Diagnosing Learning Disorders in Children: A Comparison of Certainty Factor and Dempster-Shafer Methods

Anthony Anggrawan*, Hairani Hairani, Christofer Satria, and Aprillia Dwi Dayani

***Abstract*—Even though educational technology is very advanced, some children experience learning disorders. Learning disorders in children include Dyslexia, Dysgraphia, Dyscalculia, and Dyspraxia. Ignorance about learning disorders in children will result in the child not getting help to reach his potential and have an impact on problematic behavior and destructive mental disorders in children. That is why it is necessary to make an early diagnosis to determine the presence of learning disorders in children. Therefore, for this reason, this study aims to develop an expert system for the early diagnosis of learning disorders in children using the Certainty Factor and Dempster-Shafer methods. The results show that the Certainty Factor method is more accurate than the Dempster-Shafer method in diagnosing children with disorders. The accuracy of the test results by diagnosing children's learning disorders using the Certainty Factor method is 90%, and by the Dempster-Shafer method, it is 87%. The novelty of this research is to build a system for diagnosing the types of learning disorders in children using the Certainty Factor and Dempster-Shafer methods which have never been done by previous researchers.**

***Index Terms*—Educational technology, learning disorder, children learning, certainty factor, dempster-shafer**

I. Introduction

Currently, educational technology is developing rapidly [1, 2], as well as innovations in the application of educational technology in learning vary widely [3]. Besides that educational technology supports today's learning [4]. However, some children have learning disorders even though these children have intelligence and sensory average [5]. Learning disorders are also not due to intellectual deficiencies, emotional disturbances, or cultural differences [5]. Children's learning disorders include reading, writing, and arithmetic [6]. The problem for children with learning disorders, such as reading disorders or Dyslexia, is that if reading learning disorders are not treated, the impact of subsequent disorders will also be the same [7]. Children who are not recognized or fail to be known to have a learning disorder will struggle to overcome their learning difficulties without the teacher or parents knowing the cause. As a result, it will prevent these children from getting help to reach their potential. Therefore, children who enter school with learning disabilities are at risk of being continuously left behind and further behind in learning compared to their peers. Moreover, according to Colenbrander *et al.*'s work [8], by knowing early on about learning disorders in children, these children can get appropriate help in acquiring skills and prevent problematic behavior and destructive mental disorders in children. That is why it is necessary to carry out an early detection or diagnosis to find out learning disorders in children, which is very important for early therapy [5, 8, 9]. Keeping in mind that related to problems in learning, learning difficulties or learning disorders become a topic of observation in childhood in the first year of school [10]. Still, the main problem is whether learning disorders can be identified early [11]. This research makes it happen. That is why for this reason, this study aims to develop an expert system for the early diagnosis of learning disorders in children.

Many factors that cause learning disorders in children include Dyslexia, Dysgraphia, dyscalculia, and dyspraxia [12]. Some children show disturbances in mathematics, not due to socio-economic, educational, emotional, psychological, or intellectual factors, which is called disorder dyscalculia [13]. In short, dyscalculia is a child's inability to count or learn numeracy or mathematical skills despite average intelligence [14]. Impaired ability to spell writing, or spelling errors in the production of text in children, is a dyslexia disorder [15, 16]. Dyslexia learning disorder represents a visual disability that affects reading ability [17]. Moreover, according to Talepasand and Eskandaripour *et al.*'s research [18], a child's learning disorder due to an inability to recognize words is a dyslexic disorder. Meanwhile, the inability to develop writing skills is typically a dysgraphia failure [16, 19–22]. In contrast, dyspraxia is a disorder associated with motor function in children [23]. Meanwhile, according to Pedro and Goldschmidt, dyspraxia is a learning disorder in children who have difficulty carrying out activities [24].

Many prior studies build systems that have the expertise (expert systems) in solving problems in various fields [25], including the system built using the Dempster-Shafer method [25]. However, at this time, the Certainty Factor method is starting to be dominantly used as an inference engine because of its ability to construct independent causal assumptions [26] and deal with some rules to produce conclusions [27].

