International Journal of Special Education and Information Technology

Volume 10, Issue 1, (2024) 55-69

www.jeset.eu

Enhancing understanding of chemical equations for secondary school students with learning disabilities via computer programming

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Suggested Citation:

Alanazi, F. & Gadelmawla, A. (2024). Enhancing understanding of chemical equations for secondary school students with learning disabilities via computer programming. *International Journal of Special Education and Information Technologies, 10*(1), 55-69. https://doi.org/10.18844/jeset.v10i1.9672

Received from July 20, 2024; revised from August 18, 2024; accepted from October 14, 2024.
Selection and peer review under the responsibility of Prof. Dr. Adile Askim Kurt, Editor-in-Chief, Anadolu University, Turkey

iThenticate Similarity Rate: 0%

Abstract

This research investigates the effectiveness of a targeted intervention program designed to mitigate learning disabilities (LDs) in understanding chemical equations among grade-12 students. A pre-test/post-test experimental design was employed to evaluate changes in students' abilities to write and comprehend chemical equations. The assessment involved analyzing the complexity of students' written responses to given chemical equations and their performance on a standardized chemical equations test (n=12). The findings revealed a significant reduction in the level of difficulty students experienced in writing chemical equations after the intervention, accompanied by a marked improvement in their mean scores on the chemical equations assessment. These results suggest that the intervention was effective in enhancing the chemical equation skills of students with LDs. Implications of these findings and their potential applications in chemistry education are discussed.

***Keywords**:* Science education; skill; special education; test; TRIZ.

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1. INTRODUCTION

Although many studies have indicated the difficulties of learning in the field of chemistry education (Ragkousis, 2000; Kamińska-Ostęp, & Gulińska, 2008), learning can become fun, particularly in the case of the teachers themselves possessing the ability to adjust the needed teaching tactics to harmonize with the student's tendencies and requirements, learning can be a very positive, pleasurable process; in the same vein, similarly can be said for those facing learning disabilities in the classroom environment: these special requirements need to be met, just like those without LDs, and when it comes to scientific lessons such as physics and chemistry, the relevant educators must provide the content in a way that is suitable for such difficulties (Sulu et al., 2023; Bevens et al., 2024; Aviran & Blonder 2023). Due to its complex nature, one of the most difficult subjects to understand within the science curriculum is Chemistry. Considering this, Chemistry requires multiple levels of understanding (Avargil, 2019).

Investigators within the sector of special education thus face the need to implement a range of educational ideas and concepts within their research to aid LD pupils (Abidin et al., 2024). According to Hallahan et al., (2013), the presence of the day-to-day problems LD students face has resulted in researchers completing investigations with the primary aim of pinpointing the most effective methods in meeting such specific requirements. An example of one of the concepts having to be implemented and kept in mind whilst conducting such studies is that of the Inventive Problem-Solving Theory (TRIZ), and it is because of this that this paper is putting forward a group of novel teaching strategies that would merge current technology (Smartboard; computer) and TRIZ; this has been done with the aim of LD students being able to better comprehend chemical equations, as such a merging of tactics would result in such concepts being put forward in an easier, more concise way.

1.1. Conceptual background

Considering a frequently occurring symptom of LDs is possessing a shorter-than-average attention span, the learning of the ideas listed within secondary-level science textbooks can be especially difficult for those with LDs; this is because such ideas are usually conceptual and non-literal, and even for the most academic of students it necessitates a long attention span. Indeed, such examination of these stages provides an understanding of why some concepts are more complex for students with LDs to learn than others.

Considering the majority of those battling LDs find it hard to fully grasp the chemical concepts presented to them, the majority of such students select the more literacy-based section as their preference. Indeed, considering an individual with LDs will often peak in adolescence in terms of their inability to concentrate for long periods, the 'chemistry foundations' module is often dubbed as the most difficult for LD secondary students to grasp considering the ideas within it are mainly comprised of abstract chemical ideas (the molecule; the atom; elements; the ion; mass numbers; atomic numbers). Indeed, it is also important to note that the teaching method of simply handing such a student a textbook with such ideas in it does not help in this difficulty, as textbooks do not tend to break down and slowly explain concepts such as the links and the framework underpinning such ideas.

