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Deanship of Graduate Studies and Scientific Research  
Master of Informatics

# Diagnosis and Clustering Of Dyscalculia Third Grade Students.

Submitted by:

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Thesis submitted in partial fulfillment of requirements of the  
degree "Master of Science in Informatics"

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# DEDICATION

*To my mother, father and husband , who always supported me and encouraged me to get my Master Degree. To my brothers and sisters for their support. To my children (Yazeed, Waleed, Ruoom and Ream ) who have endured the hardships of the study trip.*

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## المخلص

يعاني العديد من الطلبة من صعوبات التعلم في الرياضيات . وقد أجريت العديد من الأبحاث والدراسات لمعالجة هذه المشكلة والتي حاول معظمها تحديد ما إذا كان الطالب يعاني من صعوبات التعلم في الرياضيات أم لا. من غير أي تفاصيل إضافية أخرى عن نوع وتحديد هذه الحالة. وبناء على نتيجة التحديد اقترح الباحثون حلول وطرق لعلاج صعوبات تعلم الرياضيات لدى الطلبة. يحاول هذا البحث معالجة مشكلة صعوبات تعلم الرياضيات بين طلبة الصف الثالث في مدارس مديرية جنوب فلسطين. ذلك من خلال استخدام تقنيات وأدوات Machine Learning Clustering ، ويقترح علاج مبني على تكنولوجيا المعلومات لعلاج كل طالب تعتمد وفقا لحالته/ها. و يحاول البحث أن يخطو خطوة أخرى إلى تحديد ما هو نوع صعوبة التعلم للرياضيات لدى الطالب مثل العمليات الحسابية ، مقارنة و قراءة الأعداد ، أو أي مزيج من الثلاث مهارات. المنهج المستخدم في هذه الدراسة قد يكون السباق لاستخدام Machine Learning Clustering بدلا من استخدام Machine Learning Classification. ويحاول تجزئة مشكلة صعوبات تعلم الرياضيات إلى ثلاثة أنواع رئيسية . ولتحقيق ذلك، أجري مراجعة كثيفة للأدبيات ، ثم استخدم امتحان لصعوبات تعلم الرياضيات لوزارة التربية والتعليم العالي في فلسطين بعد تعديله وفحصه من قبل خبراء. تم تطبيق الامتحان المعدل على طلبة الصف الثالث في المدارس من كلا الجنسين في كل من مديريات الخليل ويطا. تم برمجة و ادخال نتائج الامتحان إلى R-Tool . وتم استخدام خوارزمية Hierarchical حيث تم تطبيق خوارزمتان ( Ward , Single ) . تظهر خوارزمية (Ward) نتيجة أفضل من خوارزمية ( Single )، بعد حساب Cophentic Correlation Coefficient ( CPCC ) . حيث كان ( CPCC ) لخوارزمية (Single)، هي الأقل ( 0.46 ) . بينما كان ل خوارزمية ال ( Ward ) ( 0.70 ) . لا يقتصر استخدام Clustering على تحديد ما إذا كان الطالب يعاني من المشاكل الحسابية ام لا كما في الدراسات السابقة بل يعد استخدام خوارزمية (Ward) في التجميع أكثر عمقا لتحديد نوعية الضعف الذي يعاني منه الطالب. تم وضع النتائج في سبعة مجموعات او عناقيد مثل (يعاني الطالب ضعف في المهارات الثلاث/ لا يعاني الطالب من ضعف في المهارات الثلاث / الطلبة الذين حصلوا على علامة صفر في الامتحان ...الخ) واطهرت النتائج اختلافات بين الذكور و الاناث و كذلك اختلافات في ما بين طلبة المديريتين. وأظهرت كذلك تضارب بين توزيع النتائج و مستوى التحصيل المدرسي في مادة الرياضيات . وبناء على النتائج ومراجعة الدراسات السابقة تم اقتراح نموذجا لعلاج الضعف لدى طلاب صعوبات تعلم الرياضيات حيث يتكون أيضا من مرحلة تحديد وتجميع للطلبة بناء على حالتهم. تم تقييم هذا النموذج من قبل (٢٤) خبيرا وأدرجت ملاحظاتهم ومقترحاتهم في صلب هذا النموذج.

# Abstract

Several students suffer from dyscalculia. Many research and studies have been carried out to tackle this problem. Most of these researches tried to identify whether a student suffers from dyscalculia or not, without any further details on the case. Based on results of the identification, researchers proposed solutions and ways to treat dyscalculic students. This research tries to tackle the dyscalculia problem among grade 3 students in Southern Directorate schools in Palestine. The research attempts to use artificial intelligent methods and tools to cluster students according to their dyscalculia case, and proposed information technology-based treatment for each student according to his/her case. It tries to go a further step into identifying what type of dyscalculic student on sensing number. The approach used in this research is perhaps the first to use AI tools to cluster; but not classify, dyscalculic students, and tries to break-down the dyscalculia problem into three major types using this approach. To achieve this, an intensive literature review was carried out, then an exam used by the Ministry of Education and Higher Education in Palestine was modified and tested by experts. The modified exam was applied to grade three students at schools of both genders in Hebron and Yatta directorates. Results of the exam were coded and input to an AI tool R tool. The tool uses hierarchical techniques clustering. We apply two hierarchical techniques algorithms; the Single link and

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WARD method. WARD algorithm is an agglomerative hierarchical clustering procedure, where the criterion for choosing the pair of clusters to merge at each step is based on the optimal value of an objective function. Single link is technique looks in the distance between two clusters to be equal to the shortest distance. WARD algorithm show better result than Single Link, after calculated the Cophenetic Correlalation Coefficient (CPCC ). Single Link is the lowest CPCC, which is (0.46). But Ward has (0.7) CPCC. Not only was the use of the clustering to determine if the student is dyscalculic or not as the previous work, but we also use WARD algorithm clustering more deeply to determine what kind of dyscalculia a student has. The result was clustered into seven clusters such as (weakness on the three skills, the absence of any weakness in the three skills, students who have zero mark in the exam). Results show differences among gender and among directorates, and inconsistency between clustering results and students math achievement in school. Based on the results and the literature review, a model has been proposed for the treatment of dyscalculic students, where it consists also of the identification and clustering stage. The model was evaluated by 24 experts, and their comments and suggestion were incorporated in the model.

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# Chapter 1

## Introduction

Dyscalculia (mathematics difficulties) is widespread all over the world. Most studies have indicated that the prevalence rate of dyscalculia is between 3% and 6% of the world population [1]. Low math achievement is clear in the case of students from low-income households [2].

The substrates in this chapter which will to discussion are : Background, Problem Research, Objectives of Research, Novelty and Contribution, Research Questions, Scope and Thesis Organization.

### 1.1 Background

Students with dyscalculia are delayed at least two years behind their peers. In comparisons with their peers in regular classrooms, they must have additional education and training in mathematical tasks related to their individual needs [3]. The implication of such difficulties is serious and can be sensed in adulthood. Low math achievement is specifically clear in students from low-income households, as mentioned above. Although, there has been an increasing interest in examining children with mathematics difficulties in recent years, in the best of cut knowledge perhaps there is no research that

has addressed this problem through using modern information technology in teaching and learning. Difficulties with number combinations represent basic weaknesses in number sense, such as the ability to understand counting principles or to manipulate quantities mentally. There may also be underlying problems in the working memory, spatial representation, and attention [4]. Researches indicate that mathematics content is specifically challenging for students who have learning disabilities. Learning disabled students face difficulties in processing and retaining information, therefore; they have problems in time keeping up with classroom instructions. So, it seems that learning for disabled students may greatly benefit from self-paced computer-assisted instruction [5, 6, 7, 8].

### 1.1.1 The Concept of Learning Disability

Onita Nakra, a member of the National Joint Committee for Learning Disability (NJCLD), defined learning disability in her book; "Learning disabilities is a general term that refers to a heterogeneous group of disorders manifested by significant difficulties in the acquisition and use of listening, speaking, reading, writing, reasoning, or mathematical abilities. These disorders are intrinsic to the individual, presumed to be due to central nervous dysfunction, and may occur across the life span." [7]

### 1.1.2 Types of Learning Disability

Author in [7] noted in her book different types of learning disability. A learning disability can be limited to school performance in subjects or skills. For example, reading, writing, or arithmetic, or watching the child's performance in other aspects such as art, activities in the playground, following instructions in class, and so on.

### 1.1.3 Indicators and Causes of Dyscalculia

Many researchers defined the difficulties of mathematics learning in their researches, Dyscalculia is about difficulties related to numbers and arithmetic, and not about other branches of mathematics, such as geometry” [9]. There are some indicators for dyscalculia students as Ronit Bird showed in his book. These indicators include the ability to subsidy even very small quantities, to estimate whether a numerical answer is reasonable, to count backwards reliably and to manage time in daily life. Also, the indicators include the weaknesses in both short and long term memory and in visual and spatial orientation Moreover, they include the directional (left/ right) confusion, slow processing speed when engaged in mathematical activities, trouble with sequencing, a tendency not to notice patterns, a problem with all aspect of money and a marked delay in learning to read a clock to tell the time [5].

The causes of dyscalculia are many and unknown to researchers. However, they are specified to some factors which refer to as a brain-based condition. The possible causes of dyscalculia as shown in [10] are:

1. Genes and heredity.
2. Brain development: ”The study found differences in the surface area, thickness and volume of parts of the brain. Those areas are linked to learning and memory, setting up and monitoring tasks and remembering math facts” .
3. 3. Environment:” Dyscalculia has been linked to exposure to alcohol in the womb. Prematurity and low birth weight may also play a role in dyscalculia.”
4. Brain injury.

But in [11] the possible causes of dyscalculia are the physiology of mathematical functioning, genetic and social factors, and scholastic factors. On the other hand, Victoria Simms et al. showed in their research the effect of very preterm birth on achievement in mathematics. And this study indicates that the importance to search in relationship between very preterm children and mathematics difficulties [12].

There are many researchers who described the types of dyscalculia. For example, Geary in his article in 2004 showed that there were three subtypes of dyscalculia; procedural, semantic memory and visuo-spatial. The Procedural Subtype is determined when the individual procedural developmental behavior is not mature, repetition of the errors in the implementation of procedures, misunderstanding of the concepts underlying procedural use, and encountering series of difficulties in complex procedures. This type has evidence of left hemisphere pre-frontal brain dysfunction, which can worsen with age. The second subtype is Semantic Memory which is determined where the person faces difficulties in the recovery of mathematical facts along with a high error percentage. But the third subtype the Visuo spatial Subtype which considers a difficulty with spatially represented numerical and other kinds of mathematical information and relationships. Brain differences are shown to be located in the right hemisphere posterior region [13].

### 1.1.4 Types of Dyscalculia

In her research, Gupta said that there are six types of dyscalculia which were identified by Koske (1974); Verbal dyscalculia (a difficulty in using mathematical concepts in oral language), Practognostic dyscalculia (a difficulty in manipulating concrete materials), lexical dyscalculia (a difficulty in reading mathematical symbols), graphical dyscalculia (a difficulty in writing mathe-

matics symbols), ideognostic dyscalculia (a difficulty in understanding mathematical relationships), operational dyscalculia (a difficulty in performing specified mathematical operations).” [14] ”Developmental dyscalculia originates from a specific impairment in the brain function. Acalculia is observed when a person loses all sense of meaning of numbers. Pseudo-dyscalculia is based on emotional blockage or a confidence problem.” These are the three types of dyscalculia which are referred on Guptas research [14].

## 1.2 Back Ground to the Problem Statement

It is necessary to address on the main skills by which learning mathematics occurs in this research. The skills are; a sense of number, long-term memory, short-term memory, working memory and an ability to learn crucial sequences of words and numbers [15]. In contrast, on the ” Developmental dyscalculia and basic numerical capacities: In a study on 89-year-old students, the researchers concluded that the dyscalculia was the consequence of specific difficulties on elementary numerical processing, rather than the result of disability in other cognitive abilities [16]. In another study titled ” Children’s Mathematics Performance: Five Cognitive Tasks across Five Grades”, the researchers examined a set of primary mathematical tasks. After that, they classified performance in grades 1 to 5 [17].

On the other hand, Lyons, I. M., et al (2014), indicated that there is a difficulty in determining any one elementary numerical skill in grades 35, that replace the others [18]. Furthermore, depending on the result of the study conducted by the researchers Magda Praet et al ” Language in the Prediction of Arithmetics in Kindergarten and grade 1; the number naming and number comparison are better predictors than number line estimation

## 1.2. BACK GROUND TO THE PROBLEM STATEMENT

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of arithmetic skills in kindergarten” [19].

From the above mentioned description, experts who used judgment exam in this research concluded the primary skills which play major roles in sensing number, naming numbers, comparison number and operation. There are models which are designed only to identify and diagnose a student with learning disability or non-learning disabled. For example, some of the models are designed by implementing a soft computing technique named Learning Vector Quantization; a model which is designed to implement a soft computing technique. This model classifies a student as learning disabled or non-learning disabled. Also, it finds out the type of learning disability that classifies the students into dyslexia, dysgraphia and dyscalculia [8]. Also, there are no clues in the literature for the model which defines the type of weakness on mathematics skills (type of Dyscalculia), using machine learning on artificial intelligence to cluster to an appropriate group. For instance, there are many standard tests for identifying dyscalculic students based on statistical method [20]. Here we must note that on a previous article and similar research, researchers who used artificial intelligence (supervised learning), were using the classification not clustering. Classification algorithm needs to learn groups with label data. For instance, its use category labels which tag objects with previous identifiers and already learn the things from their train data. But the clustering algorithm does not use category labels which tag objects with previous identifiers. It does not know anything before, in other words, there is no train data for applying it. [21, 22] Hence we will try on our research use (un-supervised learning) clustering rather than (supervised learning) classification for identifying dyscalculic students and determine in which skills there is weakness. Also, an expert used student grade as criteria for analysis dyscalculia clusters.

In addition, the previous independent study and others didn't find that any model treatment dyscalculic students in directly. In addition, an IT-based model to treat dyscalculic students using Machine Learning tools and techniques could not be found in literature.

### 1.3 Problem Statement

Literature review showed that previous dyscalculia studies used previously assigned criteria to classify students. This classification method put students in groups depending on their dyscalculia degree. This method of dyscalculia classification need trained examiner who can apply criteria efficiently as seen in latent growth modeling [23, 24], and ANN SVM [20].

The research aimed at proposing a diagnosis and treatment model based on Machine Learning clustering method, and technology; adaptively. It used clustering analysis to identify whether third grade students have dyscalculia or not. It also determined which type of dyscalculia students have in sensing number, focusing on 3 criteria of sensing number: operation, comparison, and naming numbers. This computer adaptive approach do not need a trained dyscalculia examiner and do not use train data [21, 22].

### 1.4 Objectives of Research

The main objective of this research is to suggest computerized model based on artificial intelligence to identify dyscalculic students, and to determine where the problem exists, then proposing suitable treatment to the problem.

In particular, this research aims at achieving the following objectives:

1. To determine whether the third grade student is dyscalculic or not.

2. To determine the type of dyscalculia, by implementing cluster analysis.
3. To propose a model for treatment and enhancement for the dyscalculic students.

## 1.5 Novelty and Contribution

Reviewing previous literature explained that there are few works identifying dyscalculia students through machine learning. Those who used machine learning, they use classification not clustering. On the other hand, few other studies have focused on clustering the type of disability. In addition, we use an exam from the Ministry of Education in Palestine, designed especially for the students with mathematical learning disabilities. The exam was modified either by removing or adding questions. Then, it was given to experts for validity and judgment.

The contribution on this research is focused on the following points:

1. Determining if the student is dyscalculic or not, through criteria which are identified from experts and previous study.
2. Identifying the specific dyscalculia area (operation, comparison, and naming number) through hierarchical clustering algorithm, and choosing the best algorithm.
3. Proposing a model to identify and treat dyscalculia students based on the clustering results reached.
4. Using and applying Machine Learning in this field, and proposed an integrated model for identifying (through clustering), and treating dyscalculic students, by incorporating technology with other elements adaptively is the first to attempt.

## 1.6 Research Questions

In order to accomplish the objective of the research, four questions were raised to steer the research:

1. How can dyscalculic student be identified? In order to identify dyscalculia students, the researcher implemented the exam from the Ministry of Education in Palestine. The exam was modified either by removing or adding question.
2. How can we identify the specific dyscalculic area (operation, comparison, and naming number)? In order to identify the specific dyscalculia area, the researcher needs to determine the criteria for mathematic skills, which relates to the number sensing which was extracted from the literature.
3. What is the best clustering method for identifying and grouping dyscalculic students? To choose appropriate clustering method, there must be a comparison between a set of algorithm clustering.
4. How could a model be proposed to treat dyscalculic students based on the clustering results reached? The proposed model combines an essential component which tries to enhance dyscalculic students.

## 1.7 Scope

This research diagnoses dyscalculia third grade students and clusters where they have problem, and propose a model for their enhancement. In this capacity, the research will cover issues related to the cluster mechanism and school education in general. The diagnosis for dyscalculia student takes into

account important criteria for sensing number. These criteria are determined through the literature review. An essential data obtained from appropriate exam which contained an important criteria for sensing number. Also, the study is limited to a proposed model which focuses on enhancing the process. But the proposed model has not been applied.

