built, and in this research, the Dempster-Shafer theory approach is used. In the concept of the Dempster-Shafer Theory approach, probability searches are carried out based on the level of confidence used in combining existing facts. As a case study to solve the problem of diagnosing types of learning disorders in children, the following symptoms were found:

Symptom 1 (G4) : Disturbance in coordinating hand and eye movements when writing.
Symptom 2 (G10) : Difficulty in expressing something and writing it back.
Symptom 3 (G20) : Have poor short-term memory.

From the symptoms that have been obtained, they are then resolved using the Dempster-Shafer Theory approach in a step-by-step manner as follows:

Obtained symptom 1 (G1), namely: disturbance in coordinating hand and eye movements when writing. Experts have determined that this symptom has a density value of 0.7. This symptom is a symptom of dysgraphia (P1). So, the mass function value can be calculated as follows:

$$m_1\,\{\text{P1}\} = 0.7$$
$$m_1\,\{\theta\} = 1 - 0.7 = 0.3$$

Next, symptom 2 (G2) was obtained, namely: difficulty in expressing something and writing it back. Experts have determined that this symptom has a density value of 0.8. This symptom is a symptom of dysgraphia (P1) and dyslexia (P2). So, the mass function value can be calculated as follows:

$$m_2\,\{\text{P1}, \text{P2}\} = 0.6$$
$$m_2\,\{\theta\} = 1 - 0.6 = 0.4$$

After the density values for G1 and G2 have been obtained, proceed with calculating the combined values of the two densities, namely m_1 and m_2 through the use of the table of combination rules via equation (7). The combination of these two densities is used to obtain the confidence value of the new phenomenon. The rules for merging G1 and G2 to get the value of m_3 are presented in Table 4.

Table 4. Combination of Rules for m_3

		{P1, P2}	(0.6)	θ	(0.4)
{P1}	(0.7)	{P1}	(0.42)	{P1}	(0.28)
θ	(0.3)	{P1, P2}	(0.18)	θ	(0.12)

It can be seen in Table 4 that it produces rules for the m_3 combination value, which will then be calculated using equation (7). The calculation process to find m_3 is as follows:

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$$m_3\,\{P1, P2\} = \frac{0.18}{1-0} = 0.18$$
$$m_3\,\{P1\} = \frac{0{,}42 + 0.28}{1-0} = 0.7$$
$$m_3\,\{\theta\} = \frac{0.12}{1-0} = 0.12$$

Then, the next symptom is symptom 3 (G3): Have poor short-term memory. Experts have determined that this phenomenon has a density value of 0.6. This symptom is a symptom of dysgraphia (P1), dyslexia (P2), and dyscalculia (P3). So, the mass function value can be calculated as follows:

$$m_4\,\{P1, P2, P3\} = 0{,}6$$
$$m_4\,\{\theta\} = 1 - 0{,}8 = 0{,}4$$

After the density values for G1, G2, and G3 have been obtained, proceed with calculating the combination values using the combination rules table. This combination is then presented in Table 5.

Table 5. Combination Rules for m_5

		{P1, P2, P3}	(0,6)	θ	(0,4)
{P1, P2}	(0.18)	{P1, P2}	(0,108)	{P1, P2}	(0,072)
{P1}	(0.7)	{P1}	(0,42)	{P1}	(0,28)
θ	(0.12)	{P1, P2, P3}	(0,072)	θ	(0,048)

Table 5 produces rules for the combination value m_5. Based on equation (7), the calculation process is as follows:

$$m_5\,\{P1, P2\} = \frac{0.108 + 0.72}{1-0} = 0.18$$
$$m_5\,\{P1, P2, P3\} = \frac{0.072}{1-0} = 0.072$$
$$m_5\,\{P1\} = \frac{0.42 + 0.28}{1-0} = 0.7$$
$$m_5\,\{\theta\} = \frac{0.048}{1-0} = 0.048$$

Based on the results of the m_5 density combination calculation, all the symptoms in this case study have been combined. So, from these results, it can be seen that the highest value is P1, which gets a value of 0.7, or 70%. This means that the diagnosis based on this case study is dysgraphia (P1).