Saying this, a question is posed regarding such a method: as much as this tactic has thus far been applauded for possessing the ability to expand students' horizons and nurture their respective skills, whether possessing LDs or not, at a range of different ages, can this technology be fully effective for secondary school students with LDs being taught the complex topic of chemistry? And, in line with this question, can TRIZ and such current technology be merged in such a way to tackle such issues in secondary pupils' learning of science subjects? Indeed, there is a range of questions concerning the above that could be posed; however, all of these can, indeed, be condensed into one simple research question: How capable are computer methods in enhancing the comprehension of chemical equations in secondary students with LDs?

1.2. Literature review

1.2.1. Computer program

Being outlined as an 'activity set concerning the learning of subject's students with learning disabilities via computer-based techniques primarily and then train session handouts within a specified place and time to enhance chemical equation recall and comprehension', the computer program implemented within the current investigation lists the research materials.

1.2.2. Learning disabilities

The federal Interagency Committee on Learning Disabilities (ICLD) was composed of representatives from 12 agencies within the Departments of Education and Health and Human Services. The ICLD members found fault with the NACHC's old definition and pinpointed four specific problematic areas. The first concerned a lack of clarity on the heterogeneity of learning disabilities. The second related to the failure in that definition to acknowledge that learning disabilities are a lifelong condition. The third had to do with the lack of clear specificity of the inherent changes in processing information in individuals with learning disabilities. The fourth was the lack of recognition that learning disabilities can co-occur in individuals with other kinds of handicaps—for example, hearing impairment (Torgesen, 2004).

Handwriting is an ability acquired by students in the classroom (McMaster & Roberts 2016). It is a complex activity that involves continuous interaction between lower-level perceptual-motor and higher-level cognitive processes (Stievano et al., 2016). Being able to accurately spell in Standard English requires efficient coordination of multiple knowledge sources; therefore, spelling is a word-formation problem-solving process that can be difficult to learn (Daffern, 2017). So, spelling abilities are vital in teaching students to read and write effectively (Goodman, et al., 2015), spelling also is an important ability that is crucial to effective written communication (McCurdy, et al., 2016), it is a prerequisite to expressing vocabulary in writing (Sumner et al., 2016). Spelling is one of the most challenging areas for students with learning disabilities (LD), and improving spelling outcomes for these students is of high importance (Williams, et al., 2017).

Zhao, et al., (2017) examine the contribution of meta-linguistic abilities to the English spelling ability of Grade 8 Chinese students who study English as a foreign language (EFL group) and of third graders in the U.S. whose first language is English (EL1 group). Liu, et al., (2011) have investigated the effectiveness of mind mapping used as a learning strategy with students in English as Second Language classrooms. Seventy-nine ESL students participated in the study. Variables of interest were students' achievement when learning from English-language text, students' reported use of self-regulation strategies (self-monitoring and knowledge acquisition strategies), and students' self-efficacy for learning from English-language text. A randomized pre-test–post-test control group design was employed. The findings showed a statistically significant interaction of time, a method of instruction, and a level of English proficiency for self-monitoring, self-efficacy, and achievement. For all four outcome variables, the mind mapping group showed significantly greater gains from pre-test to post-test than the individual study group. The findings have implications for both practice and research.

The role of technology in second language education has become the focus of several studies in the last few years (Toledo &Díaz, 2017). Also, "the emergence of digital technologies has significantly transformed the forms, genres, and purposes of writing both inside and outside the classroom" (Zheng &Warschauer, 2017). Also, considering the characteristics of students with learning disabilities (neuropsychological processing deficits that interfere with academic achievement in handwriting, spelling, and/or written expression, students with specific learning disabilities (SLD) have disparate neuropsychological processing deficits that interfere with academic achievement in spelling, writing fluency, and/or written expression. Although there are multiple potential causes of written expression-specific learning disabilities, there is a paucity of research exploring this critical academic ability from a neuropsychological perspective (Fenwick, et al., 2016).

Impacting their comprehension of the spoken/written language within the science topics, learning disabilities can be classed as a condition in at least one basic psychological process, this study specifically focuses on secondary pupils; indeed, such a condition may be particularly displayed in the sufferer's struggle in thinking, listening, reading, speaking, spelling, writing, or demonstrating basic chemical equation processes. Furthermore, it is important to note that, according to Hallahan et al., (2013), such struggles do not also entail audio-, sight-, emotional-, mental-, or inaesthetic-related issues, nor do they include any economic- or environmental-induced problems felt by pupils. To clearly outline how they should be implemented in terms of teaching secondary students possessing LDs the chemistry curriculum, please find below the TRIZ's principle and strategy definitions.