A Dempster-Shafer is helpful in the embodiment of modeling structures [28]. Dempster-Shafer or also known as evidence theory [29, 30], is a very popular method used in various research [30] and is widely used in multiple applications because the Dempster-Shafer is very flexible

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and effective in uncertainty modeling [31] and making decisions with uncertainty [32]. In essence, the Dempster-Shafer represents independent pieces of evidence [30, 32], also known as beliefs [30, 33] or the theory of belief function [32, 33]. This theory provides a framework for embodiment modeling and methods for combining different sets of evidence [33]. In short, Dempster-Shafer is a mathematical tool for dealing with uncertainty in attributes [34]. Meanwhile, the certainty factor is useful as an inference engine and makes assumptions [6]. The Certainty Factor method can realize the level of certainty over identification based on evidence or characteristics [35]. In essence, the certainty factor accommodates the uncertainty of an expert in analyzing information [27]. This study developed an expert system for early diagnosis of learning disorders in children using the Certainty Factor and Dempster Shafer methods.

The structure of further discussion in this manuscript is as follows. The second subsection discusses previous related work and compares the differences with this work. Meanwhile, the third subsection describes the methodology of this research. The fourth subsection focuses on describing the results and discussing the research results. The last subsection (fifth subsection) discusses the study's conclusions and represents the novelty of the research and suggestions for further investigation.

II. Related Work

Some of the latest related works of prior study are as follows.

Kuerten *et al.* conducted a literature review on dyslexia learning disorder [36]. The previous research was a literature review on dyslexic children's learning disorders. In contrast to the research in this article, this study builds a system for the early detection of learning disorders in children. Thus the difference between the two studies is in the methods and objectives of the study. Pedro and Goldschmidt revealed the teacher's level of understanding of learning disorder dyspraxia and the support needed in teaching children with learning disorders of dyspraxia [24]. The difference between this previous research and this article's research lies in the research method and the purpose and object of the research.

Yulianti *et al.* compared the effectiveness of Dempster Shafer and Certainty Factors in determining adolescent learning styles [37]. This previous research has different objectives and objects from this article's research. Likewise, the research conducted by Sari *et al.* [38] has different objectives and research objects compared to the research in this article.

Waber *et al.* described learning disorders in children and diagnosed the clinical characteristics of children with dyspraxia disorders in children with dyslexia [23]. Previous research is not the same as the research in this article in terms of research methods and objectives. In essence, previous studies diagnosed the characteristics of learning disorder dyspraxia in children with learning dyslexia. In contrast, the research in this article diagnoses children with learning disorders early, either dyspraxia, Dysgraphia, dyscalculia, or dyspraxia. Vlachos and Avramidis perform comparisons to show developmental Dyslexia and developmental Dysgraphia as distinct learning disorders in children [16]. The difference between this previous study and the research in this article is that previous studies reviewed dyslexia and dysgraphia learning disorders. In contrast, the research in this article builds a system for early detection of learning disorders in children, both dyslexia and dysgraphia learning disorders, as well as dyscalculia and dyspraxia in children.

Pagliarin *et al.* [39] assessed children's and adults' special situation anticipatory abilities. This previous research has a different purpose from our study in this article. Previous research has focused on learning disorders or developmental Dyslexia. Instead, the research in this article focuses on the early diagnosis of learning disorders: Dyslexia, Dysgraphia, dyscalculia, and dyspraxia in children.

Safarova *et al.* [40] conducted quantitative research to assess handwriting ability on learning disorders Dysgraphia. However, this prior study has a different objective, object, and method than this article's study. The previous research was a survey study with the object of learning dysgraphia disorder and aimed to assess the level of dysgraphia learning disorder. In contrast, the research in this article builds a system with objects to detect the type of learning disorder in children using the Certainty Factor and Dempster-Shafer methods.

Meanwhile, Mammarella *et al.* [41] examined the characteristics of children who have dyscalculia or mathematical learning disorders. Even though this previous study has similarities with the research in this article in examining learning disorders in children, the two studies have different objectives and research methods. Previous research revealed the characteristics of the learning disorder dyscalculia in children. On the other hand, the research in this article diagnoses the presence or absence of learning disorders in children early.

O'Dea *et al.* synthesized discrete qualitative study findings about the preferences of children and adolescents with developmental coordination disorder with a meta-ethnographic approach. Previous research compared with the study of this article is different in methods, objectives, and research objects. The previous research method synthesized the literature study results. In contrast, the research method in this article was to build an early prediction system for learning disorders using the certainty factor and Dempster-Shafer methods; likewise, if this previous study synthesized the results of prior research, while the research in this article builds a system to recognize the types of learning disorders in children.