## **1.8 Thesis Organization**

The remaining parts of the thesis are organized as follows: Chapter 2 contains a summary of some previous studies related to this work. Chapter 3 covers the methodology used in this thesis. Chapter 4 demonstrates experiments, results and discussion. Finally, chapter 5 concludes the work and proposes some new direction for the future work.

# Chapter 2

## Literature Review

There are many methodologies for identification and intervention of dyscalculia, which addresses different aspects of this task by proposing appropriate methodologies and procedures. These would be classified into three dimensions. The first is the contribution focusing on using technologies, the second is based on neurological description, and the third is the diagnostic method for developmental dyscalculia.

### **2.1 The Intervention of Using Learning Technologies**

The most important factor of unknowing and unlearning arithmetic in the normal way is the lack of sense of number [3]. The researchers issued a computerized test which uses the (Dots2Track) and the (Dots2Digits) program, the Dyscalculia Screener, which works on computers and uses key board responses. The experiment was applied on four children with dyscalculia. The results showed the response time of these four children. When each new number is entered, the learner responds much more slowly, but responses speed up

## 2.1. THE INTERVENTION OF USING LEARNING TECHNOLOGIES

as they become more trained. Some researchers have addressed this problem by using the latent growth modeling (LGA) [6], which represents repeated measures of dependent variables as a function of time and other measures. The above study tries to identify children with dyscalculia using the latent growth modeling approach, which reduces several limitations; for example arbitrary cutoff, measurement error, lacking consideration of growth [6].

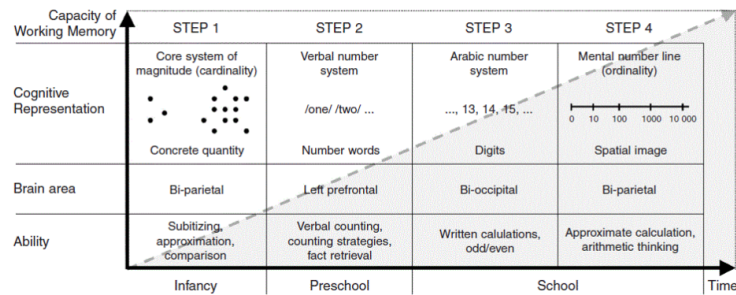


Figure 2.1: Four Step Developmental Model .  
[23, 24]

LGA was conducted to categorize participants into different teams depending on their arithmetic performance over 3 years. The category which showed the bad performance over 3 years would be a possible candidate. According to this, participants were classified into five categories which are shown in Figure 2.1. Another research identifies this problem faced by dyscalculia students and supports the different accommodation for them such as pedagogy skills, presentation of techniques, and test provisions which enables the dyscalculia student to gain confidence in their mathematical abilities [25]. It would have been better if it provided software training for this category and measured progress in their results or use the multimedia for learning [26]. The researchers offer a design and a first pilot evaluation of

## 2.1. THE INTERVENTION OF USING LEARNING TECHNOLOGIES

the computer-based training program *calcularis* for student with dyscalculia.

The learning process provided during multimodal cues is based on current neuro- psychological results. The characteristics of this program of control algorithm can adapt with the user and provide the best learning environment and process. Assessment of this program explains that the important training affects in the number representation, for instance in subtraction. The program also proves positively a good adaption to the needs of the student with dyscalculia, and gives a feedback from the participants. Another design and evaluation for dyscalculia was addressed by [27]. In this design, authors discussed requirements imposed on the developed programs which come from practical experiences, and the development process was analyzed. They used three tests to measure the levels of achievement. The results showed that the programs provide an adequate help for teacher working with dyscalculia students. The feedback of computer program helped dyscalculia students to become self-confident. It also offered the opportunity to practice individually. The others offer descriptive summary of the software and the cognitive tasks. Another point is the review of the results about neural correlates of computer based cognitive tasks, which is used to examine dyscalculia. It will also be the assembly for the results of neuro-structural and neuro-functional imaging. There is no standard dyscalculia examination, so they developed computer-based examination (DD test) for 6-9 years old school children who have already begun with multidisciplinary team and approach [4].

Others develop an E-learning and an adaptive E-learning tool which trains dyscalculia student on an entertaining numerical comparison task using display problems adapted according to the level of performance of student individually. It provides an opportunity to increase learning and skill optimization using educational software. The results explained that the software was

## 2.1. THE INTERVENTION OF USING LEARNING TECHNOLOGIES

adapted well for different levels of initial knowledge and learning speeds [2]. The problem which dyscalculia students faced was the sense of number, as discussed earlier. The visual-spatial learning which is one of eight types of learning styles defined in Howard Gardner's theory of Multiple Intelligences. Visual Spatial Learning styles (VSLs) refer to a person's ability to recognize, analyze, and understand visual information in the around. Results showed the importance of spatial ability to identify the learners' use of cognitive resources [9]. These characteristics help in the identification of visual spatial learners, but not all the visual spatial learners will conform with all these characteristics: To like complex ideas and tasks, to have poor listening skills, to have difficulty finishing tasks/school work, to have a poor handwriting, to love Lego, puzzles, jigsaws, computer games, television, to make things, likes art and/or music, to have a poor sense of time, to be extremely sensitive to criticism, to be emotionally very sensitive, to have difficulty with spelling/times tables, to have a vivid imagination and/or disturbing dreams, to be distractible, to be very disorganized [9]. VSLs learn best by discovery or inductive techniques. They also excel when they are involved with participation, visual representation, models, and computers [9]. In addition, VSLs remember what they see, so we can use visuals and hands-on experiences. Imagination, creativity, visualization and pattern finding are their primary strengths [9]. Interactive virtual image displays enhanced by special processing and by non-visual display methods [28]. It offers a new communication medium for human-machine interaction. Also, it submits techniques for solving control problems. In addition, Virtual Environment (VE) displays have broad applications potential- in education, procedure training, and high level programming. VE has been used to test whether a fun virtual environment can improve math efficiency levels and motivate dyscalculia students

## 2.1. THE INTERVENTION OF USING LEARNING TECHNOLOGIES

to face challenges conducting mathematical skills. The results were positive not only because the computer was eye-catching to the students, but also because of the learning strategy implemented in the VE. In addition the VE was designed to enter featured games that address mathematical skills. The positive results show that pedagogical methods implemented using games may help students learn and make efficient, flexible use of learning time if the games are related to a virtual environment which allows free exploration without an established order of execution [29]. The rational use of multimedia in an educational context provides a great potential in offering the learning environment more accessible to dyscalculia students. E-learning resource developers, multimedia producers and teachers must work together to establish the context of a multimedia resource in order to ensure that the learning experience is accessible as possible to the dyscalculia students [30]. [24] The researcher offers new software with a structure which is based on neuro cognitive models. The number design, which is developed for the software, enhances important aspects of number understanding and facilitates learning of important concepts of number. The adaptability of the software allows to adjust learning speed and to focus on specific problems of each particular student. The family has an influence on the school development of their students. The results showed that family socioeconomic level, its classification characteristics, an appropriate home environment, and parents' positive attitude on education and their active participation in it, are factors affecting the academic development of the vast majority of students. This effect is even more important for dyscalculia students. Other factors which affect students learning are positions, perceptions and parental expectations regarding their academic performance. Where, parents' positive positions towards their children and family provide an increased students' confidence

## 2.2. THE INTERVENTION BASED ON NEUROLOGICAL DESCRIPTION

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in their abilities. Also, the cooperation between their families and schools is an important aspect for students' academic success [31].

On the other hand [32] research aims at designing a decision support system in e-learning which adapts with the learner automatically through the assessment to the students learning style by using literate-based method. In addition, [33] developed a software program to enhance dyscalculia students [33]. Another study showed the nature of dyscalculia. It follows that Emerson House (EH) may be effective for children who faced various difficulties [34] Thus, there is no study indicating to this problem as suitable model involving set of variables to enhance academic level for dyscalculia.

## 2.2 The Intervention Based on Neurological Description

Some researchers described a four-step developmental model which allows expectations of neuropsychological imbalances for Developmental Dyscalculia (DD) with treatment models that can be deduced, recommended, and applied [35]. While others discussed the advancement in understanding the reasons of dyscalculia ,the treatment of this case, and the indications that we shouldn't be confused with "primary" and "secondary" developmental dyscalculia. The primary DD associated with the weakness of development of brain's mechanisms for processing numerical magnitude information which leads to self-neuro developmental factors. The secondary DD, which relates to mathematical deficits, results from external factors such as poor teaching, low socioeconomic status and behavioral attention problems [36]. The important factor in the development of mathematical cognition is the working memory WM. Researchers test Baddeley and Hitch's multi-component

WM in the context of arithmetic problem solving abilities in children. They used a group of neuropsychological assessments of mathematical ability and working memory, and functional neuro-imaging in the context of a single well-controlled cognitive task involving arithmetic problem solving. Their results indicated a basic role for visual-spatial VS abilities through ages 7-9, a major stage in the development of mathematical abilities in children, and the usefulness of the multi-component Baddeley and Hitch WM model in fractionating the neural-correlates of arithmetic problem solving through development. There are studies needed to test how brain systems are associated with each WM component interacting dynamically to provide arithmetic problem solving and skill development in young children [37]. Dinkel PJ et al showed in their research that there are no differences in performance for the set of dyscalculia children based on deviating neural mechanisms. Also, they indicated in their study that the fMRI examination results can't be at the same diagnostic level with behavioral examination results [38].

## **2.3 Diagnostic Method For Developmental Dyscalculia**

The diagnosis of students with learning disabilities (Dyscalculia) requires very hard work. Especially for teacher work, who doesn't have enough technical skills. Although that there are two artificial intelligence techniques have been applied, for identification or diagnosis of students with learning disabilities. There are artificial neural network (ANN) and support vector machine (SVM) which were explained by Tung Kuang .. et al in their research. The results experiment showed that the (ANN) performance better

### 2.3. DIAGNOSTIC METHOD FOR DEVELOPMENTAL DYSCALCULIA

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than (SVM) [39]. Identification of children with mathematical learning disabilities (MLDs) using latent class growth analysis research for the purpose of trying to identify children with MLD using the latent growth modeling approach. It showed deficits in all number- related cognitive processing, including number sense. During the class, it was identified that there were no observable deficits in cognitive processing [40].

In 2012, Manghirmalani P. et al [41] presented a model which could classify any learning disability into its various types using fuzzy expert system.

Another study addressed that the most representative researches aimed at applying artificial intelligence tools for solving problem in diagnosis and intervention of specific difficulties [42] In 2009, Kavita Jain et al [43] suggested a perceptron based on an artificial neural network model for diagnosing the learning disability by using a method based on a test. The model consisted of a single input layer with eleven units which were connected to different sections of a conventional test and one output unit. In 2013, Athanasios S. et al [44] reviewed the existing literature related to diagnostic and intervening approaches based on the artificial intelligence techniques, but they didnt make comparison between them.

In 2011, Tung-Kuang Wu et al [20] applied two artificial intelligence techniques, for the identification or diagnosis of students with learning disabilities. The two techniques were artificial neural network (ANN) and support vector machine (SVM). The results of the experiment showed that the (ANN) performance was better than (SVM).

Lain Kaufmann and Michael von Aster showed in their research particular skills which are important for the scope special of treatments. They also

### 2.3. DIAGNOSTIC METHOD FOR DEVELOPMENTAL DYSCALCULIA

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found a tool for intervention whenever it is effective [45].

The study [46] indicated that the measures which are valid and reliable indicators for prospective mathematics difficulties in kindergartners . The researchers in [18] tested 125 children with phonological, visuospatial short-term memory (STM), and non-symbolic quantitative skills which support the calculation skills . Another research tested the relations between eight elementary numerical skills on (1391) children from grades 1-6. [47] Researchers in thesis [48] were tested the latest version of the Number Race (version 3.0). The number of participants was twelve aged 5-7 years old. The Participants varied in comparing numbers in terms of the speed and accuracy. They got their results after taking standardized tests and a computerized battery, the participant carry out the number race for a month (20 minutes daily) .

Giannis Karagiannakis and Anna Baccaglini-Frank described that the DeDiMa battery available group of mathematical tasks helped identify the features of students mathematical performances. The participants for this study were fifth and sixth grade students. [49].

The study [50] showed that the systematic provides procedures for determining and clustering students who have dyscalculia in elementary schools in India. Researchers describe in their study different tools which were used in the study sample. Through this paper, it was tackled "Arithmetic Diagnostic Test (Ramaa, 1990, 1994)". It diagnoses the difficulties faced by students in elementary schools for grades IIV. This test include three main scopes for mathematics; " namely number concept, arithmetic processes (operations) addition, subtraction, multiplication and division, and arithmetical reasoning." [50]

## 2.4 Discussion:

The following table will explore the features and the differences between the models that diagnose dyscalculia students.

In our research we are depending more than one study to conclude the diagnosis and treatment dyscalculic student . For example using machine learning clustering ( Hierarchical techniques ) from some research for instance [1, 51, 52, 53, 54, 55, 56, 22] rather than another techniques. These study does not use for diagnosis dyscalculic students.

Also, we are conclude and determine a basic criteria for sensing number, which is an elementary element for diagnosis dyscalculic student [40, 18, 12, 27, 7, 10, 8, 25, 13]

In addition in [2, 29, 28, 24, 30] studies, we are deduce an essential component for proposed model.

2.4. DISCUSSION:

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Table 2.1: Methods To Diagnose Dyscalculia

Frame work Model	Summary	Features
1.Artificial neural network (ANN) and support vector machine (SVM). (W. Tung, et al , 2007)	This model to diagnose if the student have dyscalculia or not. Uses machine learning based on classification methods.	Classification methods needs to knowing the groups depending on label data. This model does not determine type of the dyscalculia.
2.Model Learning Vector Quantization. (M.Pooja , et al , 2011).	This model to diagnose if the student has learning disable or not. Then determine the type of learning diable ( dyscalculia, dylexia and dysgraphia).	This model does not determine type of the dyscalculia.
3.Latent growth modeling ( Wong, et al ,2014).	LGA was conducted to categorize participants into different teams depending on their arithmetic performance over 3 years.	This model does not determine type of the dyscalculia.

## 2.5 Clustering

Clustering techniques have been used in different scopes of research. For example, engineering, medicine, biology and data mining [57]. "Cluster analysis is the formal study of methods and algorithms for grouping, or clustering, objects according to measured or perceived intrinsic characteristics or similarity." [21] The goal of clustering is to look for the structure in data, so it is considered as an exploratory analysis. [57, 21].

Data clustering is usually used for three major objectives: underlying structure, natural classification and compression [21].

- Underlying structure: For having an insight into data, creating assumptions, discovering anomalies and determining key features.
- Natural classification: For determining measures of similarity between forms or organisms.
- Compression: As a way for grouping the data and summarizing by cluster forms.

Below we will address the schemes of clustering [53, 51]:

1. Density-based: This technique depends on the density, which is the detection of clusters based on the continually increasing density in a particular group as long as the density in the neighborhood overruns a certain threshold.
2. Distance-based: For categorical feature vectors, the concept of distance which works in some cases is the number of common characteristics.
3. Partition-based: Constructing a partition of database  $D$  of  $n$  objects into a set of  $k$  clusters.

4. Hierarchical: This will be in two forms. Initially, all objects are supposed to be single cluster. After that, each step is divided into two clusters which are "far" from each other. The operation finished when each point is in a cluster by itself. The researcher will later talk about this technique extensively.
5. Model-based: This method deals with each cluster as a mixture of ordinary distributions and computes the probability which indicates that each point belongs to a certain cluster.

The researcher will address the partition-based and hierarchical techniques in details in the next section.

### 2.5.1 Clustering Methods

The fact states that the concept of cluster is undefined carefully; the clustering method is under development. Farley and Raftery divided the clustering method into two main groups: hierarchical and partitioning methods [58, 59].

### 2.5.2 Hierarchical Methods

A hierarchical clustering method is based on grouping objects into a tree of clusters. There are two categories for hierarchical technique; agglomerative and divisive. These categories depend on whether the hierarchical decomposition is formed in a bottom-up (merging) or top-down (splitting) fashion [58, 52].

- Agglomerative Hierarchical Clustering: At first, each object is in its own cluster. Then, these clusters merge into larger and larger clusters, until all of the objects become in a single cluster or until certain termination conditions are satisfied [59].

## 2.5. CLUSTERING

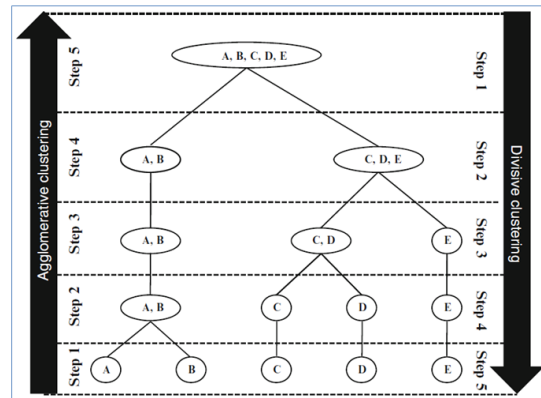


Figure 2.2: Agglomerative and divisive clustering.  
[60]

- **Divisive Hierarchical Clustering:** This technique works in a reverse order to the agglomerative hierarchical clustering. In the beginning, it takes all objects in one cluster. Then, it splits the clusters into smaller pieces until each object forms a cluster on its own or until it satisfies certain termination conditions [59].