1.2.3. Inventive Problem-Solving Theory (TRIZ) strategies

This name is an abbreviation of the Russian name "TeoriaResheniqyIzobriatatelskikhZadatch", the English abbreviation is TIPS (Theory of Inventive Problem-Solving) (Barry et al., 2010; Sheng & Kok-Soo 2010); indeed, by this definition, according to Hua et al., (2006), TRIZ is a prediction, analysis, and problem-solving material sourced from internationally registered patents. This theory is supported by a vast quantity of countries globally and has been implemented within a range of psychological and educational contexts (Vincent & Mann, 2000; Hipple, 2005; Barak, 2009) even though it is derived from chemistry, and physics, technology, engineering, and applied science contexts (Blackburn et al., 2012; Moehrle, 2005). Indeed, it is important to note when considering the above that the above concepts and ideas can be implemented to coach students in tackling any issues they may come across, in either a conceptual or an in-real-life format, even though these concepts may appear to be hard to apply; saying this, the idea of either 'accelerating oxidation' or 'composite materials', as a for-instance, could only ever realistically be applied to the context of a laboratory. However, even still, other concepts can, indeed, be applied to in-real-life contexts and situations, whether the learner is at a primary or secondary level, or if they possess an LD or not.

Indeed, there are a range of benefits in implementing the concepts put forward by TRIZ on the grounds of the prior theoretical framework when it comes to students with LDs and, if such benefits were witnessed amongst both students and teachers, there would, according to past findings, most likely be a drastic decrease in the hurdles faced whilst learning the science curriculum and grasping chemical equations specifically. Vincent & Mann (2000) aimed to utilize TRIZ's concepts in a novel way within problem-solving teaching, as well as to implement TRIZ in the context of bioscience, they found within their study that pupils' abilities to generate advanced answers enhanced drastically post-problem-solving training, thus making it reasonable to conclude that TRIZ is reliable in terms of leaving students fulfilled in terms of their progress in approaching questions in a more inventive, original way.

Bearing in mind the above evaluations and discussions concerning previously conducted research related to TRIZ, LDs, and computer-based methods of teaching, we can summarize with the following:

- The results garnered from such studies have showcased computers' capabilities in how students with LDs are taught and in nurturing the separate stages of intellectual development.
- All of the previously cited research within this sector has showcased TRIZ theory as being effective in obtaining the aims of such studies, regardless of the different variables amongst such studies.
- A few of the researches relied wholly on effective TRIZ principal implementation when it comes to tackling the problems linked with the teaching of the science curricula to younger samples; saying this, none of these such researches merged TRIZ principles and computer-based methods when aiming to enhance chemical equation comprehension.
- In terms of the previously conducted research in this field, there has been no recorded research that has evaluated computer programs' capabilities in enhancing chemical equation grasp bearing in mind the different variables that come with different program contexts (e.g., teaching approaches; content; and teaching materials).

1.3. Purpose of study

Notably, when it comes to computer-based teaching, in the context of altering the sizes, colors, forms, symbols, and numbers implemented within the chemical equations, these cannot be altered despite the same system giving a range of features enabling the implementation of such concepts. This paper aimed to underline because it is comprised of putting forward a computer-based teaching method that effectively enhances chemical equation comprehension including in line with TRIZ theory, as this has been showcased on numerous occasions as being useful in eliminating the effects of LDs when it comes to learning such content. This research investigated the effectiveness of a targeted intervention program designed to mitigate learning disabilities (LDs) in understanding chemical equations among grade-12 students**.** This research's hypotheses are:

- There are statistically significant differences between the mean scores obtained between the pre-measurement and post-measurement of the experimental group in favor of the post-measurement results on the chemical equations test.

- There are statistically significant differences between the mean scores obtained between the pre-measurement and post-measurement of the experimental group in favor of the post-measurement results on the chemical equations writing disabilities scale (when copying the equations).

- There are statistically significant differences between the mean scores obtained between the pre-measurement and post-measurement of the experimental group in favor of the post-measurement results on the chemical equations writing disabilities scale (when solving the equations).

2. METHOD AND MATERIALS

The quasi-experimental approach was used. The following details the research procedures at hand.