Mustafaeva investigated the phenomenon of learning and teaching disorders in reading and spelling foreign languages [42]. Previous research has investigated the phenomenon of learning and teaching disorders in children, in contrast to the research in this article which focuses on developing a system for the early detection of learning disorders in children. Thus, the striking difference between the two studies is in the purpose of the study and the research method.

Taylor and Vestergaard investigated previous studies in psychology and dyslexia neuroscience-related learning disorders [7]. This previous study is a literature study of the

prior experimental research on dyslexia learning disorders. The previous research has different methods and objectives compared to the research in this article, namely using the certainty factor method and the Dempster-Shafer for early diagnosis of learning disorders in children.

A review of some of the most recent related works (see also Table I) confirms that the research carried out in this article differs from previous jobs. This study's results help identify children with learning disorders early. So that by knowing early, children with learning Disorders Dyslexia, Dysgraphia, Dyscalculia, and Dyspraxia can get therapy earlier. The novelty of this study is to build a learning disorder detection system in children using the Certainty Factor and Dempster-Shafer methods which previous researchers have never studied. Table I compares this research work with several prior related researches.

TABLE I: COMPARISON OF THIS RESEARCH WORK WITH SOME PRIOR RELATED RESEARCHES

Research by	Type of Research	Method Used		Type of Learning Disorders Studied				Research Result
		Certainty Factor	Dempster Shafer	Dyslexia	Dysgraphia	Dyscalculia	Dyspraxia	
Kuerten *et al.* (2019) [36]	Literature Review	No	No	Yes	No	No	No	Recognizing and detecting the occurrence of reading disorders (Dyslexia) in children is very important.
Pedro and Goldschmidt (2019) [24]	Survey	No	No	No	No	No	Yes	The study concluded that although preschool teachers know the indicators of dyspraxia learning disorders, preschool teachers need training related to dyspraxia to expedite the learning process.
Yulianti *et al.* (2020) [37]	Comparison	Yes	Yes	No	No	No	No	The Dempster-Shafer method and the Certainty Factor can both be used to assist psychologists in determining learning styles, but the Dempster-Shafer method has a better level of effectiveness in determining learning styles when viewed from the range of trust values obtained.
Sari *et al.* (2020) [38]	Comparison	Yes	Yes	No	No	No	No	The Certainty Factor is the most suitable and best-used method for the early detection of depression (compared to Dempster-Shafer).
Waber *et al.* (2020) [23]	Comparison	No	No	Yes	No	No	Yes	Children with learning disorder dyspraxia have early motor delays and are less able to produce visuospatial results than other groups. Meanwhile, children with dyslexic learning disorders have poorer single-word reading and phonological processing than children with dyspraxia.
Vlachos and Avramidis (2020) [16]	Comparison	No	No	Yes	No	No	Yes	The difference between learning disorder dyslexia and Dysgraphia lies in neurobiological abilities.
Pagliarin *et al.* (2020) [39]	Experimental	No	No	Yes	No	No	No	anticipate the next sensory event. Children and adults who have Dyslexia are not able to efficiently anticipate the next sensory event.
Safarova *et al.* (2021) [40]	Survey	No	No	No	Yes	No	No	Concluded the need to make a Graphomotor Disabilities Rating Scale (GDRS) for different feature groups to help educational experts or therapists in diagnosing the development of Dysgraphia.
Mammarella *et al.* (2021) [41]	Experimental	No	No	No	No	Yes	No	The study concluded that there was no difference between normal children and children with learning disabilities (developmental dyscalculia) when analyzed from a psychometric perspective cut-off without a clinical diagnosis
O'Dea *et al.* (2021) [43]	Literature Review	No	No	No	No	No	No	Learning services for children and adolescents with dyspraxia must focus on creating a conducive social environment and attitudes.
Mustafaeva (2021) [42]	Literature Review	No	No	Yes	Yes	No	Yes	The solution to addressing the problem of Dyslexia, Dyspraxia, and Dysgraphia in children is to use the services of a therapist and community assistance or other resources for therapy.
Taylor and Vestergaard (2022) [7]	Literature review	No	No	Yes	No	No	No	Proposes to observe cognitive differences in each individual who has Dyslexia disorder. In essence, the form of cognition of people with Dyslexia plays an essential role in adaptation.
Our research	System Development and Experimental	Yes	Yes	Yes	Yes	Yes	Yes	The expert system developed in this study for early diagnosis of learning disorders in children shows that the expert system developed using the Certainty Factor method has higher accuracy than the Dempster-Shafer method.