The hierarchical clustering methods could also be classified according to the degree of similarity as measuring technique which is estimated as following: [59, 60]

1. **Single-link clustering:** It has other names such as connectedness, the minimum method or the nearest neighbor method. This technique looks in the distance between two clusters to be equal to the shortest distance from any object of one cluster to any object of the other cluster.
2. **Complete-link clustering:** It also has other names such as the diameter, the maximum method or the furthest neighbor method. In contrary to the work of the first technique, it looks in the distance between

## 2.5. CLUSTERING

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two clusters to be equal to the longest distance from any object of one cluster to any object of the other cluster.

3. Average-link clustering: It also has other names such as the minimum variance method. This method depends on the distance between two clusters. It is defined as the average distance between every pairs of the two clusters objects.
4. Centroid: At first, this technique calculates the geometric center (centroid) of every cluster. The distance between the two clusters equivalent the distance between the two centroids.

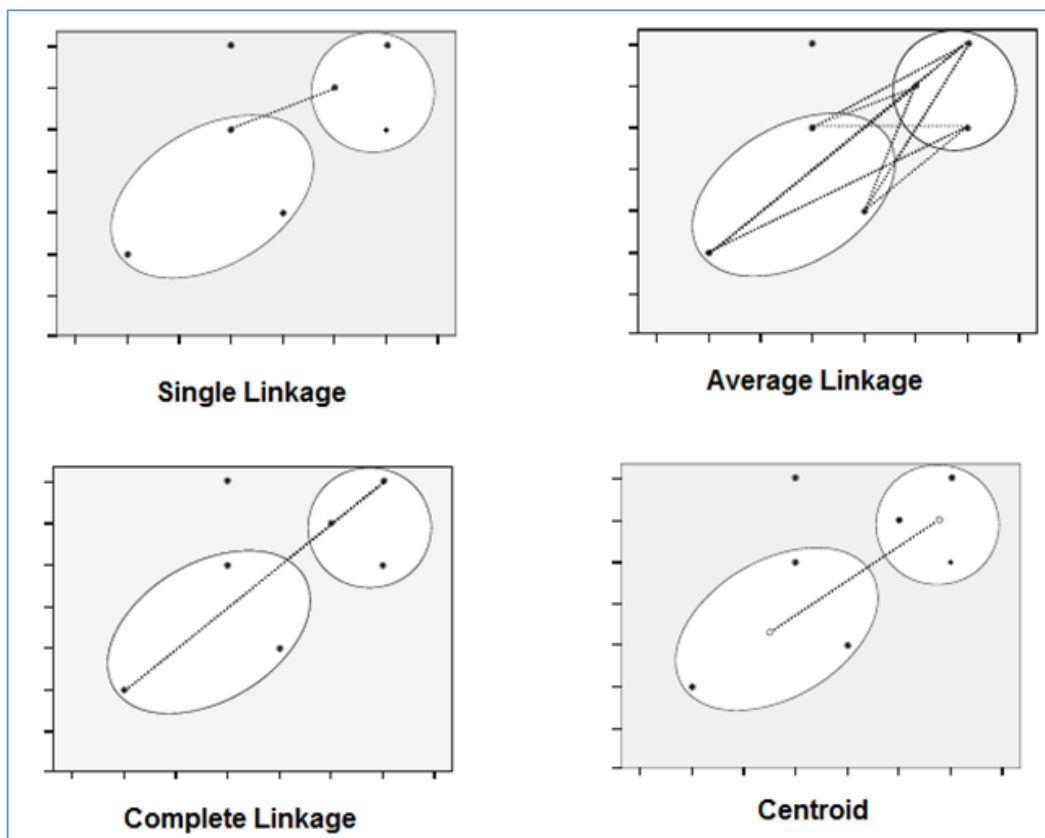


Figure 2.3: Clustering Procedures.

[60]

# Chapter 3

## Research Methodology

### 3.1 Introduction

This chapter explains the methodology which was used in the research. The methodology has four parts; the mechanism for the identification of dyscalculia students, determining the specific dyscalculia area (operation, comparison, and naming number), employing a better clustering technique for identifying and grouping dyscalculia students, and proposing a model to treat dyscalculia students based on the clustering results reached.

### 3.2 Identifying Dyscalculic Students

Previous related work showed that there was no specific way to help the primary school teacher identify dyscalculia student. So, the first step in this research is identifying the dyscalculia student through an exam. We read a set of exams for this purpose. They were structured in specific criteria for mathematical skills. We address the most important skill in the exam; sensing number. It is based on three criteria; operation, comparison and naming number. We used an exam from the Ministry of Education in Pales-

### 3.3. IDENTIFYING TYPE DYSCALCULIC STUDENTS

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tine, designed especially for learning disabilities in mathematics. An exam was modified either by removing or adding questions, and then it was given to experts for validity and judgment. After that the study sample which is needed to implement the test was drawn from two areas; Hebron and Yatta. 530 students of third grade in eight schools - four female and four male schools took the exam.

There were 500 valid exams. Exam results will be used as an input to a clustering tool. In the contrast on the previous studies for example (Calvo, et. Al, 2015) [18] examined 125 children, also in ( Kucian, etal, 2013) [23] evaluated 15 children. We took into the consideration such as Lain Kaufmann and Michael von Aster who noted in their research, that "A child is said to have a mathematical learning disability (MLD) when his or her performance on a test of mathematical skills falls below an arbitrarily chosen percentile in a study population, without reference to the child's general intelligence level". [45]Also, experts used the level of grade on an exam for determining the level of difficulties which any student has.

### **3.3 Identifying Type Dyscalculic Students**

Sensing number is an important skill in tests which is used for determining if the student is dyscalculia or not. Every students result in each skill will identify whether the problem exists or not. We noted from the previous study that the focus was on determining only if the student is dyscalculia or not. But in our research we identify which skill has problem, through students grade as experts used to. The test was also given at the same time to all students in order to give accurate results.

## 3.4 Best Clustering Method For Diagnosis and grouping Dyscalculic Students

After taking the exam and getting the results, we used the exams results as an input to a clustering tool.

Here, we must take into consideration the cluster evaluation which is part of cluster analysis. In other research, they used the Cophenetic Correlation Coefficient ( CPCC) for evaluating the clusters which is a popular evaluation to hierarchical clustering [56].

A series of experiments will be implemented on hierarchical cluster, after calculating the ( CPCC) for the four techniques. The four hierarchical clustering techniques which were calculated by CPCC are: single link, complete link, group average and ward's. Depending on the result of (CPCC) we decided to select appropriate techniques. After that, we determine the correct number of cluster by Elbow Method.

Next, we saved the result of clusters as excel file for calculating some criteria. After that, we must analyze this result and find the relationship in it. It is possible to suggest a model for the working mechanism as described in the figure [3.1].

## 3.5 Proposing Model

In this stage, we will draw a proposed model to treat dyscalculia students. A questionnaire was used after the first version of the proposed model. The questionnaire contained several questions and the answers were five-point Likert scale, such as SA strongly agree, A agree, N neutral, D disagree, and SD strongly disagree. The number of questions was suitable for the proposed

### 3.5. PROPOSING MODEL

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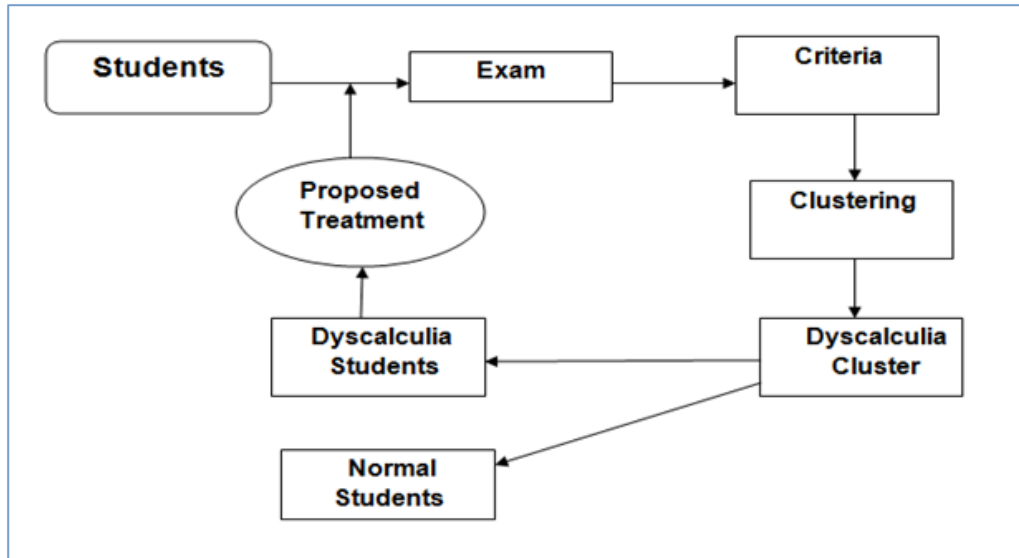


Figure 3.1: Proposed Model For Diagnosis.

model. ”The questionnaire was adopted from Shahin (2012) [61] to evaluate the proposed model which is distributed to experts.

The attached proposed model is to find a suitable artificial intelligence; a based approach to identify students with dyscalculia, the type of dyscalculia they have, and propose a technology-based treatment by taking into consideration other elements, as shown in the model.

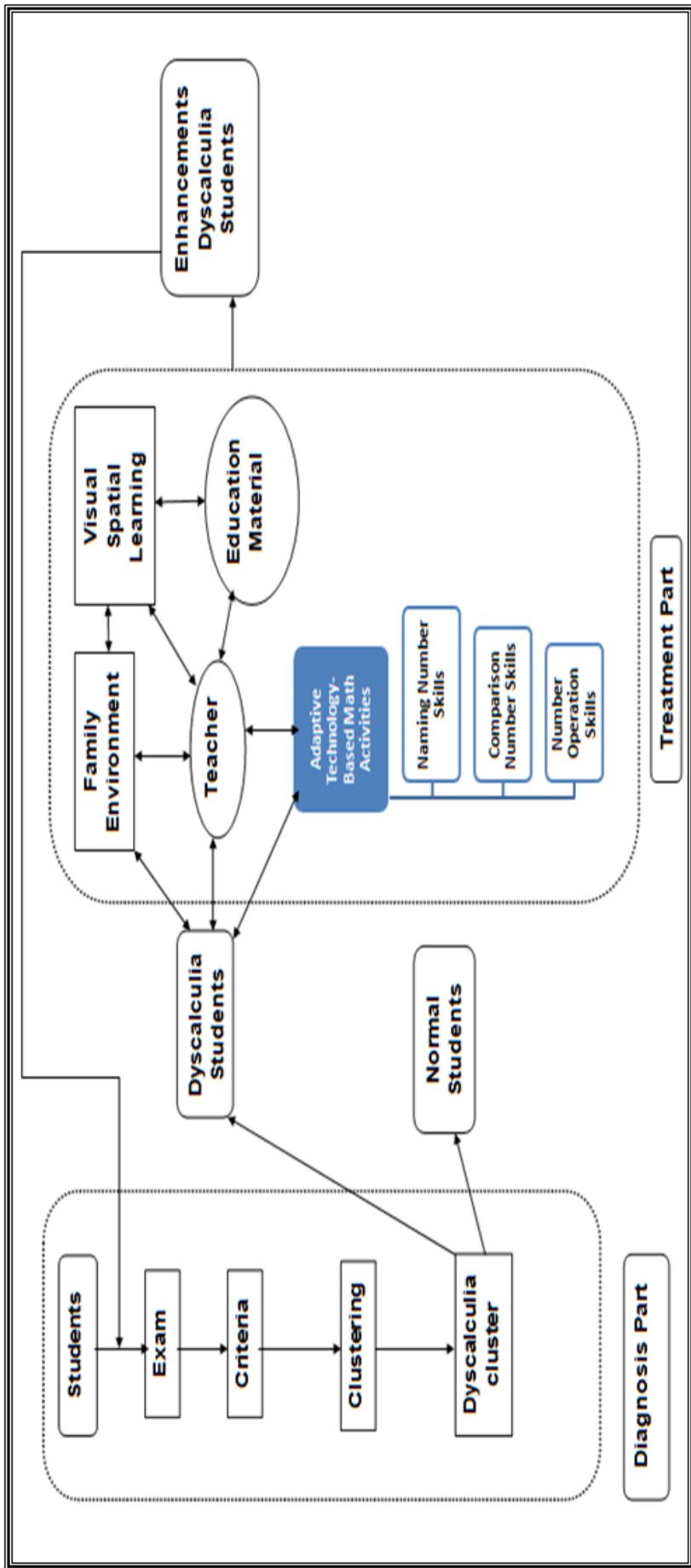


Figure 3.2: Proposed Conceptual Model for Diagnosis and Enhancement of Dyscalculia Students.

### 3.5. PROPOSING MODEL

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The proposed model is graphically represented above. It aims at identifying (diagnosis) the dyscalculia students, and particularly, the type of dyscalculia a student might have. The model consists of two parts; the diagnosis part and the treatment part. The diagnosis part depends on the students results to identify the type of dyscalculia he/she has (if any), based on a set of criteria. These criteria include three main skills (naming number, comparing number and adding / subtracting process) which are the basic skills for sensing number. They are the main criteria that teacher depends on to evaluate students in traditional way at the school.

The exams' results were processed clustering tool/ algorithm to find what and how many clusters there will be, so the student will be identified and classified according to the cluster they belong to. Based on the result, dyscalculia students will be a subject of a treatment procedure as shown in the model. The treatment part of the model consists of several components such as family environment, teacher, Visual Spatial learning (VSL), education material, and technology-based mathematical activities.

The subject of the treatment would be an enhanced dyscalculia student. This student would be sent back to set for the dyscalculia identification exam to measure the level of enhancement, and to decide if he/she needs further treatment or, just become a normal student. The teacher plays a core role in this part of the model, where he/she is the center for such treatment. The teacher uses technology tools and educational materials, and coordinates with family and the overall VSL. After preparing the proposed model graphically, it was given to experts for validity and judgment. The experts have high academic qualifications and have experience in these fields (education, mathematics and information technology).

# Chapter 4

## Research Results and Discussions

### 4.1 Introduction

In our research, we use the hierarchical techniques clustering for our data. We use hierarchical rather than k- means, because the hierarchical cluster permits to choose from a large number of distance functions invented for binary data and it sounds more theoretically for them than simply Euclidean distance [62].

We also use R(R i386 3.1.3) tool for clustering analysis and evaluation. The laptop we use during our experiments has the following characteristics: the processor is ( intel core Tm i3-2348 M, Cpu @2.3 GHz), RAM memory has 4 G. Byte and the operating system is windows system 32bit).

We used an exam designed for dyscalculic students. 530 students of third grade in eight schools were took the exam. There were 500 valid exams. Exam results will be used as input to a clustering tool. A series of experiments were implemented by using the four hierarchical clustering techniques.

## 4.2 Optimal Numbers Of Clusters:

We also use the elbow method to find the correct number of clusters. It is "direct method which consists of optimized criterion, such as the within cluster sums of squares" [63].

The following figure shows that the seventh cluster is the optimal number of clusters we must use in our experiments; because the values in this figures start fixing from the sixth number. So that adding another cluster doesn't give much better result of the data.

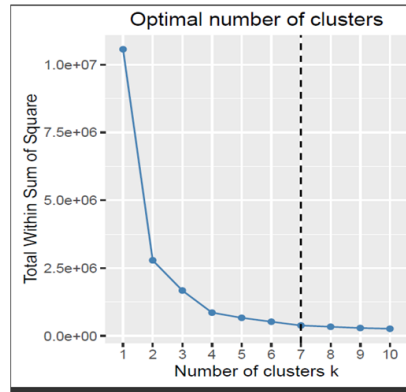


Figure 4.1: Four Step Developmental Model.

## 4.3 Different Between Single and Ward Techniques:

In our research, we apply two hierarchical techniques algorithms; the single link and Ward's method. Depending on an unsupervised evaluation of Hierarchical clustering which measures the goodness of clustering structure with no consideration to external information. This measurement of cluster validity is divided into two classes: cluster cohesion (compactness, tightness),

#### 4.3. DIFFERENT BETWEEN SINGLE AND WARD TECHNIQUES:

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And the result we obtained is in the table below:

Table 4.1: Cophenetic Correlation Coefficient (CPCC) and Four Agglomerative Hierarchical Clustering Techniques.

Technique	CPCC
Single Link	0.46
Complete Link	0.74
Group Average	0.74
Ward's	0.70

that decides how the joining related to the objects is in a cluster. And cluster separation (isolation) which determines how featured or well divisive a cluster is from other clusters.