2.1. Participants

The participants in this study were 12th-grade students enrolled in a secondary school. This group was specifically selected due to their curricular exposure to advanced topics in chemistry, including chemical equations, which are a fundamental yet challenging component of the grade-12 chemistry syllabus. The participants consisted of a diverse cohort representing varying levels of academic performance, with some students demonstrating specific learning disabilities (LDs) that affected their understanding of chemical equations. A total of 12 students participated in the study, ensuring a manageable sample size for detailed observation and individualized support during the intervention process.

2.2. Data collection instruments

The study utilized two primary instruments for data collection: a Chemical Equations Test to evaluate students' understanding and application of chemical equations, and a Chemical Equations Writing Disabilities Scale to identify and measure the severity of learning disabilities in writing chemical equations.

2.3. Procedure

2.3.1. Chemical equations test

The majority of the selected equations mainly centered on double and simple substitution reactions, this test was generated to calculate pupils' chemical equations comprehension, as well as their capabilities in effectively solving them; this comprised a total of ten selected equations, the students then being asked to solve them with the highest possible test score being 38.

Notably, because the score calculation relies on the partial elements to calculate each equation effectively, the sum of each equation's scores may vary from the other assigned equations. In the same vein, the test comprised of two forms, the first of which is put forward in pre-measurement; this is the conventional test form, whereby the equation would be presented in the following format:

$$Ag^{+} + Cl^{-} \rightarrow ....$$

Conversely, the second form was put forward in the initial training program stages, being comprised of several additions aiming to enhance discrimination, visual perception, and attention:

$$Ag^{+} + Cl^{-} \rightarrow \boxed{......}\ \boxed{......}$$

The above scale was formulated in mind the ultimate objective of pinpointing the writing disabilities impacting chemical equation comprehension within learners, and how this was established was via teacher interviews, whereby the given teacher would rate a given student's writing disability influence on a scale of 1-3 (1 = Usually Happen, 2 = Sometimes Happen, and 3 = Rarely Happen). Furthermore, there were a total of nine questions comprising the interview, meaning a score of 9 would indicate a severe disability and a score of 27 would indicate no disability present in this context. Indeed, this method of scaling was authenticated by members of the jury, and, to eliminate any further uncertainty in terms of this method's efficiency, it also underwent a split-half coefficient calculation.

Table 1

The scale of Chemical Equations Writing Disabilities

No.	Item	Usually, Happen	Sometimes Happen	Rarely Happen
1.	Chemical elements are written backward (e.g., **eF** instead of **Fe**).			
2.	Elements unrelated to the equation's product with no link to the reactors are written (e.g., **Ca O+CO2→CnCu$_3$** instead of **Ca O+CO2→CaCO$_3$**).			
3.	The reactants are placed as a product, whilst substituting its parts (e.g., writing **NaOH** as **OHNa**in terms of its products).			
4.	The reactors as the product are rewritten without alteration (e.g., **Mg+AlCl$_3$→Mg+AlCl$_3$** instead of **Mg+AlCl3→MgCl2+Al**).			
5.	Symbols unrelated to the equation are added (e.g., **-** instead of **+**; repeating **→**; consecutive symbols without elements separating them, like **+ →**).			
6.	Numbers are not written as a subscript (e.g., **No3** instead of **No$_3$**).			
7.	The two reactants are written as two products, substituting the first with the second (e.g., **2HI+Li$_2$S→2HI+Li$_2$S** instead of **2HI+Li$_2$S→H$_2$S+2LiI**).			
8.	Sequential products are written without the + symbol (e.g., **Fe+CuSO$_4$→FeSO$_4$Cu** instead of **Fe+CuSO4→FeSO$_4$+Cu**).			
9.	Reactant elements are omitted when writing products (e.g., **HBr+NaOH→H$_2$ar** instead of **HBr+NaOH→H$_2$O+NaBr**).			

Table 2

Internal Consistency Validity of the Chemical Equations Writing Disabilities Scale

Item	1st	2nd	3rd	4th	5th	6th	7th	8th	9th
Total Score	.595**	.589**	.810**	.798**	.773**	.611**	.549**	.608**	.775**

Table 3

Reliability of the chemical equations writing disabilities scale

Variable	Items No.	Split-Half (Spearman-Brown)	Guttmann	Alpha Cronbach
Writing Disabilities	9	0.859	0.859	0.784

Ineed, upon review of the above tables (Tables 1, 2, and 3), we can see that there is a sufficient amount of reliability and validity showcased in terms of the chemical equation writing disability scale.