Table I shows the differences in previous related studies and their differences from the research conducted in this article. Previous related studies did not test the method/results' accuracy. Not only that, previous research was not a study by building a system like this research and then conducting trials (experiments) on the system built using the Certainty Factor and Dempster-Shafer method in diagnosing learning disorders in children as was done in this research article.

III. Research Methodology

The programming language used in building a web-based intelligent system in this study is PHP (Personal Home Page or PHP Hypertext Preprocessor). PHP is the most popular high-level programming language used in building web-based or mobile computer programs [44, 45]. The stages of research and development of an expert system for early diagnosis of learning disorders in children using the Certainty Factor and Dempster-Shafer methods in this study used or adopted the Waterfall model. The Waterfall is a management model for developing application programs [46]. The sequence of processes in the Waterfall model is sequential from the initial stage to the next step [47]. Fig. 1 shows a series of development of an expert system for early diagnosis of learning disorders in children in this study.

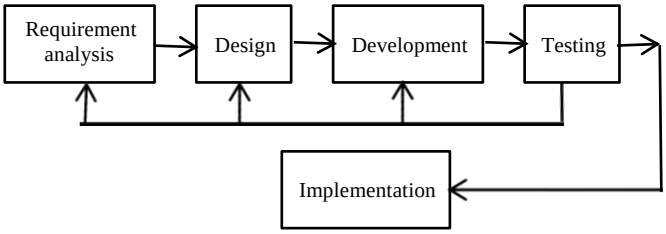

Fig. 1. The Waterfall model of system development in this study [48].

The requirements analysis stage is a step to get the data needed (data collection) to develop an application system. The design stage is realizing the expert system's knowledge base, which contains symptoms of learning disorders and certainty factor scores from experts (see Fig. 2). Meanwhile, the development stage is the stage of applying the research method used or developing the system being built. The testing stage is testing the developed system and whether it follows the needs. If it is inappropriate, then a review of the previous stage is carried out at this testing stage. Finally, the implementation stage is the last stage. At this implementation stage, an expert system was developed to determine the performance of the system being built.

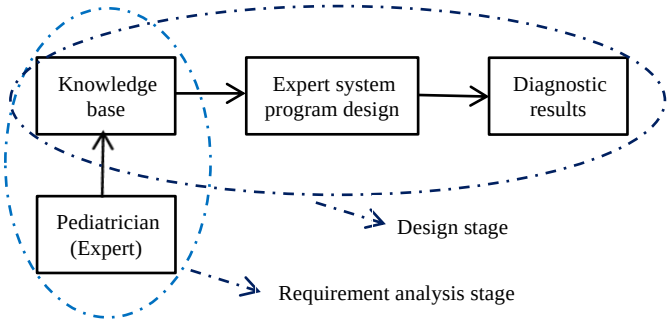

Fig. 2. Stages of requirements analysis and design of the expert system.

IV. Result and Discussion

A. Requirement Analysis

Interviews with the expert were obtained to determine the types of learning disorders in children and the accompanying symptoms in this study. The expert interviewed was a pediatrician. The collection of data about the types and symptoms accompanying learning disorders of children was carried out in early 2022 by experts. The symptoms accompanying each type of learning disorder in children, obtained from the expert doctor, are the reference data for the realization of the expert system. The expert system developed works like an expert who can diagnose types of learning disorders in children. Table II shows the types or classifications of learning disorders in children.

TABLE II: Types of Learning Disorders in Children

Learning disorder code	Types of learning disorders
P1	Dyslexia
P2	Dysgraphia
P3	Dyscalculia
P4	Dyspraxia

B. Design

The design stage is the stage of realizing the knowledge base of an expert system of learning disorders in children with accompanying symptoms and a score of Certainty Factors (CF) obtained from expert doctors (see Table III).