"Cophenetic Correlation Coefficient (CPCC) is a standard measure of how well a herarchical clustering fits the data" [56]. We apply the following code to calculate the Cophenetic Correlation Coefficient (CPCC).

```
require(graphics)
data=readworksheetFromFile("D:/dalal.xlsx", sheet=1)
d1 <- dist(data)
hc <- hclust(d1, "ave")
d2 <- cophenetic(hc)
cor(d1,d2)

hc <- hclust(d1, "ward.D")
d2 <- cophenetic(hc)
cor(d1,d2)

hc <- hclust(d1, "single")
d2 <- cophenetic(hc)
cor(d1,d2)

hc <- hclust(d1, "complete")
d2 <- cophenetic(hc)
cor(d1,d2)
```

Figure 4.2: R Code for Calculate The Cophenetic Correlation Coefficient (CPCC).

#### 4.3. DIFFERENT BETWEEN SINGLE AND WARD TECHNIQUES:

We notice that the single link is the lowest CPSS, but the other values are close to each other. When we use a single technique, we get the following results figure.

The below diagram shows seven clusters, each cluster has one to two objects. And one cluster has large objects as the research mentioned as reference [60]. But this may be illogical for the objective of this research. Also, the single link technique is one of the oldest techniques of hierarchical clustering [54]. In addition, there are some disadvantages for single link and complete link. Some points on single link appear as bridge between two clusters, which makes them look like one cluster. While, average-link leads to elongated clusters to divide neighboring elongated clusters to merge [59].

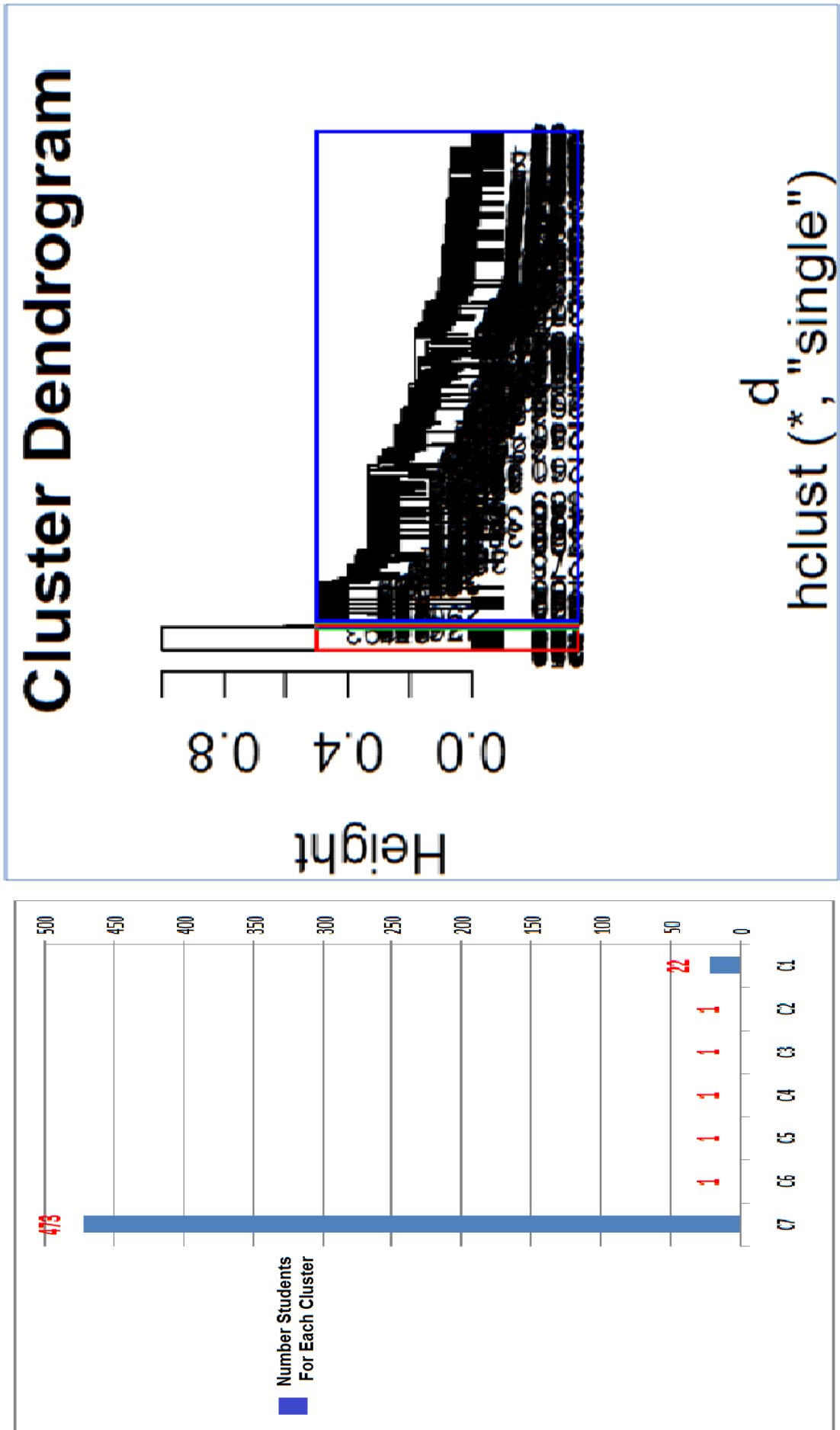


Figure 4.3: Single Cluster Dendrogram.

#### 4.3. DIFFERENT BETWEEN SINGLE AND WARD TECHNIQUES:

Although the value of CPCC for ward technique is close to the values of other techniques, we decide to choose it rather than others in our research. This technique was described in 1963 [55] it's advantage is providing memory, However, not all distance values are stored but distances are computed as they are needed [64]. The results of Ward experiments, which are applied on our data set, are shown in the following chart:

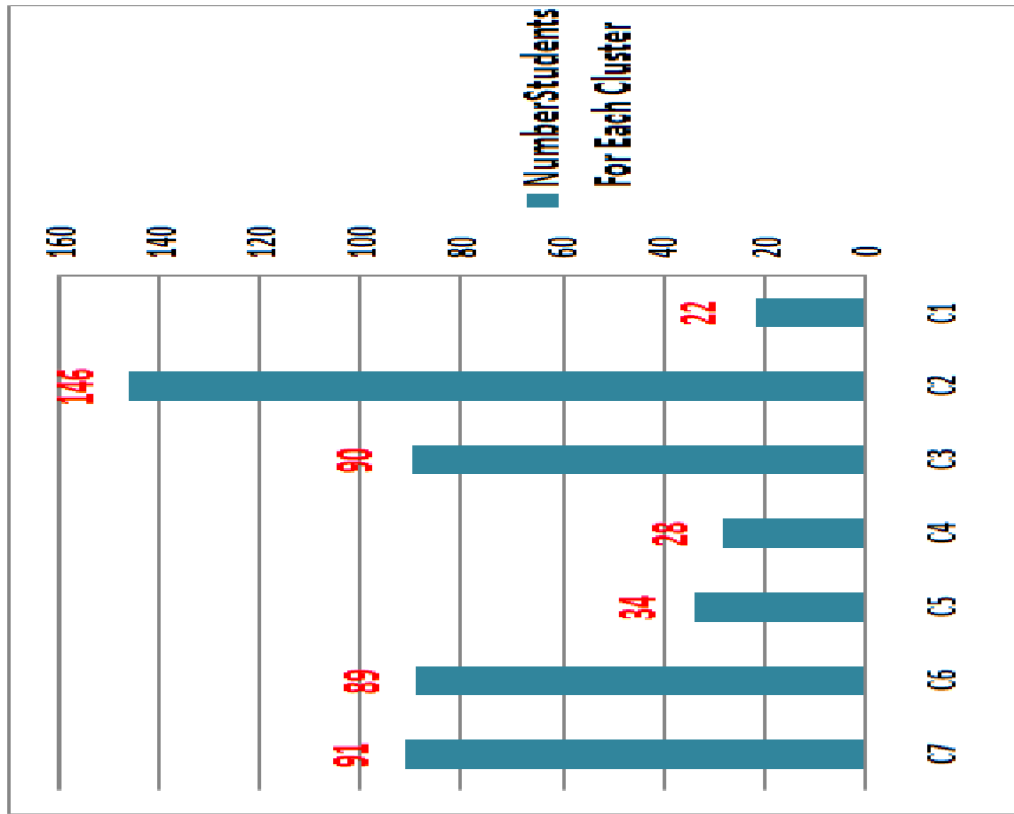
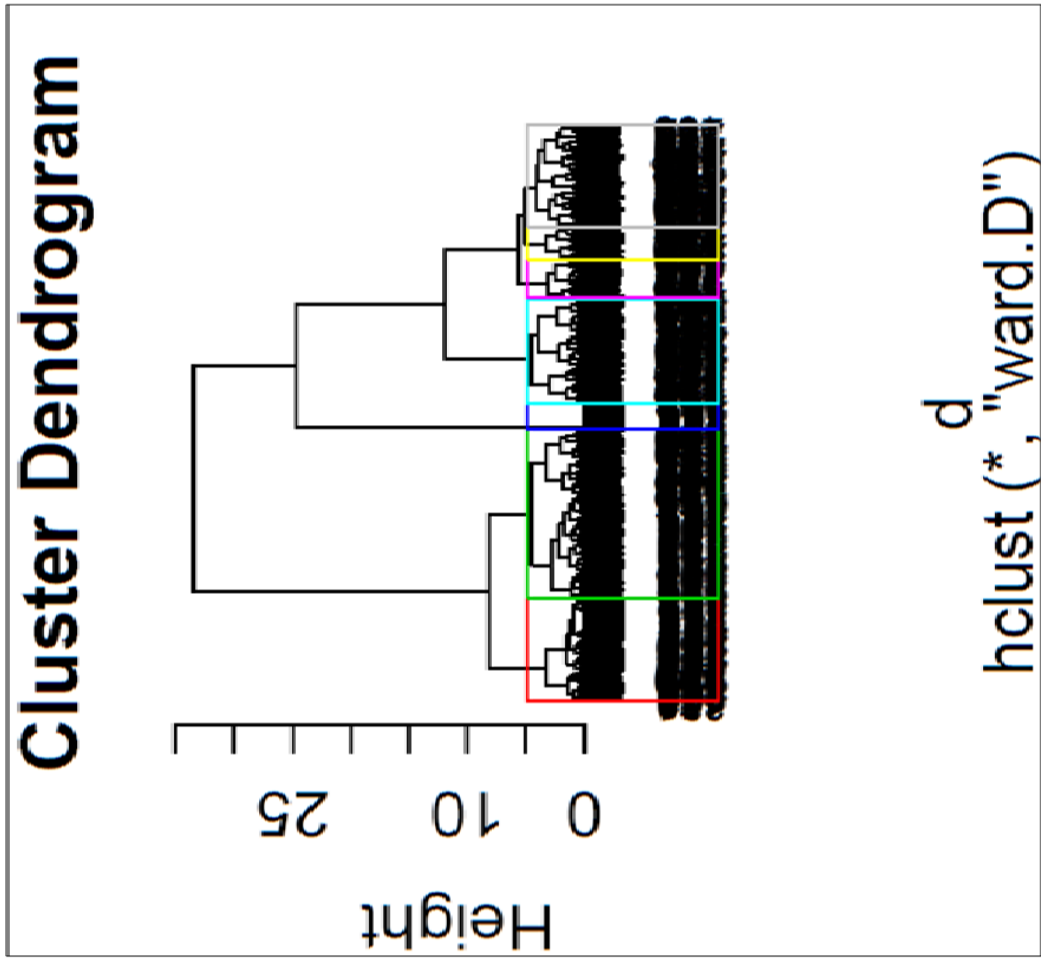


Figure 4.4: Ward Cluster Dendrogram.

## 4.4 Result research and discussion:

The result we obtain from the first experiment, which used ward technique is shown in the figure below:

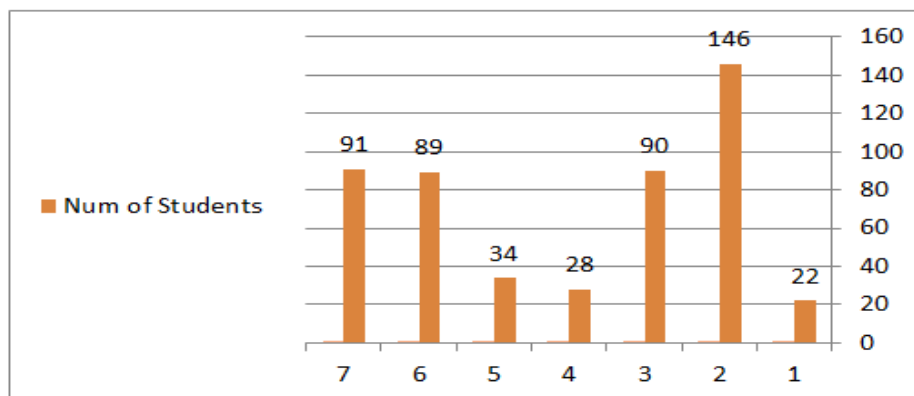


Figure 4.5: Students Number for Each Cluster.

### 4.4.1 Experiment 1:

In the first cluster, 22 students get zero in all the questions of the exam. The students have three difficulties in mathematical skills. The result of this cluster is 4% from the sample of this research which has 50% of the research population from the city and the remainder from Yatta.

Also, 27% of the population are female. All of them are from villages. The other 73% are male. 31% are from Yatta and 69% are from Hebron. On the other hand, 45% of the students have an average of (50 Marks) in mathematics and less which are named delinquent. 27% of the students have acceptable estimate. But 18% have average estimate, and only 10% have good estimate.

The second cluster has 146 students whose grades are ranging from 5 to 14. In this cluster, we classify them into six groups as the following:

#### 4.4. RESULT RESEARCH AND DISCUSSION:

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1. The first group does not have any problems regarding mathematical skills. It includes 41 students equivalent to a rate of 29%.
2. The second group has the highest rate problem in the second skill which identifies the comparison area for dyscalculia students. This group cluster has 70 students equivalent to a rate of 49%.
3. The dyscalculic students in the third group have a problem in naming numbers skill. There are only 7 students in this group, equivalent to a rate of 4%.
4. The fourth group has 22 students equivalent to a rate of 15%. The dyscalculia students have a problem in naming numbers and making comparison.
5. The fifth group has only 4 students equivalent to a rate of 2%. The dyscalculia students in the this group have a problem in the three skills (naming numbers, making comparison and operation).
6. The final group is the lowest one. It includes only 2 students equivalent to a rate of 1% , They have a problem in making comparison and operation.

On the other hand, we can analyze this cluster in order to find the strength and weakness for each skills (naming numbers, comparison and operation).as shown in the figure below:

From the ratio above, we must focus on the second skill in the first stage, with a little focus on the first skill.

In this cluster, it was noted that 40% of the population were from Yatta, and 60% were from Hebron. 60% of the students from Yatta are female and 40% are male. While 34% of the students from Hebron are male and 66%

#### 4.4. RESULT RESEARCH AND DISCUSSION:

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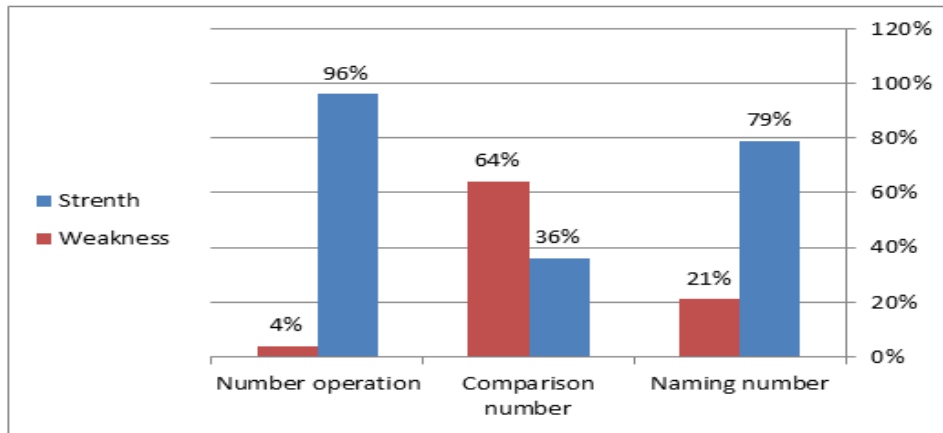


Figure 4.6: Strength and Weakness for Three Skills to Second Cluster.

are female. In addition we must note that the ratio with excellent average in mathematics is the greatest majority.

The table above shows the percentage of the independent students based on their averages in mathematics.

#### 4.4. RESULT RESEARCH AND DISCUSSION:

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Table 4.2: Relationships Between Geographical Distribution, Gender and Mathematics Average in Second Cluster.