2.3.2. Understanding of chemical equations enhancing computer program

Founded on the grounds of the TRIZ theory principle implementation and computer use, the primary research material being used here is the computer program that is being put forward to enhance chemical equation comprehension, the program itself involves secondary school pupil coaching in the context of chemical equation comprehension in terms of color, numbers, size, backgrounds, symbols, printed materials, and TRIZ-derived principles.

2.4. The program's foundations

To formulate the program according to this study's goals, a group of foundations (listed below) were formulated.

- It is possible to enhance visual perception, attention, and comprehension when being taught via computer (Nsabayezuet al., 2022).
- Coding is a huge focal point of working memory, meaning that the object can be learned effectively and transferred into eligible code when the data is presented properly; on this note, we can conclude that chemical equations, when put forward in a similarly proper fashion, can be comprehended and transferred well. It is with this in mind that the visual factors of the program have been selected specifically to aid learning.
- Information retrieval is impacted by the approach used to do so, and so this has been implemented in the program to highlight the suitable visual organization of the given symbols. This will, in turn, lead to students finding it easier to perceive and, thus, utilize them when solving chemical equations.
- When it comes to discriminating against symbols, LD students can struggle, thus explaining why chemical equations are a particularly sore point for such individuals, their previously discussed lack of attention span and lack of visual perception also contribute to this difficulty. As well as any science-learning-related issues at the primary school, age (Abdullhadi, 2008).
- As in the studies of Schunk (1998), and Gui et al., (2023) computer games can be utilized as tools for enhancing general and readable text understanding.

2.5. Program content

As a way to enhance comprehension of chemical equations amongst secondary school pupils, the program can be put forward in adherence to the TRIZ theory principles.

Table 4

Program sessions

No.	Session Title	Objectives (Learning Outcomes)	Training Techniques Used	Tools
1.	Introductory Session	• Involved students introduce themselves to one another and the teacher. • Program locations and times are pinpointed by the pupils.	• Tangible Reinforcement (e.g., pens). • Intangible Reinforcement (e.g., students praised by teacher).	• Computer • Pupils' names on printed paper cards.

		• The program’s advantages, essentiality, and most influential factors are pinpointed by the pupils.		
2.	Pinpointing LD common figure models.	• Writers’ and scientists’ (who are successful despite their LDs) models are pinpointed by pupils. • A want to imitate them is demonstrated by the pupils. • A newfound sense of assertion is found within the students in terms of their skill sets.	• Intangible/Tangible Reinforcement (e.g., pointers; conversation; independent work).	• Photos of discussed writers/scientists. • Computer with images of writers/scientists and lesson title.
3.	Differentiating between chemical equations’ elements	• Symbols are differentiated by the pupils. • The suitable reading of the signs (e.g., +and →), symbols (e.g., chlorine = Cl; potassium = K), and subscripts (e.g., Fe3; Na5) is pinpointed by the pupils. • Each sign’s function is stated by the pupils.	• The principles of TRIZ theory (i.e., adding a mediator; changing chemical symbols’, signs’, and/or numbers’ colors; decreasing/increasing parts for differentiation purposes). • Behavior alteration methods (i.e., intangible/tangible reinforcement; modeling; replication; oral instruction; response, and critique.	• Cards with chemical equations. • A computer.
4.	Differentiating between chemical compounds with two elements.	• The chemical compounds’ names are read aloud by the students as they appear on the card/computer. • The correct way to read chemical compounds with two elements is pinpointed by the pupil (e.g., **NaCl**). • With the aid of the added kinetic effects and different colors, the elements are differentiated between the pupils.		• The same materials are detailed above.
5.	Differentiating between chemical compounds with three elements.	• The correct way to read chemical compounds with three elements is pinpointed by the pupil (e.g., **$NaCl_3$**). • With the aid of the added kinetic effects and different colors, the elements are differentiated between the pupils. • The chemical compounds’ names are read aloud by the students as they appear on the card/computer.	• Behavior alteration methods (i.e., preventing confusion by adding different colors to different symbols and elements; signaling the end and beginning of equation parts by making the symbols thicker).	• The same materials are detailed above.
6.	The reading of a finalized equation.	• The finalized chemical equation is correctly noted both on the computer and piece of paper by the pupils. The finalized chemical equation is read aloud correctly (e.g., **$Ag^{+}+Cl^{-} \rightarrow AgCl$**). Traditional Equation Form $Ag^{+}+Cl^{-} \rightarrow AgCl$ Post-TRIZ Principle Equations **$Ag^{+}+ Cl^{-} \rightarrow AgCl$**		• The same materials are detailed above.
7.	How chemical equations can be solved.	• The required steps to solving the given chemical equation are followed by the pupils.	• Decreasing/increasing parts of the equation. • Adding mediators to the equation.	• The same materials are detailed above.