The next stage is to apply the Dempster-Shafer Theory as an inference engine for an expert system. The expert system that was built was developed based on a website, so a code editor was used, namely brackets with a MySQL database. This type of trauma detection expert system has features such as managing data on symptoms, diseases, Dempster-Shafer Theory rules, carrying out diagnoses, viewing diagnosis results, and treatment. In this system, there are two types of users: administrators and general users. The administrator is responsible for inputting symptoms, diseases, and rules of the Dempster-Shafer Theory. Meanwhile, general users can carry out diagnoses and see a list of types of learning disorders in children. To start using the system, general users will first open the application's main menu. The main menu provides features such as starting a consultation and a list of types of learning disorders in children. The main menu page interface for users is presented in Fig 2.

Fig 2. Main Menu Interface for Users

Fig 2 depicts the interface display of the decision support system's main menu form, which users can access. To carry out a diagnosis, users can click the Start Consultation button. After the diagnosis process page opens, the user can fill in the symptoms according to what they are experiencing. The user interface for the diagnosis process is presented in Fig 3.

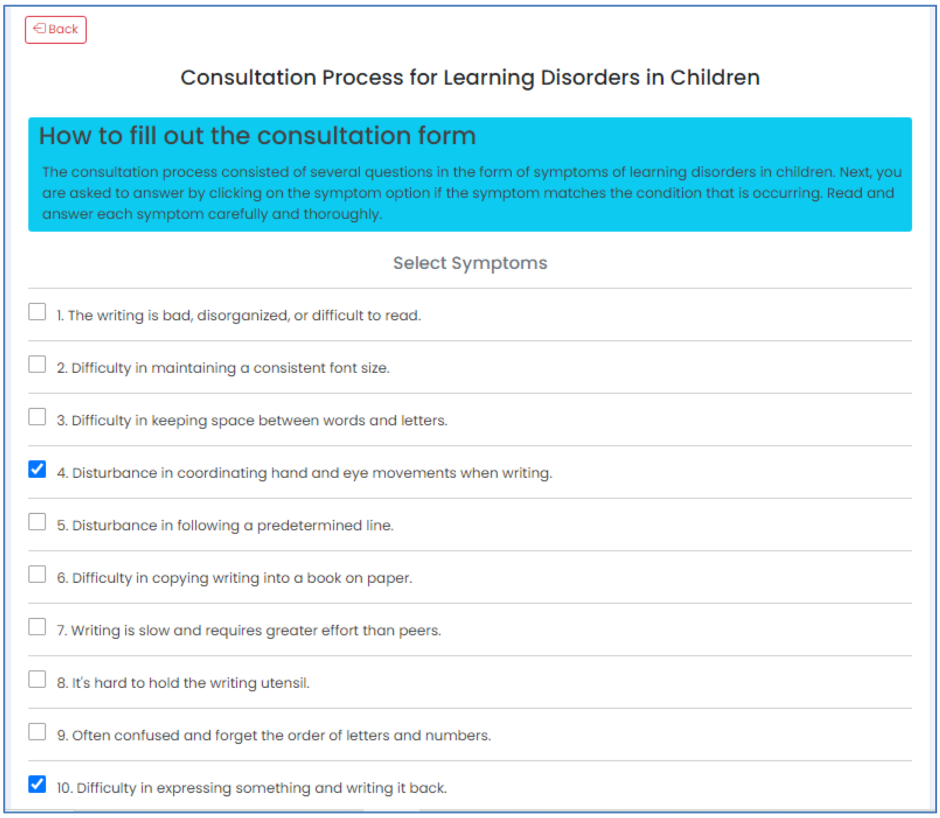

Fig 3. Diagnostic Process Interface

After the user fills in the symptoms experienced in Fig 3, the user can then press the diagnosis button. After that, the system will display the diagnosis results by displaying the calculation results of the Dempster-Shafer Theory, complete with definitions and treatment methods. The user interface display for diagnostic results is presented in Fig 4.