	<b>Yatta (40%)</b>		<b>Hebron (60%)</b>	
	Female ( 60%)	Male (40%)	Female (66%)	Male ( 34%)
Excellent Estimate (45%)	37%	52%	36%	64%
Very good Estimate (26%)	31%	22%	31%	13%
Good Estimate (14%)	17%	18%	17%	0%
Average Estimate (7%)	16%	0%	19%	13%
Reasonable Estimate (5%)	13%	4%	7%	7%
Delinquent (3%)	6%	4%	0%	3%

#### 4.4. RESULT RESEARCH AND DISCUSSION:

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The third cluster has 90 students. The grades of 18% from the population are ranging from 6 to 15. In this cluster, we calculate the strength and weakness in three skills (naming numbers, comparison and operation). The results are shown in the figure below:

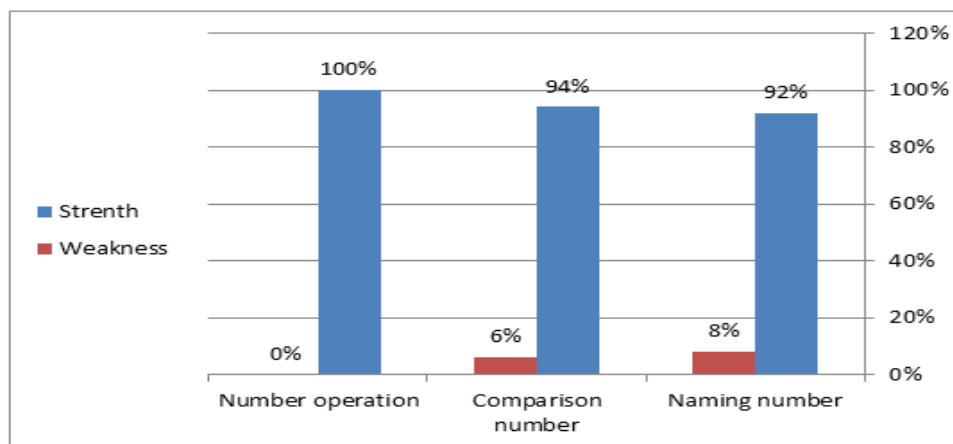


Figure 4.7: Strength and Weakness for Three Skills to Third Cluster.

The results of the implicit analysis for this cluster are as the following:

1. The first group does not have any problem in mathematics skills. There are only 78 students in this group equivalent to a rate of 87%.
2. The second group is weak in the first skill (naming numbers). There are only six students in this group equivalent to a rate 7%.
3. The third group is weak in the second skill (comparing number), there are only four students in this group equivalent to a rate 4%.
4. The final group in this cluster has only two students equivalent to a rate (2% ). They have weakness in the first and second skills (naming numbers and making comparison).

#### 4.4. RESULT RESEARCH AND DISCUSSION:

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Table 4.3: Relationships Between Geographical Distribution, Gender and Mathematics Average in Third Cluster.

	<b>Yatta (50%)</b>		<b>Hebron (50%)</b>	
	Female (33%)	Male (67%)	Female (58%)	Male (42%)
Excellent Estimate (62%)	53%	60%	35%	74%
Very good Estimate (20%)	27%	10%	35%	11%
Good Estimate (2%)	7%	3%	0%	0%
Average Estimate (11%)	13%	17%	4%	11%
Reasonable Estimate (2%)	0%	7%	0%	0%
Delinquent (2%)	0%	3%	0%	5%

50% of the students in this cluster are from Yatta and the other 50% are from Hebron. But it's not the same orientation for gender. The greatest result (87%) is for the students who do not have any problem in the three mathematical skills. 67% of the students from Yatta are male. 58% of the students from Hebron are female. Some literature review shows that male and female had similar probability, although the fact that we found that the majority is for males than females as in Vivian and et.al article [65]. But in our research, especially in this cluster, the influence of gender varies depending on the geographical areas.

#### 4.4. RESULT RESEARCH AND DISCUSSION:

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In the fourth cluster, 25 students out of 28 have weaknesses in the three skills (naming numbers, comparison and operation) equivalent to the rate 89%. The grades in this cluster are ranging from 1 to 5. The proportion of weakness in the first skill (Naming number) and the second skill (Comparison number) is 11%.

Here, we notice that the three skills are weak. The figure below shows the results:

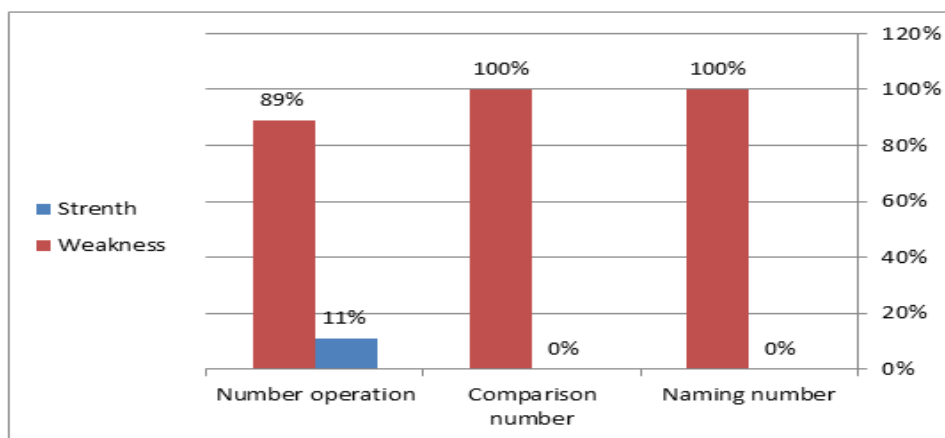


Figure 4.8: Strength and Weakness for Three Skills to Fourth Cluster.

From above ratio, this cluster shows the weakness clearly in the three skills. And the great majority consists of males from Hebron, rating 85%. The result we obtain shows that only 6% of the students have excellent estimates for the mathematical average at school. The result, as shown in the table 4.4, may be the average in mathematics at a school for males. It's not accurate as at the school for females. The majority of this cluster is for females from Yatta.

In the fifth cluster we get the results below:

1. The percentage of those who have weakness in the first skill (Naming number) and the second skill (Comparison number) is only 3%.
2. The percentage of those who have weakness in the second skill (Com-

#### 4.4. RESULT RESEARCH AND DISCUSSION:

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Table 4.4: Relationships Between Geographical Distribution, Gender and Mathematics Average in Fourth Cluster.

	<b>Yatta (71%)</b>		<b>Hebron (29%)</b>	
	Female (62%)	Male (38%)	Female (15%)	Male (85%)
Excellent Estimate (4%)	0%	0%	0%	6%
Very good Estimate (11%)	0%	67%	0%	6%
Good Estimate (21%)	0%	33%	33%	24%
Average Estimate (18%)	40%	0%	33%	11%
Reasonable Estimate (21%)	20%	0%	33%	24%
Delinquent (25%)	40%	0%	0%	29%

#### 4.4. RESULT RESEARCH AND DISCUSSION:

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parison number) and the third-skill (Number operation) is only 9%.

3. The percentage of those who have weakness in the first skill (Naming number), the second skill (Comparison number) and the third-skill (Number operation) is 74%.
4. The percentage of those who have weakness in the first skill (Naming number) and the third skill (operation) is only 5%.
5. Finally, the percentage of those who have weakness in the third skill (Number operation) is only 9%.

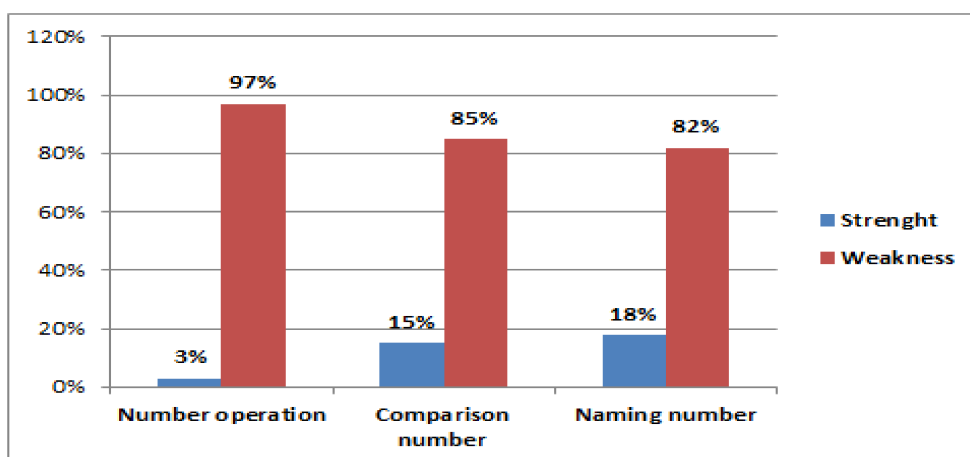


Figure 4.9: Strength and Weakness for Three Skills to Fifth Cluster.

In this cluster, the grading of the exam ranges from 1 to 9. Each skill has ratios of weakness and strength separately as the following figure shows:

In the contrast, we present an independent analysis below based on the geographical areas of the students, their gender, and their average in mathematics. In this cluster, we notice that the weakest majority in the three skills is found in the males from Hebron.

#### 4.4. RESULT RESEARCH AND DISCUSSION:

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Table 4.5: Relationships Between Geographical Distribution, Gender and Mathematics Average on Fifth Cluster.

	<b>Yatta (41%)</b>		<b>Hebron (59%)</b>	
	Female (86%)	Male (14%)	Female (25%)	Male (75%)
Excellent Estimate (3%)	0%	0%	0%	7%
Very good Estimate (9%)	17%	0%	20%	0%
Good Estimate (15%)	8%	0%	20%	20%
Average Estimate (24%)	17%	50%	20%	40%
Reasonable Estimate (32%)	25%	50%	20%	40%
Delinquent (18%)	33%	0%	0%	13%

#### 4.4. RESULT RESEARCH AND DISCUSSION:

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In the sixth cluster which has ratio 18%. The students grades are ranging from (1) to (10). The students are classified into seven groups:

1. The first group includes the students who show weakness in the three skills (Naming number, Comparison number and Number operation), its ratio is 57%.
2. The second group includes the students who show weakness in the second and the third skills (Comparison number and Number operation), its ratio is 12%.
3. The third group includes the students who show weakness in the first and the third skills (Naming number, and Number operation), its ratio is 1%.
4. The fourth group includes the students who show weakness in the first and the second skills (Naming number and Comparing number), its ratio is 18%.
5. The fifth group includes the students who show weakness in the first skill (Naming number) only, which ratio is 1%.
6. The sixth group includes the students who show weakness in the second skill (Comparison number), its ratio is 10%
7. Finally, the members of the last group in this cluster have weakness in the third skill (Number operation), its ratio is 1%.

The next figure shows the ratio of weakness and strength in each skill separately:

#### 4.4. RESULT RESEARCH AND DISCUSSION:

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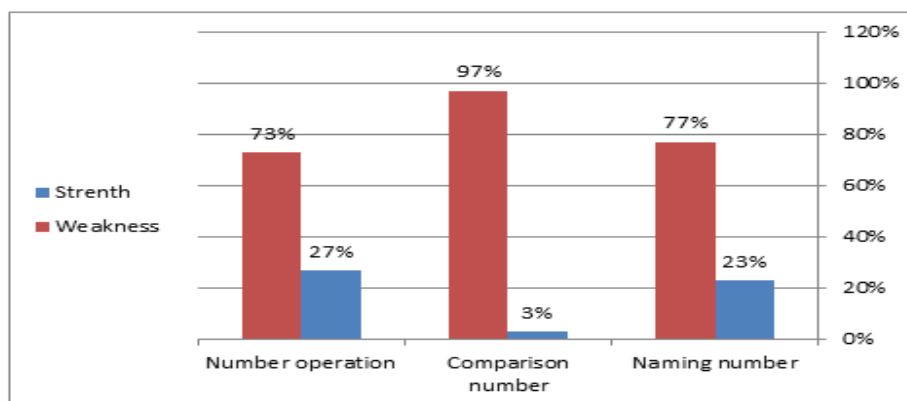


Figure 4.10: Strength and Weakness for Three Skills to Sixth Cluster.

To sum up, it seems to be a priority to focus on the weakness of the students in the second skill based on the previous results.

In the analysis presented above, the great majority of students in this cluster are males from Hebron. In the final cluster we get the following results :

1. 1% of the students groups do not show any weakness in the three skills.
2. 31% of the students groups have weakness in the three skills (Naming number, Comparison number and Number operation).
3. 39% of the students groups have weakness in the first skill (Naming number) and the second skill (Comparison number).
4. 15% of the students groups have weakness in the second skill (Comparison number) and the third skill (Number operation).
5. 1% of the students groups have weakness in the first skill (Naming number) and the third skill (Number operation).
6. 11% of the students groups have weakness in the second skill (Comparison number).

#### 4.4. RESULT RESEARCH AND DISCUSSION:

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Table 4.6: Relationships Between Geographical Distribution, Gender and Mathematics Average on Sixth Cluster.

	<b>Yatta (37%)</b>		<b>Hebron (63%)</b>	
	Female (48%)	Male (52%)	Female (21%)	Male (79%)
Excellent Estimate (8%)	6%	0%	0%	14%
Very good Estimate (10%)	23%	0%	17%	7%
Good Estimate (16%)	47%	13%	8%	18%
Average Estimate (26%)	12%	31%	50%	23%
Reasonable Estimate (26%)	6%	56%	8%	27%
Delinquent (9%)	6%	0%	17%	11%

#### 4.4. RESULT RESEARCH AND DISCUSSION:

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7. 2% of the students groups have weakness in the third skill (Number operation).

In this cluster, we must focus on the second skill which has the highest weakness ratio.

As it is shown in the figure:

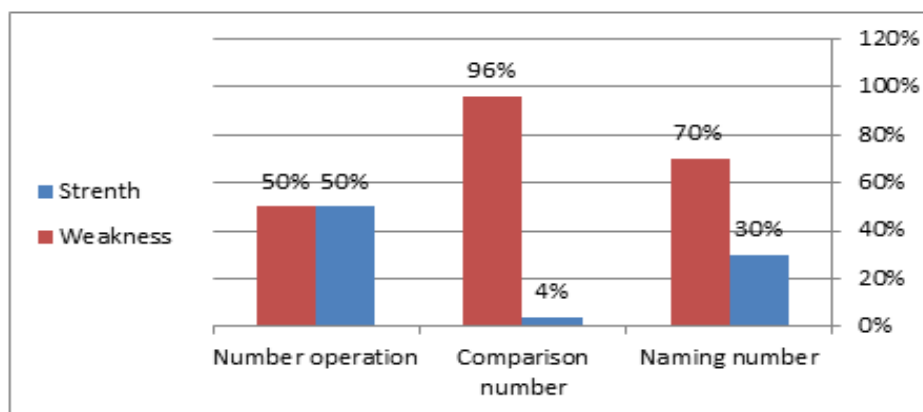


Figure 4.11: Strength and Weakness for Three Skills to Seventh Cluster.

In this cluster, Hebrons males schools have the highest percentage as the next table shows.

We conclude with the results in the table above, that female schools in Yatta are more reliable in the mathematics grades.

#### 4.4. RESULT RESEARCH AND DISCUSSION:

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Table 4.7: Relationships Between Geographical Distribution, Gender and Mathematics Average on Seventh Cluster.

	<b>Yatta (23%)</b>		<b>Hebron (77%)</b>	
	Female (48%)	Male (52%)	Female (31%)	Male (69%)
Excellent Estimate (22%)	0%	18%	27%	25%
Very good Estimate (22%)	20%	27%	23%	21%
Good Estimate (23%)	20%	18%	32%	21%
Average Estimate (13%)	30%	0%	5%	17%
Reasonable Estimate (15%)	30%	18%	14%	13%
Delinquent (8%)	0%	18%	0%	4%

#### 4.4. RESULT RESEARCH AND DISCUSSION:

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Table 4.8: Distributed Ratio for Second Cluster.

Kind of Weakness	Ratio
No Problem	31%
Weakness on Second Skills	59%
Weakness on Second and Third Skills	6%
Weakness on First and Second Skills	4%

Table 4.9: Strength and Weakness for Three Skills to Second Cluster.

Skills	First Skills	Second Skills	Third Skills
<b>Strength</b>	<b>97%</b>	<b>31%</b>	<b>94%</b>
<b>Weakness</b>	<b>3%</b>	<b>69%</b>	<b>6%</b>

#### 4.4.2 Experiment 2:

We apply the same algorithm which was used in experiment 1, but on different sample size. The sample is only for female students which contains 226 students. The results we obtain are shown in the following seven clusters:

- The first cluster has six students whose grades are zero in the exam.
- The second cluster has 32 students who are distributed as in table 4.8.

From the ratio in table 4.9 we must focus on the second skill.

- The third cluster has 69 students who are distributed in the following tables:

Table 4.10: Distributed Ratio for Third Cluster.

Kind of Weakness	Ratio
No Problem	81%
Weakness on First Skills	4%
Weakness on Second Skills	12%
Weakness on First and Second Skills	3%

#### 4.4. RESULT RESEARCH AND DISCUSSION:

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Table 4.11: Strength and Weakness for Three Skills to Third Cluster.

Skills	First Skills	Second Skills	Third Skills
<b>Strength</b>	<b>93%</b>	<b>86%</b>	<b>100%</b>
<b>Weakness</b>	<b>7%</b>	<b>14%</b>	<b>0%</b>

From the result presented above, we noted that there is no problem in general.