- How chemical equations can be solved is pinpointed by the pupils.
- The correct answer is successfully noted on the computer and paper by the pupils.

Equation Traditional Form before the solution
Ag++Cl-→ ……….
Equation Traditional Form after the solution
Ag++Cl-→ AgCl
Equation before solution using TRIZ principles.
$Ag^{+}+Cl^{-}\rightarrow$ [ ] [ ]
Equation after solution using TRIZ principals
$Ag^{+}+Cl^{-}\rightarrow AgCl$

- Post-pupil coaching in linking elements and the corresponding color, colors are removed, and the equation is worked through again.

8. Retraining how chemical equations are solved.

- The required steps to solving the given chemical equation are followed by the pupils.
- How chemical equations can be solved is pinpointed by the pupils.
- The correct answer is successfully noted on the computer and paper by the pupils.

Equation Traditional Form before the solution
Na+ Cl→ ………..
Equation Traditional Form after the solution
Na+ Cl→ NaCl
Equation before solution using TRIZ principles.
$Na+Cl\rightarrow$ [ ] [ ]
Equation after solution using TRIZ principals
$Na+Cl\rightarrow NaCl$

- Post-pupil coaching in linking elements and the corresponding color, colors are removed, and the equation is worked through again.

- Behavior alteration methods (i.e., adding mediators; changing colors; decreasing/increasing parts).

-
- The same materials are detailed above.

9. Because the remainder of the program is unrestricted, each professor can determine at their discretion what content should be added/revisited.

Regarding the above guideline, it is up to the teachers at hand to decide whether they would like to include additional topics/classes; indeed, this would likely be decided in line with each class's objectives in terms of its LD students learning science subjects.

3. RESULTS

3.1. First hypothesis-related findings

First, we will delve into the results garnered concerning the first hypothesis outlined earlier in this paper (stating, 'When it comes to the chemical equations test, there will be statistically significant variations in the mean score between the post- and pre-measurement of the experimental group in favor of the post-measurement results'); bearing this hypothesis in mind, the Wilcoxon test of related samples was implemented (see Table 5) as a method to authenticate the collected results.

Table 5

The chemical equations test differences in direction

Variable	Difference in Direction	N.	Mean Rank	Ranks Sum	Calculated Wilcoxon (t)	Tabulated Wilcoxon (t)		Sig. Level
						0.05	0.01	
Chemical Equations Test	Negative	2a	1.50	3.00	3.00	11	5	0.01
	Positive	8b	6.50	52.00				
	Neutral	2c						
	Total	12						

Indeed, upon analysis of the results listed in Table 5, it is apparent that the tabulated value (in terms of the significance level) is higher than that of the Wilcoxon value; further, it can also be seen that, whilst both negative and neutral alterations occurred within a total of two pupils, a total of eight students saw positive alterations, thus proving our hypothesis.

3.2. Second hypothesis-related findings

Next, our second hypothesis (stating, 'When it comes to chemical equations scale when copying equations in terms of writing disabilities, there will be statistically significant variations in the mean score between the post- and pre-measurement of the experimental group in favor of the post-measurement results'); indeed, as in the above evaluation, the Wilcoxon test of related samples was implemented (see Table 6) as a method to authenticate the collected results.

Table 6

Chemical equations' difference in direction when copying equations on the scale of writing disability

Variable	Difference Direction	N.	Mean Rank	Sum of Ranks	Calculated Wilcoxon (t)	Tabulated Wilcoxon (t)		Sig. Level
						0.05	0.01	
Writing Difficulties when Copying Equations	Negative	0[d]	0.00	0.00	0.00	17	10	0.01
	Positive	12[e]	6.50	78.00				
	Neutral	0[f]						
	Total	12						

Indeed, upon analysis of the above table, we can see that the tabulated value at the significance level is higher than that of the Wilcoxon value; indeed, it is indicated that, whilst no negative or neutral shifts whatsoever were recorded, a total of 12 students endured positive changes, thus proving our hypothesis.