TABLE III: Knowledge Base of Expert System of Learning Disorder

No.	Learning Disorder Code	Symptoms of learning disorders	Expert CF			
			P1	P2	P3	P4
1	G1	Read the letters interchanged letters; for example like, read b for letter d	1.0	-	-	-
2	G2	Poor or slow in discrimination visual	0.8	-	-	-
3	G3	Lack of ability or slow perception of spatial	0.8	-	-	-
4	G4	Inability or slow in distinguishing vowels and consonants	0.8	-	-	-
5	G5	Inability or slow to understand alphabet and symbol concept	0.8	-	-	-
6	G6	Inability to distinguish parts or directions Right and left	0.8	-	0.8	-
7	G7	Difficulty holding stationery with good, like holding a pencil	-	0.6	-	0.8
8	G8	Frequently bumping into other objects, such as crashing chairs and so on	-	-	-	0.8
9	G9	Having trouble jumping	-	-	-	0.8
10	G10	Having a delay in using the dominant hand	-	-	-	0.8
11	G11	Having trouble closing and unbuttoning the shirt	-	-	-	0.8
12	G12	Having difficulty interacting with others	-	-	-	0.6
13	G13	Slow or inability to recognize letters and spell them	1.0	-	-	-
14	G14	Talk to yourself often and often pay attention to hands when writing	-	0.6	-	-

15	G15	Reading slowly and haltingly	1.0	-	-	-
16	G16	Not able to understand the sentence read or heard well	0.8	-	-	-
17	G17	Not able to understand the sentence read or heard well	0.8	-	-	-
18	G18	Inability to remember words	0.8	-	-	-
19	G19	Very slow in doing homework	0.8	-	-	-
20	G20	Inability to do work written	0.8	-	-	-
21	G21	Inability to understand the concept of time, like distinguishing morning and afternoon	0.8	-	-	-
22	G22	Often writes with font sizes that are not consistent	-	0.8	-	-
23	G23	When writing a lot, mix up capital letters and lowercase	-	0.8	-	-
24	G24	Difficulty in expressing an idea, knowledge, and understanding through writing	-	0.8	-	-
25	G25	Disproportionate font size and shape too small or too big	-	0.8	-	-
26	G26	Not able to copy the writing already available	-	0.8	-	-
27	G27	The way of writing is inconsistent, like not following the right line	-	0.8	-	-
28	G28	Difficult to count change or money to pay when shopping	-	-	1.0	-
29	G29	Difficulty doing math problems, simple and difficult to sort number	-	-	0.8	-
30	G30	Sometimes experiencing disorientation like time disorientation	-	-	0.8	-
31	G31	Having difficulty learning music, like learning the sequence of notes	-	-	0.8	-
32	G32	Difficulty in distinguishing numbers that have the same shape, for example, the numbers 9 and 6	-	-	0.6	-
33	G33	Difficulty in distinguishing signs in mathematics, such as positive signs and the like	-	-	1.0	-
34	G34	Difficulty in distinguishing shape geometry	-	-	0.8	-

Table III contains the knowledge base of the expert system built into this study which consists of symptom codes, the symptoms that accompany learning disorders, and the value of the certainty factor (CF) from experts.

C. Development

1) Certainty factor method

The Certainty Factor method begins by selecting the symptoms and the level of belief in the chosen symptom. The next step is calculating the value of CF (with a single premise). The value of CF is the sum of the user's CF value with the expert's CF value or CF (H, E) = CF (user) × CF (expert). Then, calculate the CF Combine or CF Combine (CF1, CF2) = CF1 + CF2 × (1 − CF1). With the completion of all these calculations, the highest value obtained from the calculation of the CF Combine is the final result of this diagnostic process.

The diagnostic process results conclude that the type of learning disorder in children is Dyslexia, Dysgraphia, Dyscalculia, or Dyspraxia (see Fig. 3).

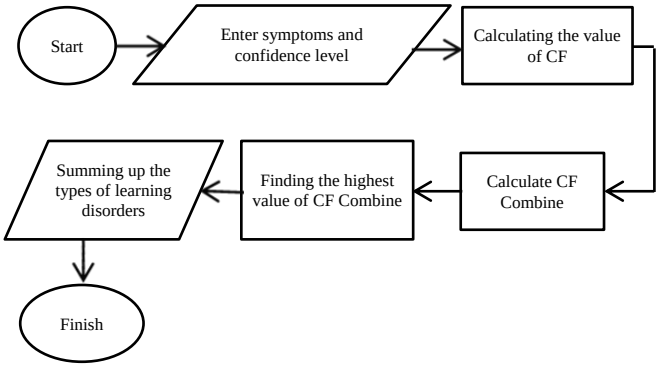

Fig. 3. The process of diagnosing learning disorders in children with the Certainty Factor method.