- The fourth cluster has 58 students who are distributed in the following tables:

Table 4.12: Distributed Ratio for Fourth Cluster

Kind of Weakness	Ratio
Weakness on Second Skills	40%
Weakness on Third Skills	2%
Weakness on First and Second Skills	22%
Weakness on First and Third Skills	2%
Weakness on Second and Third Skills	16%
Weakness on First, Second and Third Skills	3%

Table 4.13: Strength and Weakness for Three Skills to Fourth Cluster.

Skills	First Skills	Second Skills	Third Skills
<b>Strength</b>	<b>69%</b>	<b>16%</b>	<b>69%</b>
<b>Weakness</b>	<b>31%</b>	<b>84%</b>	<b>31%</b>

- Fifth cluster has 18 students who are distributed in the following tables:
- Sixth cluster has 22 students who are distributed in the following tables:
- Seventh cluster has 21 students who are distributed in the following tables:

#### 4.4. RESULT RESEARCH AND DISCUSSION:

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Table 4.14: Distributed Ratio for Fifth Cluster.

Kind of Weakness	Ratio
Weakness on Second Skills	6%
Weakness on First and Second Skills	44%
Weakness on Second and Third Skills	6%
Weakness on First, Second and Third Skills	44%

Table 4.15: Strength and Weakness for Three Skills to Fifth Cluster.

Skills	First Skills	Second Skills	Third Skills
Strength	11%	0%	50%
Weakness	89%	100%	50%

Table 4.16: Distributed Ratio for Sixth Cluster.

Kind of Weakness	Ratio
Weakness on Second Skills	4.5%
Weakness on First and Second Skills	4.5%
Weakness on Second and Third Skills	4.5%
Weakness on First, Second and Third Skills	86.5%

Table 4.17: Strength and Weakness for Three Skills to Sixth Cluster.

Skills	First Skills	Second Skills	Third Skills
Strength	9%	0%	9%
Weakness	91%	100%	91%

#### 4.4.3 Experiment 3:

In this experiment, we apply the same algorithm, but the sample is the result of the seventh cluster from the first experiment. It has the highest ratio 39% regarding weakness in the first and the second skills.

The seventh cluster result is:

#### 4.4. RESULT RESEARCH AND DISCUSSION:

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Table 4.18: Distributed Ratio for Seventh Cluster.

Kind of Weakness	Ratio
Weakness on Third Skills	4.5%
Weakness on First and Second Skills	4.5%
Weakness on Second and Third Skills	4.5%
Weakness on First, Second and Third Skills	86.5%

Table 4.19: Strength and Weakness for Three Skills to Seventh Cluster.

Skills	First Skills	Second Skills	Third Skills
Strength	29%	19%	0%
Weakness	71%	81%	100%

- The first cluster has 13 students who are distributed in the following tables:

Table 4.20: Distributed Ratio for First Cluster.

Kind of Weakness	Ratio
Weakness on Second Skills	23%
Weakness on First and Second Skills	54%
Weakness on Second and Third Skills	15%
Weakness on First, Second and Third Skills	8%

Table 4.21: Strength and Weakness for Three Skills to First Cluster.

Skills	First Skills	Second Skills	Third Skills
Strength	40%	0%	23%
Weakness	60%	100%	77%

From the result presented above, we must focus on the second skill.

- The second cluster has 19 students who are distributed in the following

#### 4.4. RESULT RESEARCH AND DISCUSSION:

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tables:

Table 4.22: Distributed Ratio for Second Cluster.

Kind of Weakness	Ratio
Weakness on Second Skills	21%
Weakness on First and Second Skills	5%
Weakness on First and Third Skills	5%
Weakness on Second and Third Skills	32%
Weakness on First , Second and Third Skills	37%

Table 4.23: Strength and Weakness for Three Skills to Second Cluster.

Skills	First Skills	Second Skills	Third Skills
Strength	53%	5%	26%
Weakness	47%	95%	74%

- The third cluster has 7 students who are distributed in the following tables:

Table 4.24: Distributed Ratio for Third Cluster.

Kind of Weakness	Weakness on Second and Third Skills	Weakness on First, Second and Third Skills
Ratio	29%	71%

Table 4.25: Strength and Weakness for Three Skills to Third Cluster.

Skills	First Skills	Second Skills	Third Skills
Strength	29%	0%	0%
Weakness	71%	100%	100%

- The fourth cluster has 15 students who are distributed in the following tables:

#### 4.4. RESULT RESEARCH AND DISCUSSION:

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Table 4.26: Distributed Ratio for Fourth Cluster.

Kind of Weakness	Ratio
Weakness on Second Skills	6.5%
Weakness on First and Second Skills	87%
Weakness on First , Second and Third Skills	6.5%

Table 4.27: Strength and Weakness for Three Skills to Fourth Cluster.

Skills	First Skills	Second Skills	Third Skills
Strength	6%	0%	93%
Weakness	94%	100%	7%

Table 4.28: Strength and Weakness for Three Skills to Fifth Cluster.

Skills	First Skills	Second Skills	Third Skills
Strength	0%	0%	0%
Weakness	100%	100%	100%

- The fifth cluster has 5 students who have weakness in the three skills.
- The sixth cluster has 15 students who are distributed in the following tables:

Table 4.29: Distributed Ratio for Sixth Cluster.

Kind of Weakness	Ratio
Weakness on Second Skills	7%
Weakness on First and Second Skills	80%
Weakness on First , Second and Third Skills	13%

Table 4.30: Strength and Weakness for Three Skills to Sixth Cluster.

Skills	First Skills	Second Skills	Third Skills
Strength	7%	0%	13%
Weakness	93%	100%	87%

#### 4.4. RESULT RESEARCH AND DISCUSSION:

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- The seventh cluster has 17 students who are distributed in the following tables:

Table 4.31: Distributed Ratio for Seventh Cluster.

<b>Kind of Weakness</b>	<b>Ratio</b>
<b>Weakness on Second Skills</b>	<b>12%</b>
<b>Weakness on Third Skills</b>	<b>5.5%</b>
<b>Weakness on First and Second Skills</b>	<b>12%</b>
<b>Weakness on Second and Third Skills</b>	<b>24%</b>
<b>Weakness on First , Second and Third Skills</b>	<b>41%</b>
<b>Without any Problem</b>	<b>5.5%</b>

Table 4.32: Strength and Weakness for Three Skills to Seventh Cluster.

<b>Skills</b>	<b>First Skills</b>	<b>Second Skills</b>	<b>Third Skills</b>
<b>Strength</b>	<b>47%</b>	<b>18%</b>	<b>24%</b>
<b>Weakness</b>	<b>63%</b>	<b>82%</b>	<b>86%</b>

#### 4.5. VALUATING THE RESULTS CLUSTERS:

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We conclude from the three experiments that the result is better when we use a small number of sample data as shown in first experiment. From above results, we noted that a logical similarity in each category. For example the first cluster which has zeros mark, is mostly from male Hebron school. Also, there is many important factors, which play a role on the nature of clusters, for instance Geographical area and gender.

### 4.5 Valuating The Results Clusters:

Since this study is the first study study that used machine learning cluster methods for dyscalculic student. We compared the results of the study with results of 30 students clustered by an experts.

1. The first cluster has 100% validity. Which contains students having zeros mark for each skills.
2. The second cluster has 60% validity. Which contains students having weakness on comparison skills. Here, we must note that this cluster need a second level clustering.
3. The third cluster has 100% validity. Which represent un- dyscalculic students.
4. The fourth cluster has 100% validity. Which represent dyscalculic students in three skills .
5. The fifth cluster has 75% validity. Which represent dyscalculic students in three skills .
6. The sixth cluster has mixed result as shown in section (4.2), this cluster has dyscalculic in three skills or in comparison and operation dyscal-

#### 4.6. *RESULT OF MODEL EVALUATION:*

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culic. 50% validity is dyscalculic in three skills and 50% validity is comparison and operation dyscalculic.

7. The seventh cluster has 75% validity Which represent dyscalculic students in comparison and operation skills.

### **4.6 Result of Model Evaluation:**

The proposed model has been undergone evaluation by experts to clarify the extent of acceptance, and to show that the model includes all the necessary components. It also aims at proving that the proposed model is a feasible and acceptable solution to diagnose and treat dyscalculic students. The following table shows the result of the analysis has been collected from 24 experts after distributing 60 model design evaluation forms.

#### 4.6. RESULT OF MODEL EVALUATION:

Table 4.33: Means Questions .

Item	SA	A
<b>A. The model is :</b>		
1. Understandable	3.9565	0.92826
2. Clear	3.8696	0.75705
3. Complete	3.9130	0.66831
4. Comprehensive	3.9130	0.59643
5. Self-explained	3.5652	1.03687
<b>B. The graphical representation ( layout ) of the model is:</b>		
6. Understandable	3.7826	0.79524
7. Clear	3.6957	0.8756
8. Complete	3.7391	0.75181
9. Comprehensive	3.7391	0.75181
10. Matching the textual explanation	3.7391	0.91539
<b>C. The textual explanation of the model is :</b>		
11. Understandable	3.7826	0.85048
12. Clear	4.0870	0.41703
13. Complete	3.9545	0.65300
14. Comprehensive	3.7391	0.68870
<b>D. The components are all:</b>		
15. Understandable	3.7391	0.81002
16. Necessary	3.9130	0.59643
17. Relevant	3.8696	0.62554
18. Sufficient	3.7826	0.67126
<b>E. The relationships between components are :</b>		
19. Understandable	3.9565	0.76742
20. Clear	3.7826	0.59974
21. Meaningful	3.7826	0.59974
<b>F. The graphical representation of the components is :</b>		
22. Understandable	3.8261	0.77765
23. Clear	3.7826	0.73587
24. Suitable	3.6957	0.82212
<b>G. 'Students' component is :</b>		
25. Necessary	3.6087	0.72232
26. In the right place	3.9565	0.63806
<b>H. ' Exam' component is :</b>		
27. Necessary	4.00	0.52223
28. In the right place	3.9565	0.56232

4.6. RESULT OF MODEL EVALUATION:

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Item	SA	A
<b>I. ' Criteria ' component is :</b>		
29.Necessary	3.9565	0.63806
30.In the right place	3.8261	0.83406
<b>J. ' Clustering ' component is :</b>		
31.Necessary	4.2174	0.67126
32.In the right place	4.2174	0.59974
<b>K. 'Dyscalculia Cluster ' component is :</b>		
33. Necessary	3.8696	0.75705
34.In the right place	3.7391	0.91539
<b>L. 'Normal Students' component is :</b>		
35.Necessary	4.0435	0.47465
36.In the right place	3.7391	0.75181
<b>M. 'Dyscalculia Students' component is :</b>		
37. Necessary	4.000	0.60302
38. In the right place	3.9565	0.5632
<b>N. ' Adaptive Technology Based Math Activities ' component is :</b>		
39. Necessary	3.9130	0.66831
40. In the right place	3.9130	0.59643
<b>O. 'Family Environment' component is :</b>		
41. Necessary	3.9130	0.79275
42. In the right place	3.9565	0.63806
<b>P. ' Teacher ' component is :</b>		
43. Necessary	4.0870	0.59643
44. In the right place	3.9130	0.66831
<b>Q. ' Visual- spatial learning ' component is :</b>		
45. Necessary	3.8696	0.75705
46. In the right place	3.8696	0.75705
<b>R. ' Education Material ' component is :</b>		
47. Necessary	4.0435	0.63806
48. In the right place	3.8696	0.62554
<b>S. ' Enhancements Dyscalculia Students ' component is :</b>		
49. Necessary	3.9565	0.92453
50. In the right place	3.9565	0.70571

#### 4.6. RESULT OF MODEL EVALUATION:

---

In general, the reported means show that the model has received acceptance and was evaluated positively to a large extent. The lowest mean is (3.5652) which was observed during the evaluation to the model. After getting the results of the evaluation and the comments from the experts about model, we received some suggestions for a modified model as the following figure shows.

In chapter two, section (2.1) (2.2), the researchers discussed the analysis of different researches in this scope. Perhaps, none of them focus on the treatment of the problem using a combination of several factors to build appropriate model. This research tries to develop a model based on several factors combined together. Some researchers present a model of the cognitive processes of mathematical development. Here, this system is adaptive to the learning experience, which improves both success and motivation. These benefits would be improved if we combine it with other factors.

So, in the proposed model shown in figure 4.12, the system of training consists of the following components (technology, VE, and family) that would improve both success and motivation for dyscalculic student. As we have seen; a problem of sense of number coordinates is the base of dyscalculia. There are many factors, when combined together; we might get the best result. In addition, we consider that each factor is represented as an adaptive learning. The tool uses an algorithm to adapt to an individual student's ability and submit intensive training in an entertaining context. This approach for remediation of Dyscalculia allows intensive training in number sense, and Specifically the type of weakness on the three number sense skills. So, we suggest the following conceptual model which describes how we deal with the dyscalculic students. The teachers can identify the level of

#### 4.6. RESULT OF MODEL EVALUATION:

---

the problem in the student's usage of software technology. After that they decide to provide him/her with software training using appropriate multimedia. Depending on the education material, which is activated by teacher and family, using software training, and appropriate multimedia that is dedicated to find out the number and improvement on the mathematical skills of the student. Also, teacher can implement learning strategy in the (VE). We must note that, whenever we train student, we get a positive change on the level of their mathematical skills. After that student must be submitting adaptive exam, which depending on type of weakness in number sense skills. The result of kind clustering student (dyscalculic or not ), determine where student directed.

It should be note that an e-learning system can provide great opportunities to create and acquire knowledge for dyscalculic student. Following skills are required by the learner for e-learning: Observation, attention, manipulation, and problem solving [66]. The previous skills are important for students using e-learning system. However to DD students who face problems with these skills, the most important factors to help them would be family and teacher as shown in figure 4.12.

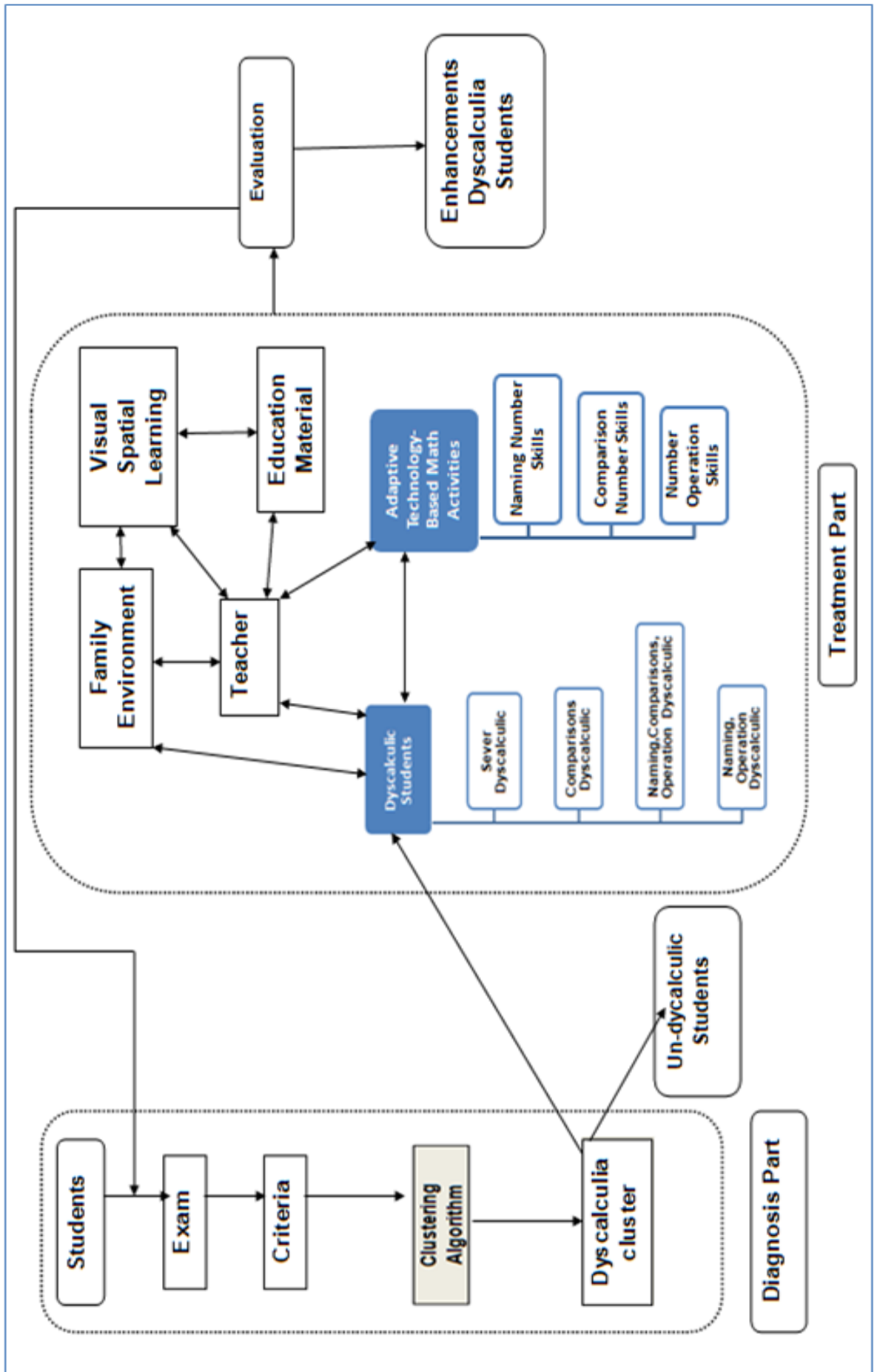


Figure 4.12: Strength and Weakness for Three Skills to Fourth Cluster.