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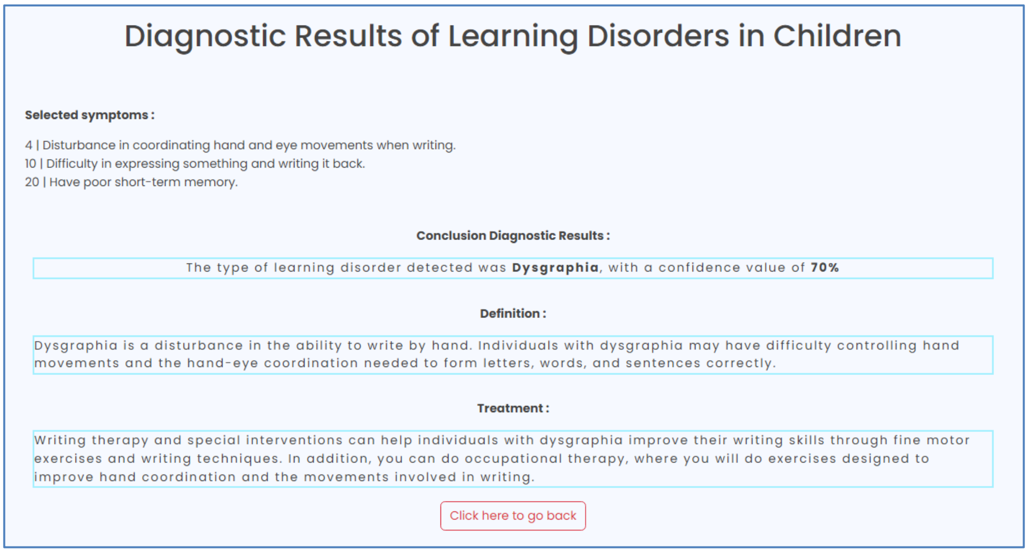

Fig 4. Diagnostic Results Interface

Fig 4 shows the diagnosis results, a definition, and an explanation of the types of learning disorders diagnosed and how to treat them. Apart from the user who will carry out the diagnosis, this system has administrator access, which manages the data used for the diagnosis. For administrator users, it is used by experts to carry out data processing, including disease data and treatment, symptom data, rules, and Dempster-Shafer reports. The main user menu display for administrators can be seen in Fig 5.

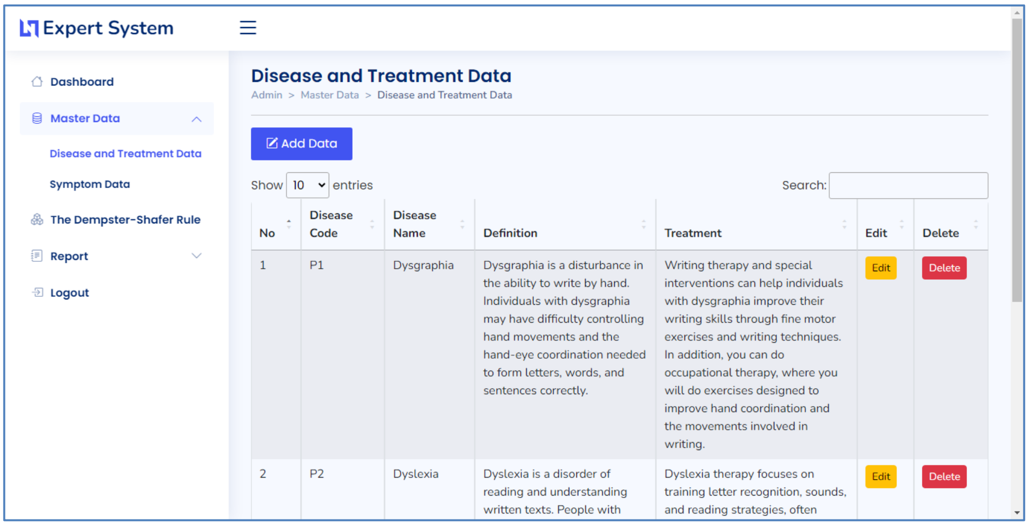

Fig 5. Interface for Administrators

Before an expert system is used, it needs to be tested first. This is done so that the performance of the developed system can be measured and is in accordance with the requirements. The test carried out tests accuracy by comparing the output results of the system with the diagnoses produced by experts. The test sample applied was 50 test cases, which were randomized for the symptoms experienced. In these cases, the results obtained by the expert system and the results of an expert will be compared. After testing the 50 cases, the system was able to correctly diagnose 46 cases and incorrectly diagnose 4 cases. To obtain the level of accuracy required, the results obtained were calculated by equation (8). The following is the calculation process to find the accuracy value:

$$Accuracy = \frac{46}{50} \times 100\% = 92\%$$

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Based on the results of obtaining the accuracy value, a value of 92% was obtained. So, the percentage of inaccuracy is 8%. For greater clarity, the results of this accuracy test are presented in graphical form, as shown in Fig 6.