3.3. Third hypothesis-related findings

And, finally, the third hypothesis (stating, 'When it comes to the chemical equation scale when solving the equations in terms of writing disabilities, there will be statistically significant variations in the mean score between the post- and pre-measurement of the experimental group in favor of the post-measurement results'); as per, the Wilcoxon test of related samples was implemented (see Table 7) as a method to authenticate the collected results.

Table 7

The chemical equations' difference in direction when solving equations on the scale of writing disability

Variable	Difference Direction	N.	Mean Rank	Sum of Ranks	Calculated Wilcoxon(t)	Tabulated Wilcoxon(t)		Sig. Level
						0.05	0.01	
Writing Difficulties when Solving Equations	Negative	2[g]	3.25	6.50	6.50	14	7	0.01
	Positive	9[h]	6.61	59.50				
	Neutral	1[i]						
	Total	12						

Indeed, we can see, upon observing the above table, that the tabulated value at the significance level is higher than that of the Wilcoxon value; furthermore, we can also perceive that, whilst a total of two students endured negative shifts and a total of one pupil endured a neutral shift (the former of which did not see enhancement in their writing in terms of solving the given equations), *all* the students within the sample endured a wealth of improvement in their writing skills when it came to copying equations, a total of nine of which being noted to have endured a positive shift. From this, we can sensibly conclude that, whilst students can improve dramatically in terms of their copying of chemical equations, their main issue lies in their solving of chemical equations. Thus, from this, we can see that there is a necessity for the presence of additional coaching in problem-solving skills within such a population, which is very possible when reviewing Table 7, which indicates an overall positive change in pupil performance post-measurement in terms of their writings when solving the equations.

4. DISCUSSION

Aligning with those of a wealth of other studies within the field of TRIZ theory's efficacy (Hipple, 2005; Barak, 2009), the results garnered from this investigation showcase the fact that, when it comes to enhancing comprehension of chemical equations and improving writing amongst students with learning disabilities, training is especially valuable and reliable.

During the initiation of the given program, the students within the sample underwent a range of steps in terms of their respective journeys in improving their comprehension and writing skills within the chemistry topic, and it is via the evaluation of such steps/stages that we can effectively unravel our study results; indeed, this correlates with a range of other investigations within this area (Vincent & Mann, 2000). It is also worth noting that, to aid students in distinguishing between the separate sections of a given equation (thus preventing confusion) via the incorporation of different frames and colors, a computer was used within the study; this, indeed, is aligned with Toledo &Díaz (2017) results, which identified technology as being especially helpful and effective tools in aiding learning processes. Notably, another element of this study that effectively aided students in achieving comprehension of the given equations was the implementation of a consistent, coherent sequence of steps during the training process, which progressed as follows: simple chemical elements; two-element chemical compounds; three-element chemical compounds, etc.

An additional element of this investigation that undoubtedly aided in the ultimate comprehension of chemical equations was that of the intangible reinforcement that was employed; indeed, whenever a pupil either made tangible progress or succeeded in answering/writing/copying something correctly that they had previously struggled with, some form of reward would be given. Saying this, it is important to bear in mind that all students possess varying levels of learning disability, and so those possessing minimal achievement levels may require more coaching than others. Indeed, all achievements vary in line with each pupil's abilities and struggles.

Indeed, another key feature of this research that aided significantly in achieving its objective was that of the incorporation of features aiding in visual differentiation between different elements of an equation; the addition of different colors, mediators, and decreases/increases when needed succeeded in directing focus to one part of the equation at a time, thus preventing confusion within students and increasing motivation via the rapid reduction in mistakes being made. Further, a dramatic increase in writing skills was observed at this time.

Even though it is essential to bear in mind that levels of complexity may vary for each student respectively, the investigation at hand has stressed the essentiality behind the application of the above features to all science skills in need of development within the curriculum as a whole; as we can see from the results, any pupil, regardless of learning difficulties, can reach their full potential with effective reinforcement, coaching, and consistency within their lessons, as this increases comprehension and recall of the topics at hand. Indeed, these findings are supported by those of Abdulhadi (2008), who navigated the impact of TRIZ theory on learning and found it to be effective.