## 4.7 Scenario of How The Model Works:

Third grade students took the exam which was adopted and built on the criteria of the basic skills. It depends on the grading of the test, this helps decide the cluster for each student. Based on this, we can identify if the student has a problem in his/ her basic mathematical skills, or not. If the student has a problem in the basic skills, he/ she must be transferred to the treatment part of the model. This part of the model includes several components, which work with each other in an integrated way. For example, if the student has two problems (naming number and comparison number), the teacher plays a major role in uniting the efforts to improve the level of the student.

An important component is to adopt technology in mathematical activities in which the content is appropriate for the skills which have problems. In a parallel way, the teacher provides an appropriate exercise for the student, in his/ her problem, through family by using appropriate visual spatial learning. The teacher may also use appropriate visual spatial learning with educational materials. After that, we get an evaluation for the student based on an evaluation through issuing a judgment either by re-examination or enhancement to the students.

## 4.8 Algorithm for Dyscalculic Students:

To ensure good working for this treatment part model. We supposed some theoretic hypotheses:

1. If student mark in operation skills less than 3; then student has operation dyscalculia.

#### 4.8. ALGORITHM FOR DYSCALCULIC STUDENTS:

---

2. If student mark in comparison skills less than 3; then student has comparison dyscalculia.
3. If student mark in naming numbers skills less than 3; then student has naming numbers dyscalculia.

When student combines more than one rule of cluster dyscalculia. The model will use priorities.

Priorities of the skills in the following order: naming numbers, comparison and operation skills. An adaptive treatment model is designed to trains dyscalculic students naming numbers tasks; if the student has level mark greater or equal 3. The model automatically transfers him/ her to the next skills. This operation will repeat until we get the level un-dyscalculic student.

It is important to note that for all eventualities expected cases of third grade student. As shown in the bellow table:

4.8. ALGORITHM FOR DYSCALCULIC STUDENTS:

---

Table 4.34: Cluster Rule and Conditions

Rule	Condition	Model Results and Acted
C1	If it is True	Student has operation dyscalculia. So, give him/her appropriat training exercise
	If it is False	Student hasn't operation dyscalculia
C2	If it is True	Student has comparison dyscalculia. So, give him/her appropriat training exercise
	If it is False	Student hasn't comparison dyscalculia
C3	If it is True	Student has naming numbers dyscalculia So, give him/her appropriat training exercise
	If it is False	Student hasn't naming numbers dyscalculia
C1 & C2	If it is True	Student has operation and comparison dyscalculia. So,give him/her appropriat training exercise
	If it is False	Student hasn't operation and comparison dyscalculia.
C1&C3	If it is True	Student has operation and naming numbers dyscalculia. So,give him/her appropriat training exercise
	If it is False	Student hasn't operation and naming numbers dyscalculia.
C2 & C3	If,it,is True	Student has comparison and naming numbers dyscalculia. So,give him/her appropriat training exercise
	If it is False	Student has comparison and naming numbers dyscalculia.
C1&C2& C3	If it is True	Student has operation, comparison and naming numbersdyscalculia. So, give him/her appropriat training exercise
	If it is False	Student hasn't operation, comparison and naming numbers dyscalculia.

# Chapter 5

## Conclusion and Future Work

### 5.1 Introduction

This research proposes a novel approach that aims at finding a suitable artificial intelligence- based approach in order to identify the students with dyscalculia, the type of dyscalculia they have, and proposes a technology-based treatment mechanism, taking into consideration several other elements, as shown in the model.

### 5.2 Conclusion

To conclude the study, we must consider the results in light of the objectives: The first objective in our research is finding out a mechanism for identifying the students with of dyscalculia. As we saw in the literature review, the mechanism used for analyzing data from the students is the statistical analysis or the classification mechanism. The result we obtained after using cluster analysis is a good one as indicated by experts. The results were logically categorized to determine if the student is dyscalculic or not. The second objective was to determine the specific dyscalculia area i.e. operation, com-

## 5.2. CONCLUSION

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parison, and naming number. This objective was achieved after analyzing the results clustering and through the evaluation received from the experts. Having determined that the student is dyscalculic, the weakness problems have been accurately determined, as shown in the analysis of results.

The third objective was to employ a better clustering technique for identifying and grouping dyscalculic students. It was implemented through using Ward technique rather than single technique. As shown in the results, Ward technique has advantages, i.e. providing memory and having logic clusters. The clusters obtained from applying Ward technique included the students with zero marks on exam, weakness on second skills (comparison skills), strengths on the three skills, weakness on three skills and weakness on first skills (naming number) and second skill (comparison of numbers). In contrast, the Single technique results were illogical, that is, two clusters were abridged as one cluster. The fourth objective was to propose a model for treating dyscalculia students. This objective was achieved by evaluating the proposed model and receiving feedback from experts. Next, the comments and suggestions were incorporated within the model. As shown earlier throughout the literature review, several models and attempts have been conducted to identify and/or treat Dyscalculia focusing on one side or factor of the problem. Our proposed conceptual model for identifying dyscalculic student, determining specific weakness problems in sensing number and enhancing learning of dyscalculic students focuses on visual- spatial learning, technology, and family environment. The aim was to develop this conceptual model which allows each dyscalculia student, parent, and teacher to use through technology based on clustering algorithm which would result in diagnosing the student learning ability, and through software training that consists of an appropriate multimedia and VE in treatment part. We in-

tend to expand our research one step further into enhancing, validating and testing this proposed model in Palestine.

### **5.3 Recommendations to the Ministry of Education in Palestine:**

Taking into account the male schools rather than female schools in terms of follow-up when taking their mathematics exam, the evaluation of the results showed that female schools have more credibility in the results of academic achievement than male schools. On the other hand, results analysis indicated that, results of male schools in Hebron and female schools in Yatta were bad. Henceforth, new mechanisms of dealing with these matters need to be followed in girls' schools in villages and boys' schools in cities, with disregard to the relative improvement noticed. This can be achieved through amending and reforming the existing rules. Submission of computerized exams is easy using and electronic entering of exam results for clustering would be better than using paper exams. So, Ministry of Education ought to work on improving the existing technology infrastructure all over schools that may allow submission of computerized exam.

### **5.4 Recommendation to Researchers:**

Clustering result is very good and logically-valid as experts said. However, when the researchers use the hierarchical clusters for their data set, it is better to employ another cluster level to obtain better results if the data set is large. Also, attention need to be paid to the type of data. Hierarchical clusters algorithm could be better for binary data. Orientation researchers

also need to shed more light on the causes of gender differences and other relevant areas as shown in the research results section.

## 5.5 Future Work

Although this research has covered an important issue regarding identifying the third grade students with dyscalculia, and the type of dyscalculia they have in Hebron and Yatta, there is still a need for further research and enhancement to this study. Suggested future work may include:

1. Using other mathematical skills suitable for other grades, through using the same steps and operations taking into consideration the criteria for each skill.
2. Applying the proposed model on other students in different grades to compare the results of this study.
3. Adding a new case to our data set, and repeating the cluster process. Thus, for analysis the mechanism hierarchical clustering algorithm.
4. Submitting mathematics exam online rather than handwritten exam, in order to implement the exam in short time. To consider the time element which helps to determine dyscalculic student or not.
5. Focusing and analyzing the difference between expert clusters and our cluster noticed as shown in section 4.3 Valuating The Results Clusters.
6. The proposed model in our search highlighted diagnosis of dyscalculic students and presenting methods of treatment. Dealing with undyscalculic students and promoting their performance have not been approached.

# Bibliography

- [1] Osama Abu Abbas et al. Comparisons between data clustering algorithms. *Int. Arab J. Inf. Technol.*, 5(3):320–325, 2008.
- [2] A Brunda and J Bhavithra. Adaptive computer assisted instruction (cai) for students with dyscalculia (learning disability in mathematics). In *A2CWIC*, pages 12–1, 2010.
- [3] Brian Butterworth and Diana Laurillard. Low numeracy and dyscalculia: identification and intervention. *ZDM*, 42(6):527–539, 2010.
- [4] Banu CANGÖZ, Arif Altun, Sinan Olkun, and Funda Kacar. Computer based screening dyscalculia: Cognitive and neuropsychological correlates. *TOJET: The Turkish Online Journal of Educational Technology*, 12(3), 2013.
- [5] Ronit Bird. *The Dyscalculia Toolkit: supporting learning difficulties in maths*. Sage, 2013.
- [6] Mahnaz Akhavan Tafti. Acknowledging the difference: Lessons from differentiated instruction, multiple intelligences, and visual-spatial learning theories for students with learning disabilities. *Applied Psychology*, 2(6):1–10, 2014.
- [7] Onita Nakra. *Children and learning difficulties*. Allied Publishers, 1996.
- [8] Pooja Manghirmalani, Zenobia Panthaky, and Kavita Jain. Learning disability diagnosis and classification—a soft computing approach. In *Information and Communication Technologies (WICT), 2011 World Congress on*, pages 479–484. IEEE, 2011.
- [9] Zainab Pirani and M Sasikumar. Accommodation for dyscalculic children in an e-learning environment. *International Journal of Computer Applications*, 70(2), 2013.
- [10] MORIN A. Understanding dyscalculia. <http://WWW.UNDERSTOOD.ORG/EN/LEARNING-ATTENTION-ISSUES/CHILD-LEARNING-ISABILITIES/DYSCALCULIA/UNDERSTANDING-DYSCALCULIA>. Retrieved September 5, 2015, 2014.
- [11] J. B. Hale. Causes of dyscalculia math learning difficulties. <http://www.dyscalculia.org/dyscalculia/math-ld-causes>. Retrieved September 5, 2016.

## BIBLIOGRAPHY

---

- [12] Victoria Simms, Lucy Cragg, Camilla Gilmore, Neil Marlow, and Samantha Johnson. Mathematics difficulties in children born very preterm: current research and future directions. *Archives of Disease in Childhood-Fetal and Neonatal Edition*, 98(5):F457–F463, 2013.
- [13] David C Geary. Mathematics and learning disabilities. *Journal of learning disabilities*, 37(1):4–15, 2004.
- [14] HEAD DEAN. *DYSCALCULIC CO-MORBIDITY IN SECONDARY SCHOOL GOING CHILDREN-A COMPREHENSIVE STUDY OF PREDICTING PARAMETERS AND REMEDIES*. PhD thesis, Citeseer.
- [15] Jane Emerson and Patricia Babbie. *The dyscalculia assessment*. Bloomsbury Publishing, 2014.
- [16] Karin Landerl, Anna Bevan, and Brian Butterworth. Developmental dyscalculia and basic numerical capacities: A study of 8–9-year-old students. *Cognition*, 93(2):99–125, 2004.
- [17] Alex M Moore and Mark H Ashcraft. Childrens mathematical performance: Five cognitive tasks across five grades. *Journal of experimental child psychology*, 135:1–24, 2015.
- [18] Elena Soto-Calvo, Fiona R Simmons, Catherine Willis, and Anne-Marie Adams. Identifying the cognitive predictors of early counting and calculation skills: Evidence from a longitudinal study. *Journal of experimental child psychology*, 140:16–37, 2015.
- [19] Magda Praet, Daisy Titeca, Annelies Ceulemans, and Annemie Desoete. Language in the prediction of arithmetics in kindergarten and grade 1. *Learning and Individual Differences*, 27:90–96, 2013.
- [20] Tung-Kuang Wu, Shian-Chang Huang, Ying-Ru Meng, Wen-Yau Liang, and Yu-Chi Lin. Rough sets as a knowledge discovery and classification tool for the diagnosis of students with learning disabilities. *International Journal of Computational Intelligence Systems*, 4(1):29–43, 2011.
- [21] Anil K Jain. Data clustering: 50 years beyond k-means. *Pattern recognition letters*, 31(8):651–666, 2010.
- [22] Yadav.V. <http://www.quora.com/What-is-the-difference-between-/Clustering-and-Classification-in-Machine-Learning>. Retrieved November 12,2016. published on 2013.
- [23] Tanja Käser, Gian-Marco Baschera, Juliane Kohn, Karin Kucian, Verena Richtmann, Ursina Grond, Markus Gross, and Michael von Aster. Design and evaluation of the computer-based training program calcularis for enhancing numerical cognition. 2013.
- [24] T Käser, K Kucian, M Ringwald, GM Baschera, M Von Aster, and M Gross. Therapy software for enhancing numerical cognition. *Interdisciplinary perspectives on cognition, education and the brain*, 7:219–228, 2011.

## BIBLIOGRAPHY

---

- [25] Terry T-Y Wong, Connie S-H Ho, and Joey Tang. Identification of children with mathematics learning disabilities (mlds) using latent class growth analysis. *Research in developmental disabilities*, 35(11):2906–2920, 2014.
- [26] David Sloana, John Stratfordb, and Peter Gregora. Using multimedia to enhance the accessibility of the learning environment for disabled students: reflections from the skills for access project. *Approaches to Developing Accessible Learning Experiences: Conceptualising Best Practice*, page 39, 2013.
- [27] Gavin R Price and Daniel Ansari. Dyscalculia: Characteristics, causes, and treatments. *Numeracy*, 6(1):2, 2013.
- [28] Stephen R Ellis. What are virtual environments? *IEEE Computer Graphics and Applications*, 14(1):17–22, 1994.
- [29] Marcus Vasconcelos de Castro, Marcia Aparecida Silva Bissaco, Bruno Marques Panccioni, Silvia Cristina Martini Rodrigues, and Andreia Miranda Domingues. Effect of a virtual environment on the development of mathematical skills in children with dyscalculia. *PloS one*, 9(7):e103354, 2014.
- [30] Patricia Robledo-Ramón and Jesús-Nicasio. *The Family Environment of Students with Learning Disabilities and ADHD*. INTECH Open Access Publisher, 2012.
- [31] Brigitta Réthey-Prikkel and Márta Turcsányi-Szabó. Design and evaluation of maths related programs for special education. *Bratislava: Proceedings of EuroLogo*, 2007.
- [32] W Yahya and N Noor. Decision support system for learning disabilities children in detecting visual-auditory-kinesthetic learning style. In *The 7th International Conference on Information Technology*, 2015.
- [33] Onintra Poobrasert and Waragorn Gestubtim. Development of assistive technology for students with dyscalculia. In *e-Learning and e-Technologies in Education (ICEEE), 2013 Second International Conference on*, pages 60–63. IEEE, 2013.
- [34] Sue Gifford and Freda Rockliffe. Mathematics difficulties: does one approach fit all? *Research in Mathematics Education*, 14(1):1–15, 2012.
- [35] Michael G Von Aster and Ruth S Shalev. Number development and developmental dyscalculia. *Developmental Medicine & Child Neurology*, 49(11):868–873, 2007.
- [36] Arron WS Metcalfe, Sarit Ashkenazi, Miriam Rosenberg-Lee, and Vinod Menon. Fractionating the neural correlates of individual working memory components underlying arithmetic problem solving skills in children. *Developmental cognitive neuroscience*, 6:162–175, 2013.
- [37] Chester E Finn Jr, Andrew J Rotherham, and Charles R Hokanson Jr. Rethinking special education for a new century. 2001.

## BIBLIOGRAPHY

---

- [38] Philipp Johannes Dinkel, Klaus Willmes, Helga Krinzinger, Kerstin Konrad, and Jan Willem Koten Jr. Diagnosing developmental dyscalculia on the basis of reliable single case fmri methods: promises and limitations. *PloS one*, 8(12):e83722, 2013.
- [39] Tung-Kuang Wu, Shian-Chang Huang, and Ying-Ru Meng. Evaluation of ann and svm classifiers as predictors to the diagnosis of students with learning disabilities. *Expert Systems with Applications*, 34(3):1846–1856, 2008.
- [40] Terry T-Y Wong, Connie S-H Ho, and Joey Tang. Identification of children with mathematics learning disabilities (mlds) using latent class growth analysis. *Research in developmental disabilities*, 35(11):2906–2920, 2014.
- [41] Pooja Manghirmalani, Darshana More, and Kavita Jain. A fuzzy approach to classify learning disability. *INTERNATIONAL JOURNAL OF ADVANCED RESEARCH IN ARTIFICIAL INTELLIGENCE*, 1(2), 2012.
- [42] Athanasios S Drigas and Rodi-Eleni Ioannidou. Artificial intelligence in special education: A decade review. *International Journal of Engineering Education*, 28(6):1366, 2012.
- [43] Kavita Jain, Pooja Manghirmalani, Jyotshna Dongardive, and Siby Abraham. Computational diagnosis of learning disability. *International Journal of Recent Trends in Engineering*, 2(3):64–66, 2009.
- [44] Athanasios S Drigas and Rodi-Eleni Ioannidou. A review on artificial intelligence in special education. In *World Summit on Knowledge Society*, pages 385–391. Springer, 2011.
- [45] Liane Kaufmann and Michael von Aster. The diagnosis and management of dyscalculia. *Dtsch Arztebl Int*, 109(45):767–78, 2012.
- [46] Russell Gersten, Nancy C Jordan, and Jonathan R Flojo. Early identification and interventions for students with mathematics difficulties. *Journal of learning disabilities*, 38(4):293–304, 2005.
- [47] Ian M Lyons, Gavin R Price, Anniek Vaessen, Leo Blomert, and Daniel Ansari. Numerical predictors of arithmetic success in grades 1–6. *Developmental science*, 17(5):714–726, 2014.
- [48] Patricia Pratibha Kant. the number race: an efficacy study of an adaptive software in 5-to-7-year-old new zealand children with low numeracy. 2015.
- [49] Giannis Karagiannakis and Anna Baccaglini-Frank. The dedima battery: a tool for identifying students mathematical learning profiles. *Health Psychology Review*, 2(4), 2014.
- [50] S Ramaa and I Gowramma. A systematic procedure for identifying and classifying children with dyscalculia among primary school children in india. *Dyslexia*, 8(2):67–85, 2002.