An example of a calculation using the Certainty Factor method in diagnosing the type of learning disorder in children with three symptoms that have been given weights by experts and the symptom weights entered by the user is the calculation as shown in Table IV. The next calculation step is to calculate the value of the CF combination obtained from the multiplication in the previous steps. Finally, the results of their combinations are shown in Table V.

TABLE IV: THE RESULT OF MULTIPLYING SYMPTOM WEIGHTS FROM EXPERTS AND SYMPTOM WEIGHTS FROM USER INPUT

Symptom Name	Expert Weight Value	Value of User Possibility	Multiplication	Learning disorders
(G1) Read the letters interchanged letters	1	0.8	0.8	P1
(G5) Inability or slow in understanding alphabet and symbol concept	0.8	0.8	0.64	
(G9) Having trouble jumping	0.8	0.6	0.32	P4

TABLE V: COMBINATION RESULTS

Symptom Code	CF Values of Symptoms	CF Combination	Learning disorders
(G1)	0.8	= CF1 + CF2 × (1 − CF1)	P1
(G5)	0.64	= 0.8+0.64 (1 − 0.8) = 0.8 + 0.128 = 0.928 (CF old1)	
(G9)	0.32	0.32	P4

The result of the diagnosis of the type of learning disorder in children is the type of Dyslexia disorder (P1) with a confidence of 0.928 or 92.8% (See Table V).

2) Dempster-shafer method

The Dempster Shafer method starts with initialization, then choosing the symptoms that are felt and calculating using the Dempster Shafer formula. The Dempster-Shafer method includes the Belief formula (Bel), which represents a measure of certainty or confidence in the evidence of a set. If the value is 0, it indicates no evidence. On the other hand, a value of 1 means there is a certainty. Plausibility (Pls) is a measure of disbelief or uncertainty against evidence. Value Pls is from 0 to 1. The Belief function and the Plausibility function are:

$$Bel(\mathrm{X}) = \sum_{Y \subseteq x} m_1(\mathrm{Y}) \quad (1)$$

$$Pls(\mathrm{X}) = 1 - Bel(\mathrm{X}) \quad (2)$$

X = Symptom 1 of the disease. Y = Symptom 2 of the disease. Bel(X) = Belief (X), meaning the belief value or certainty of disease X experiencing symptoms 1. Pls(X) = Plausibility (X), meaning the value of uncertainty or the uncertainty of disease X which experiences symptoms 1. $m_1(Y)$ = Mass function. Or confidence level of evidence (Y). If it is known that X and Y are a subset, with m1 as a function of density X and m2 as a function of density Y, then m3 is a function of the combination of m1 and m2 (see Fig. 4). The equation of m3 is as follows:

$$m3(Z) = \frac{\sum X \cap Y = Z \; m1(X) \cdot m2(Y)}{1 - \sum X \cap Y = \theta \; m1(X) \cdot m2(Y)} \quad (3)$$

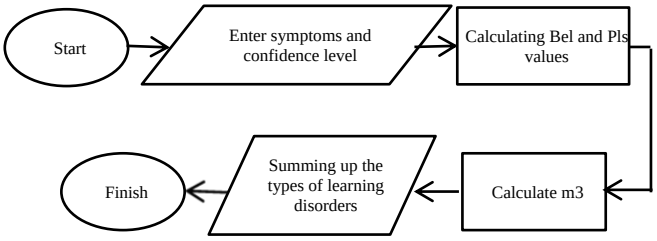

Fig. 4. The process of diagnosing learning disorders in children with the Dempster-Shafer method.

An example of the calculation of the Dempster-Shafer method in diagnosing the type of learning disorder in children with three symptoms that experts have weighted is shown in Table VI.

TABLE VI: WEIGHT VALUE FROM EXPERT

Symptom Name	Expert Weight Value
(G1) Read the letters interchanged letters; for example, like, read b for letter d	1
(G5) Inability or slow in understanding alphabet and symbol concept	0.8
(G9) Having trouble jumping	0.8

The next step is calculating the belief and plausibility values for each symptom in Table VI. But, first, calculate the belief and plausibility values in G1, as shown in Table VII.