Meanwhile, in terms of the scores from the students in terms of the writing difficulties scale, the pupils' accomplishments were compared and contrasted in terms of their prior capabilities in copying and solving equations; it was upon such comparison that it became clear that the sample produced the best scores when copying chemical equations rather than solving them. This can, from another angle, be perceived as the students finding it less complex to write when the answers were already before them for them to copy. Meanwhile, the entire equation likely seemed more overwhelming and complex when students had to solve them.

5. CONCLUSION

Notably, throughout this investigation, the students also began both solve and copy test questions independently, the evaluations of which ultimately being as follows:

- There was a witnessed improvement in the sample's performance in equation-solving post-program when compared with before.
- There was a witnessed improvement in the sample's performance in equation-writing post-program when compared with before.
- There was a witnessed improvement in the sample's performance in equation copying with an answer key when compared with without an answer key.

A multitude of other tactics were employed during this study that were unrelated to TRIZ theory's principles, as follows: The program incorporated several instructional strategies to support students in mastering chemical equations effectively. Oral Direction was utilized to guide students through the stages of solving chemical equations and to help them distinguish between different sections of an equation. Critique and Response, provided by the program's teacher, involved observing students' problem-solving approaches and offering constructive feedback to refine their techniques and correct errors. Replication required students to mimic the teacher's problem-solving steps during independent practice, reinforcing their understanding and providing a structured method to approach similar problems. Lastly, Modeling was employed, where the tutor demonstrated a visual model to clarify the distinct sections of a chemical equation and illustrated its application in problem-solving. Students were then encouraged to apply the same method, first on paper and later using digital tools, fostering both conceptual understanding and practical skills.

6. RECOMMENDATIONS

When reviewing the results, positive elements, and negative elements of this research, we can make a list of recommendations for future works expanding this one within this field of research; these are as follows:

- In turn, implementing varying and bold signs and symbols and colors (the emphasis being placed on the sections of high importance), bearing in mind TRIZ theory and its principles when formulating and following the science curriculum can aid in students being able to differentiate between different compounds and elements within chemical equations; this, as a result, leads to heightened attention spans and a dramatic decrease in the number of mistakes made, thus increasing confidence and motivation when faced with chemical equation problems. Indeed, the major positive impacts of the above have been recognized by the Saudi Arabia Ministry of Education and have been implemented within Saudi Arabian textbooks (as of 2018), the visual elements of a textbook layout being evaluated and altered in line with expanding students' potential, regardless of LDs.

- Considering it has been found that they aid significantly in enhancing chemical equation comprehension and in expanding science-related learning processes, extensive computer-based educational programs should be implemented.
- Taking advantage of the growing programs that predominantly aim to tackle learning problems that are frequently present within classrooms (maths-related learning disabilities) with the aid of TRIZ theory and growing technology.
- Particularly in the arenas of the addition of eye-catching mediators and colors, incorporating TRIZ theory's principles in the science curriculum across the board.
- As a way to both nurture LD sufferers' skills and enhance their respective chemical equation comprehensions, building upon pre-existing training program designs.
- To enhance LD pupils' optimism and motivation in terms of constantly forming and striving to achieve objectives within a specific range of skills, increasing related activity implementation.
- Incorporating intensive coaching in specific subjects that students with LDs are seen to struggle with (the reading of certain symbols).

As much as this paper has been overall effective in aiming its objectives, the results still pinpoint the requirement for additional study within this area; thus, in line with such future works, as follows are some further suggestions that should be incorporated to make progress within this field:

- How both TRIZ theory's principles and computer programs may aid in coaching illiterate adults in acquiring basic language-related skills (writing; reading).
- How both TRIZ theory's principles and computer programs may aid in teaching secondary school students with learning disabilities mathematics-related content.
- How students write chemical equations may make it easier to decipher whether they possess a learning disability or not.

It would be possible to devise a program that coaches' teachers within the classroom on how to utilize the computer to effectively implement TRIZ theory's principles to help students with learning disabilities further.

Conflict of Interest: The authors declare no conflict of interest.

Ethical Approval: The study adheres to the ethical guidelines for conducting research.

Funding: This research received no external funding

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