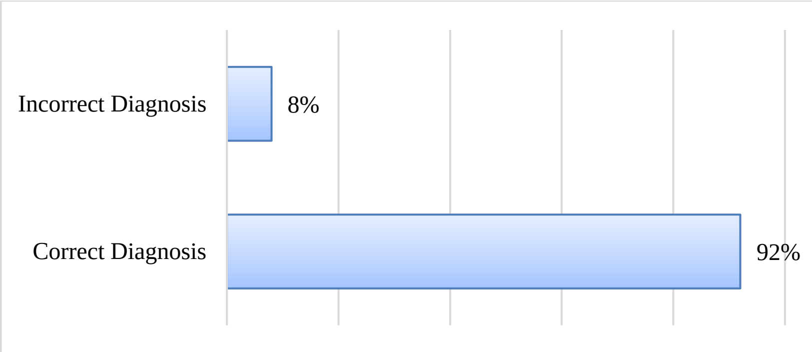

Fig 6. Graph of Accuracy Test Results

Fig 6 shows a graph of accuracy test results, where the correct diagnosis results are 92%. These results were then transformed into the following accuracy level groupings: “Good”, the value is between 76% and 100%; “Enough”, the value is between 56% and 75%; “Poor”, the value is between 40% to 55%, and “Not Good”, less than 40% (Mayatopani, Borman, Atmojo, & Arisantoso, 2021). So, based on the assessment of these criteria, the expert system developed is included in the "Good" criteria.

DISCUSSIONS

This research produces an expert system to diagnose types of learning disorders in children using the Dempster-Shafer Theory approach. The expert system developed is built on a website to make it easier to access and use. In this system, there are two types of users: administrators and general users. The administrator is responsible for inputting symptoms, diseases, and rules of the Dempster-Shafer Theory. While general users can make a diagnosis and see a list of types of learning disorders in children, The output results generated by the expert system with manual calculations show the same value, which means that the calculations produced by the system are valid. Apart from that, based on the results of accuracy testing, the score was 92%. Previous research related to growth and development disorders in children diagnosed with schizophrenia with the Certainty Factor algorithm resulted in an accuracy of 87% (Haerani et al., 2021), and research on the diagnosis of autism spectrum disorder with the Fuzzy Logic algorithm produced an accuracy of 90.59% (Wanti & Puspitasari, 2022). Although it cannot be compared because the types of growth and development disorders in children are different, this research produces better accuracy values. The factor that causes the Dempster-Shafer Theory algorithm in this case to produce high accuracy is that this approach is based on proof through levels of trust, or what is called belief, and paying attention to logical thinking patterns, or plausibility. The combination is then used to prove phenomena based on existing probabilities. Apart from that, in this case study, each type of learning disorder has almost different symptoms, which makes it easier for the algorithm to make a diagnosis. However, based on the accuracy test results, incorrect diagnoses reached 8%. From the experiments that have been carried out, there are several factors that cause inaccuracy in diagnosis, including: 1) the value of the level of belief influences the diagnosis results because the Dempster-Shafer Theory uses a combination of evidence so that the values of belief and plausibility become important factors; 2) There is no validity to the specified confidence level; this will affect the results of the diagnosis; 3) The results of a combination of evidence with the same value result in two diagnoses.

CONCLUSION

The research was conducted to develop an expert system by applying the Dempster-Shafer Theory approach in diagnosing learning disorders in children. The Dempster-Shafer approach has the ability to determine probabilities based on the level of confidence and logical thinking and combine them to get a value for the level of confidence. An expert system built based on a website with the ability to make diagnoses based on symptoms and display diagnostic results, definitions of types of learning disorders

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and treatment tips. Based on the results of testing the level of accuracy obtained a value of 92% and classified as "Good" criteria. These results show that the Dempster-Shafer Theory approach is capable of diagnosing learning disorders in children. However, the developed model needs improvement, including the absence of validity against the specified confidence level, this will affect the diagnostic results. So, for future research it is necessary to combine the Dempster-Shafer Theory algorithm with Fuzzy Logic, so that the belief value determined by an expert is clearer and the membership function is more flexible.

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