TABLE VII: DENSITY VALUE OF M1 (G1)

Symptom Name	m1 (G1)	m1 (θ)
(G1) Read the letters interchanged letters; for example, like read b for letter d	1	= 1 – m1(G1) = 1 – 1 = 0

The second step is to calculate the belief and plausibility values in G5, as shown in Table VIII.

TABLE VIII: DENSITY VALUE OF M2 (G5)

Symptom Name	m2(G5)	m2 (θ)
(G5) Inability or slow in understanding alphabet and symbol concept	0.8	= 1 – m2(G5) = 1 – 0.8 = 0.2

TABLE IX: COMBINATION FUNCTION

	m2(P1) **0.8**	**m2 (θ)** **0.2**
m1{P1} 1	m3{P1} 0.8	M3{P1} 0.2
m1 (θ) **0**	m3{P1} 0	M3{ **θ** } 0

Next is to calculate the combined function of m1 and m2 using Eq. (3) as shown in Table IX.

The summation of Dempster Shafer:

$$m3\{P1\} = (0.8 + 0.2 + 0) / (1 - 0) = 1$$

$$m3\{\boldsymbol{\theta}\} = 0$$

Calculating belief and plausibility values in G9 is as shown in Table X.

TABLE X: DENSITY VALUE OF M4 (G9)

Symptom Name	m4(G9)	m4 (θ)
(G9) Having trouble jumping	0.8	= 1 – m4(G9) = 1 – 0.8 = 0.2

Next is to calculate the combined function m3 and m4 using Eq. (3) as shown in Table XI.

TABLE XI: COMBINATION FUNCTION

	m4(P4) 0.8	m4 (θ) 0.2
m3{P1} 1	m5{ **θ** } 0.8	m5{P1} 0.2
m3 (θ) **0**	m5{P4} 0	m5{ **θ** } 0

The summation of Dempster Shafer:

$$m5\{P1\} = (0.2) / (1 - 0.8) = 1$$

$$m5\{P4\} = (0) / (1 - 0.8) = 0$$

$$m5\{\boldsymbol{\theta}\} = 0$$

Based on Table XI, the result of the diagnosis of the type of learning disorder in children is the type of Dyslexia disorder (P1) with a value of 1 or 100%.

D. Testing and Implementation

The accuracy of the Certainty Factor (CF) and Dempster-Shafer (DS) methods is tested, which is compared with the results of expert diagnosis using 30 patient (P) data (See Table XII).

TABLE XII: ACCURACY TESTING

P	Symptoms Code	Results Diagnosis			Validation	
		CF	DS	Expert	CF	DS
1	G1, G5, G9	Dyslexia	Dyslexia	Dyslexia	√	√
2	G8, G12, G16	Dyspraxia	Dyspraxia	Dyspraxia	√	√
3	G9, G13, G17	Dyslexia	Dyslexia	Dyspraxia	×	×
4	G1, G4, G9, G10, G15	Dyspraxia	Dyslexia	Dyslexia	×	√
5	G11, G12, G24	Dyspraxia	Dyspraxia	Dyspraxia	√	√
6	G20, G23, G24	Dysgraphia	Dysgraphia	Dysgraphia	√	√
7	G32, G33, G34	Dyscalculia	Dyscalculia	Dyscalculia	√	√
8	G15, G16, G30	Dyslexia	Dyslexia	Dyslexia	√	√
9	G12, G19, G28	Dyslexia	Dyscalculia	Dyslexia	√	×
10	G19, G28, G34	Dyscalculia	Dyscalculia	Dyscalculia	√	√
11	G23, G25, G26	Dysgraphia	Dysgraphia	Dysgraphia	√	√
12	G1, G19, G20	Dyslexia	Dyslexia	Dyslexia	√	√
13	G25, G26, G32	Dysgraphia	Dysgraphia	Dysgraphia	√	√
14	G1, G8, G9	Dyspraxia	Dyslexia	Dyspraxia	√	×
15	G14, G15, G16	Dyslexia	Dyslexia	Dyslexia	√	√
16	G11, G18, G30	Dyslexia	Dyslexia	Dyslexia	√	√
17	G12, G21, G26, G33	Dyscalculia	Dyscalculia	Dyscalculia	√	√
18	G16, G20, G21	Dyslexia	Dyslexia	Dyslexia	√	√
19	G11, G31, G32	Dyscalculia	Dyscalculia	Dyscalculia	√	√
20	G9, G10, G30	Dyspraxia	Dyspraxia	Dyspraxia	√	√
21	G11, G12, G30	Dyspraxia	Dyspraxia	Dyspraxia	√	√
22	G16, G17, G33	Dyslexia	Dyscalculia	Dyslexia	√	×
23	G13, G16, G30	Dyslexia	Dyslexia	Dyslexia	√	√
24	G18, G19, G23	Dyslexia	Dyslexia	Dyslexia	√	√
25	G16, G32, G33	Dyslexia	Dyscalculia	Dyscalculia	×	√
26	G21, G23, G24	Dysgraphia	Dysgraphia	Dysgraphia	√	√