## BIBLIOGRAPHY

---

- [51] Data mining - cluster analysis. [http://www.tutorialspoint.com/data-mining/dm\\_cluster\\_analysis.htm](http://www.tutorialspoint.com/data-mining/dm_cluster_analysis.htm). Retrieved June 12,2016. published on 1999.
- [52] Distances between clustering, hierarchical clustering. <http://www.stat.cmu.edu/~cshalizi/350/lectures/08/lecture-08.pdf>. Retrieved June 7,2016.
- [53] Mohammed J Zaki and Limsoon Wong. Data mining techniques. 2003.
- [54] Fionn Murtagh and Pedro Contreras. Algorithms for hierarchical clustering: an overview. *Wiley Interdisciplinary Reviews: Data Mining and Knowledge Discovery*, 2(1):86–97, 2012.
- [55] Fionn Murtagh and Pierre Legendre. Wards hierarchical agglomerative clustering method: Which algorithms implement wards criterion? *Journal of Classification*, 31(3):274–295, 2014.
- [56] Steinbach-M. Tan, P.N and V Kumar. Cluster analysis : Basic concepts and algorithms. in introduction to data mining. <http://www-users.Cs.umn.edu/~Kumar/dmbook/ch8.pdf>. Retrieved November 12,2016, 2006.
- [57] Taher Niknam, Elahe Taherian Fard, Narges Pourjafarian, and Alireza Roustaa. An efficient hybrid algorithm based on modified imperialist competitive algorithm and k-means for data clustering. *Engineering Applications of Artificial Intelligence*, 24(2):306–317, 2011.
- [58] M Emre Celebi, Hassan A Kingravi, and Patricio A Vela. A comparative study of efficient initialization methods for the k-means clustering algorithm. *Expert Systems with Applications*, 40(1):200–210, 2013.
- [59] Lior Rokach and Oded Maimon. Clustering methods. In *Data mining and knowledge discovery handbook*, pages 321–352. Springer, 2005.
- [60] E Mooi and M Sarstedt. Cluster analysis. a concise guide to market research, 2011.
- [61] OA Ghassan. *Development of a model for blended learning in traditional universities in Palestine/Ghassan OA Shahin*. PhD thesis, University of Malaya, 2012.
- [62] Cross validated. <http://stats.stackexchange.com/questions/116856/hierarchical-or-two-step-cluster-analysis-for-binary-data>. Retrieved June 10,2016.
- [63] Determining the optimal number of clusters: 3 must known methods - unsupervised machine learning. <http://www.sthda.com/english/wiki/determining-the-optimal-number-of-clusters-3-must-known-methods-/unsupervised-machine-learning>. Retrieved May 18,2016.
- [64] Daniel Müllner. fastcluster: Fast hierarchical, agglomerative clustering routines for r and python. *Journal of Statistical Software*, 53(9):1–18, 2013.

## BIBLIOGRAPHY

---

- [65] Vivian Reigosa-Crespo, Mitchell Valdés-Sosa, Brian Butterworth, Nancy Estévez, Marisol Rodríguez, Elsa Santos, Paul Torres, Ramón Suárez, and Agustín Lage. Basic numerical capacities and prevalence of developmental dyscalculia: The havana survey. *Developmental Psychology*, 48(1):123, 2012.
- [66] Tanja Käser, Alberto Giovanni Busetto, Barbara Solenthaler, Gian-Marco Baschera, Juliane Kohn, Karin Kucian, Michael von Aster, and Markus Gross. Modelling and optimizing mathematics learning in children. *International Journal of Artificial Intelligence in Education*, 23(1-4):115–135, 2013.

## Appendix

اختبار لفحص صعوبات التعلم للرياضيات للصف الثالث الأساسي. ( )

المدرسة : الإسم :

الجنس : المدينة :

١. أكتب بالأرقام العدد ثلاثمائة وست وثلاثون:

أ. ٣٦٣

ب. ٦٣٣

ج. ٣٣٦

د. ٣٠٣٦

٢. أي من الأعداد الآتية هو أكبر من العدد ٩١ ؟

أ. ١٨

ب. ٨٩

ج. ٩١

د. ٩٨

٣. ما هو ناتج العملية الحسابية الآتية ( ٧ + ٩ ) :

أ. ٩٧

ب. ١٦

ج. ١

د. ٢٠

٤. ما هو ناتج ( ٨٥ - ٢ ) :

أ. ٨٣

ب. ٦٣

ج. ٤٣

د. ١٨

٥. ما هو العدد الأقل من ( ٥٦٢٠ ) :

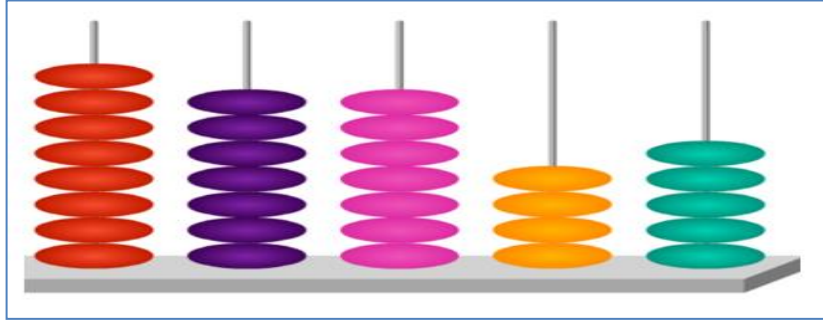
أ. ١٩٢٠

ب. ٥٧١٩

ج. ٥٦٢٨

د. ٥٦٣٠

٦.١ ما هو العدد الذي يمثله الشكل التالي:



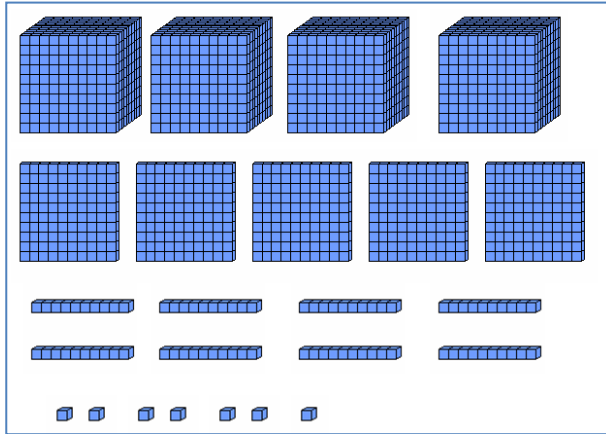
أ. ٨٧٧٤٥

ب. ٧٨٧٥٤

ج. ٥٤٧٧٨

د. ٨٧٧٥٤

٦.٢ ما هو العدد الذي يمثله الشكل التالي:



أ. ٤٩٢٣

ب. ٥٩٢٣

ج. ٤٥٨٧

د. ٣٥٩٢

٧. أي من الجمل الآتية تحتوي على أعداد مرتبة ترتيب تصاعدي:

أ. ٣١٠ ، ٤١٥ ، ٥٢٠ ، ٦٣٠ .

ب. ٧٥٠ ، ٦٥٠ ، ٥٥٠ ، ٤٥٠ .

ج. ٤٠ ، ٥٠ ، ٤٥ ، ٥٥ .

د. ١٠٠٠ ، ١٥٠٠ ، ١٤٠٠ ، ١٣٠٠ .

٨. أي من الجمل الآتية تحتوي على أعداد مرتبة ترتيب تنازلي :

أ. ١٥٠٠ ، ٢٥٠٠ ، ٣٥٠٠ ، ٤٠٠٠ .

ب. ٨٠٠ ، ٧٥٠ ، ٧٠٠ ، ٦٥٠ .

ج. ١٢٠ ، ١٣٠ ، ١٤٠ ، ١٥٠ .

د. ٢٠ ، ٢٢ ، ٢٤ ، ١٨ .

٩. ما ناتج ( ٢٨٠٥ + ١٠٥٢ ) :

أ. ١٦٥٥

ب. ٢٨٧٥

ج. ٧٢٣١

د. ٣٨٥٧

---

١٠. ما ناتج ( ٩٧٣ - ٣٨٤ ) :

أ. ٣٥١

ب. ٥٣٢

ج. ٥٢٦

د. ٥٨٩

---

١١. ما العدد التالي للعدد ١٧ :

أ. ١٦

ب. ١٧

ج. ١٩

د. ١٨

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١٢. ما العدد السابق للعدد ٨٥٠ :

أ. ٨٤٩

ب. ٨٥١

ج. ٨٥٠٠

د. ٨٠٤٩

---

١٣. ما العدد الذي يقع بين العددين ١٠٠ ، ٥٠ :

أ. ٤٠

ب. ٧٥

ج. ١٠١

د. ٤٩

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١٤. ما العدد المناسب في الفراغ لتكون العبارة ( ١٦ - ٩ = □ ) صحيحة :

أ. ٢٥

ب. ٧

ج. ٨

د. ١٣



**Palestine Polytechnic University**  
**Deanship of Graduate Studies and Scientific Research**  
**MS in Informatics**

Dear Prof/ Dr.

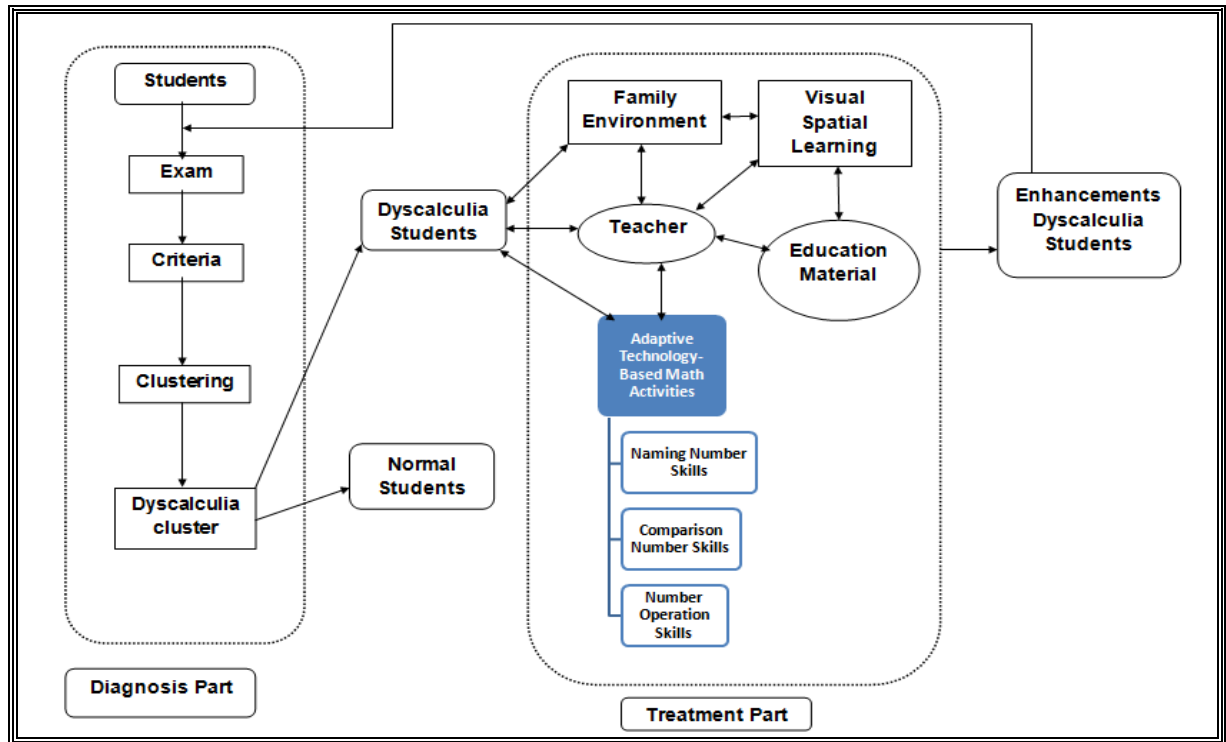
This evaluation form is part of a Master Dissertation of the Informatics program at Palestine Polytechnic University, titled “Diagnosis and Clustering Of Dyscalculia Third Grade Students”.

The attached proposed model is to find a suitable artificial intelligence based approach to identify students with dyscalculia, the type of dyscalculia they have, and propose a technology-based treatment taking into consideration several other elements, as shown in the model.

Your efforts and feedback will be invaluable for the improvement of the proposed model, and is highly appreciated.

Thank you for spending your time to fill this form.

Dalal Al-Adrah.



### Proposed Conceptual Model for Diagnosis and Enhancement of Dyscalculia Students.

The proposed model is graphically represented above. It aims at identifying (diagnosis) of dyscalculia students, and more specific, the type of dyscalculia a student might have. The model consists of two main parts; the diagnosis part and the treatment part. A student will be set for an exam to identify the type of dyscalculia he/she has if any, based on a set of criteria. Exams' results will be used by a clustering tool/ algorithm to find what and how many clusters there will be, so student will be identified based on which cluster they belong to. Based on the result, dyscalculia students will be subject to a treatment procedure as shown in the model. The treatment part of the model consists of several components; Family environment, Teacher, Visual Spatial learning (VSL), education material, and technology-based math activities. The result of the treatment would be an enhanced dyscalculia student. This student would be sent back to be set for the dyscalculia identification exam to measure the level of enhancement, and to decide if he/she needs further treatment or, just become a normal student. The teacher plays a core role in this part of the model, where he/she is the center for such treatment. Teacher uses technology tools, education material, and coordinates with family and the overall VSL.

**Dyscalculia:** is a brain-based condition that makes it hard to make sense of numbers and math concepts.

**Visual Spatial Learning styles (VSLs):** refer to a person's ability to recognize, analyze, and understand visual information in the around.

### Model Design Evaluation Form

Please read the attached brief description and the sketch of the model design. Based on that, please fill in this evaluation form. Your objective feedback is highly appreciated. Please feel free to comment on the model. Thank you for your time and invaluable feedback and comments.

Please write (X) in the appropriate answer of each item of the evaluation form. ("SA" Strongly Agree, "A" Agree, "N" Neutral, "D" Disagree, and "SD" Strongly Disagree).

Item	SA	A	N	D	SD
<b>A. The model is</b>					
1. Understandable					
2. Clear					
3. Complete					
4. Comprehensive					
5. Self- explained					
<b>B. The graphical representation ( layout ) of the model is:</b>					
6. Understandable					
7. Clear					
8. Complete					
9. Comprehensive					
10. Matching the textual explanation					
<b>C. The textual explanation of the model is :</b>					
11. Understandable					
12. Clear					
13. Complete					
14. Comprehensive					
<b>D. The components are all:</b>					
15. Understandable					
16. Necessary					
17. Relevant					
18. Sufficient					
<b>E. The relationships between components are :</b>					
19. Understandable					
20. Clear					
21. Meaningful					
<b>F. The graphical representation of the components is :</b>					
22. Understandable					
23. Clear					
24. suitable					
<b>G. 'Students' component is :</b>					
25. Necessary					
26. In the right place					
<b>H. ' Exam' component is :</b>					
27. Necessary					
28. In the right place					
<b>I. ' Criteria ' component is :</b>					
29. Necessary					
30. In the right place					

<b>J. 'Clustering' component is :</b>						
31. Necessary						
32. In the right place						
<b>K. 'Dyscalculia Cluster' component is :</b>						
33. Necessary						
34. In the right place						
<b>L. 'Normal Students' component is :</b>						
35. Necessary						
36. In the right place						
<b>M. 'Dyscalculia Students' component is :</b>						
37. Necessary						
38. In the right place						
<b>N. 'Adaptive Technology Based Math Activities' component is :</b>						
39. Necessary						
40. In the right place						
<b>O. 'Family Environment' component is :</b>						
41. Necessary						
42. In the right place						
<b>P. 'Teacher' component is :</b>						
43. Necessary						
44. In the right place						
<b>Q. 'Visual- spatial learning' component is :</b>						
45. Necessary						
46. In the right place						
<b>R. 'Education Material' component is :</b>						
47. Necessary						
48. In the right place						
<b>S. 'Enhancements Dyscalculia Students' component is :</b>						
49. Necessary						
50. In the right place						

**Comments/suggestions:**

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**Thank you for your cooperation.**