27	G13, G15, G21, G24	Dyslexia	Dyslexia	Dyslexia	√	√
28	G17, G19, G21	Dyslexia	Dyslexia	Dyslexia	√	√
29	G27, G28, G34	Dyscalculia	Dyscalculia	Dyscalculia	√	√
30	G9, G10, G11, G18, G19	Dyspraxia	Dyspraxia	Dyspraxia	√	√

As presented in Table XII, the Certainty Factor Method correctly diagnosed 27 data from 30 patient data, so the accuracy obtained was 90%. While the Dempster-Shafer method can correctly diagnose 26 data from 30 patient data, the accuracy obtained is 87%. Thus, the accuracy of the Certainty Factor method is better than the Dempster-Shafer method for diagnosing types of learning disorders in children. In short, the results of the test using the Certainty Factor method showed that there were three data on the results of testing which did not match the expert reference data. In contrast, in the results of the test with the Dempster-Shafer, there were four data on testing results that did not correspond with the expert reference data. So, the accuracy difference between the Certainty Factor and Dempster-Shafer testing methods is 3%. In other words, the accuracy of the Certainty Factor method is better than the Dempster-Shafer method in diagnosing learning disorders in children. It happens because the Certainty Factor method, in its calculations, accommodates the expert's weight value and the user's weight value, which then combines the two values to get the result. Here the Dempster-Shafer method only utilizes the value given by the expert, regardless of the user's input value in the calculation [38, 49].

The results of this study provide answers to questions from previous researchers who asked whether learning disorders can be identified early [11]. The answer is yes, it can, and not just learning disorder dyslexia but other learning disorders: Dysgraphia, dyscalculia, and dyspraxia. Besides that, the results of this study reinforce many previous studies that the development of expert systems helps solve problems in various fields [25], including systems built using the Dempster-Shafer and Certainty Factor methods. The point is that the difference or strength of this research, compared to similar related research, is that this research not only develops a system for diagnosing learning disorders in children but also conducts system trials on data on learning disorders in children. In addition, this study researched all categories of children's learning disorders (Dyslexia, Dysgraphia, Dyscalculia, and Dyspraxia), which previous researchers had never done. Also, this study tested the accuracy of the results of the method used, which previous related studies had not carried out.

V. Conclusion

The expert system for diagnosing learning disorders in children using the Certainty Factor and Dempster-Shafer methods found that the system's accuracy using the Certainty Factor method is 90%, and the Dempster-Shafer method is 87%. It means the expert system using the Certainty Factor method is more accurate than the Dempster method. The implication of the results of this study is that it is useful to help identify learning disorders in children from an early age, including learning disorders dyslexia, Dysgraphia, dyscalculia, and dyspraxia, and also at the same time, answer doubts about previous researchers who questioned whether learning disorders in children could be detected from the start.

The novelty of this study is that no previous related research has conducted this research by comparing the Certainty Factor and Dempster-Shafer methods in diagnosing the types of learning disorders in children. Suggestions for further research are to examine various objects other than learning disorders in children and compare them or use different methods. Besides that, it is necessary to carry out further research by paying attention to differences in gender, and age categories (learning level) of children.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

All authors carry out work assignments to complete research and write this article together. The level of roles and tasks of research work is the basis that places each author as the first, second, and so on. Anthony Anggrawan wrote the entire manuscript including writing research background, research analysis and research-related works, research methodology and conclusions including supporting references. Hairani Hairani has collected data and completed the necessary calculations, including calculating the accuracy of the research method results. Christofer Satria has worked on, edited, and visualized flow diagrams and tables, including assisting the second author's work. Aprillia Dwi Dayani has checked to provide additional technical input needed in the manuscript including checking the correctness of sentence structure and grammar in writing in the manuscript. All authors had approved the final version.

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