An understanding of basic mathematical concepts by students with mild intellectual disabilities through the use of online digital games

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Abstract

The purpose of this research is to examine the influence of a special education program, incorporating online digital games, on the understanding of basic mathematical concepts by students with mild intellectual disabilities. The research involved four students (one girl and three boys) with mild intellectual disabilities divided into two groups, an experimental (combined intervention) and a control group (standard intervention). The students' performance was assessed before the intervention program, immediately after the end of the program and two weeks after the completion of the intervention. Based on the results, improved performance was observed in the experimental group's students, in the areas of intervention, in relation to the students in the control group. The experimental group's students continued to perform at high standards, contrary to those of the control group. The findings show that the teaching approach integrating online digital games has a positive impact on the understanding of basic mathematical concepts by students with mild intellectual disabilities.

Keywords: *Mild intellectual disability, mathematical performance, basic mathematical concepts, online digital games.*

RESUME

Compréhension des concepts mathématiques de base auprès d'étudiants ayant une déficience intellectuelle légère à l'aide de jeux numériques en ligne

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Mots Clés: Déshabilité Intellectuelle legère , Performance mathematique, Concepts mathematique de base, online digital games.

Le but de cette recherche est d'examiner l'influence d'un programme d'éducation spéciale, en intégrant des jeux numériques en ligne, sur la compréhension des concepts mathématiques de base par des étudiants ayant une déficience intellectuelle légère. La recherche a concerné quatre étudiants (une fille et trois garçons) souffrant d'une déficience intellectuelle douce divisée en deux groupes, une intervention expérimentale (intervention combinée) et un groupe témoin (intervention standard). La performance des élèves a été évaluée avant le programme d'intervention, immédiatement après la fin du programme et deux semaines après la fin de l'intervention. Sur la base des résultats, des performances améliorées ont été

observées dans le cas, contrairement à celles du groupe témoin. Les résultats montrent que l'approche pédagogique intégrant les jeux numériques en ligne a un impact positif sur la compréhension des concepts mathématiques de base par des étudiants ayant une déficience intellectuelle légère.

Introduction

Intellectual disability is a permanent condition characterized by significant limitations in the intellectual functioning (Schalock & Luckanson, 2004) and in the adaptive capacity of individuals regarding perceptual, social and adaptive skills (self – management, living at home, self reliance, health and safety, practical learning, recreation and work). People with mild intellectual disabilities make up 89% of cases of intellectual disability. They educated in mainstream schools and may become self reliant with systematic and programmed assistance. For their training, combined behavioral and cognitive strategies are usually applied. However, the trend for innovative interdisciplinary approaches to address students with intellectual disabilities is strong. In this context, activities are needed, through which the knowledge and skills will be acquired, after being constructed and integrated through daily teaching practice. It is emphasized that the student should actively participate in these activities (Cobb, Yackel, & Wood, 1992). Alternative methods and strategies are useful for addressing the specific needs of children with mild intellectual disabilities. Information and Communication Technologies (ICT) can be effectively used for the education of people with intellectual disabilities.

The nature of school mathematics renders it a complex and "multi-level" learning object. Specifically, the basic mathematical concepts are the basis of mathematical learning hierarchy and an organic part of most mathematical operations. Basic

mathematical concepts are the concept of number, that of the positional value of digits, the distinction, reading and writing of numbers and numerical symbols and the ability to measure, count and enumerate.

The educational sector is keenly interested in educational software as a complementary factor and as a learning tool. This approach is known as Computer Assisted Instruction (CAI), where written and visual information is presented in a logical sequence to a student from a computer. The familiarity of the student population with the use of computers leads to educational planning towards an increased provision of PCs, since more than half of the students use PCs during the school day (Kleiner & Lewis, 2004). Indeed, a particular sector was created, that of educational computer games - edutainment or digital game-based learning, aimed to teach specific subjects through gaming platforms.

The research community is interested in the teaching of mathematics using new technologies and digital gaming. The results show a positive impact of digital games in mathematical performance, as they can increase the performance in mathematics and problem-solving (Shin, Sutherland, Norris & Soloway, 2012). Indeed, the digital game assists in teaching mathematics more effectively than the educational videos (Lin et all., 2013). Overall, the results show a significant contribution of digital games or applications in areas such as logical correlations or specific cognitive skills (i.e. problem solving) (Bottge, 2001). However, while in the international literature there is sufficient evidence for the usefulness of incorporation of digital games in the teaching of mathematics, there is a lack of information and knowledge regarding their use in education for children with intellectual disabilities. The few studies related to this field have weaknesses (Bahr & Rieth, 1991; Podell, Tournaki-Rein & Lin 1992). These weaknesses are usually related to the methodological design (eg no control

group, no preservation measurement results after the intervention), the type of software, variables that have to do with the students themselves and the small number of samples or period of intervention (short-term experiments and interventions).

The purpose of this research is to examine the extent to which an educational intervention program that combines online digital gaming activities could be proved positive for the understanding of mathematics by students with mild intellectual disabilities. The teaching and understanding of mathematical concepts by students with mild intellectual disabilities should be part of a more general teaching philosophy and practice in order to better implement the "learning hierarchy" of "learning stages" (Polloway & Patton, 1997). Based on the above theory and research, we were led to the formulation of the following research questions:

1. Online digital games will contribute to the understanding of basic mathematical skills and concepts and improve the performance of students with mild intellectual disabilities.

2. A significant difference in the performance of students with mild intellectual disabilities participating in this particular intervention program compared with students who follow a conventional intervention program is expected.

3. The usefulness of the intervention program in relation to the usual intervention methods will be demonstrated.

Method

Participants

In the survey four Greek students participated (N = 4), a girl and three boys. The participants were eleven (11) years old, with mild intellectual disabilities, as mentioned in the diagnostic evaluation of the responsible body. As indicated in the report, attention deficit, hyperactivity disorder (ADHD), or any other special health problems, were not observed in any of the students. The participants were randomly divided into an experimental group (N = 2) called group (EG) and a control group (N = 2) called group (CG). The two groups are equal considering the following main factors:

a) The intellectual capacity level

b) The mathematical knowledge level

The groups were considered equivalent since their subjects have about the same chronological and mental age, the same aid level and come from similar educational background (parental education level) and socio-economic environment (occupational and marital status).

Experimental design and procedure

The experimental procedure was designed to test the effect of the proposed intervention on the mathematical performance of the students. The implementation of the intervention took place in two phases. During the first phase the level of mathematical competence of students of both groups was assessed.

The second phase comprised practical intervention embodiment, the total length of which was eight weeks. The intervention areas were:

- The concept of number and numbering capability (number identification and quantity estimate, numerical scale ascent and descent),
- The positional value of the numbers (e.g. tens-units) and their comparison and order (which number is higher or lower),
- Mental calculation (addition and subtraction) and,
- The growing of measurement capacity (length, weight, time).

The control group (CG) followed an entirely conventional intervention program. The experimental group (EG) followed a combinatorial form of interference; where in a part of the program has been replaced by digital online gaming activities. The objectives and structure of the intervention program by sector was as follows:

Area: Identification numbers; estimate quantities; ascent and descent numerical scale.

First Session objectives:

Cardinality – quantity estimation - arithmetic sequence formation - numbering (at ten and twenty)

Second Session objectives:

Numbers 20-30 - numerical scale ascent and descent (1-1, 2-2 etc.) – Sets of numbers creation and composition analysis

Third session objectives:

Numbers 30-100-compound sets and separation- number comparison and estimation-addition and subtraction of numbers in enactive (action-based) and iconic (image-based) level.

The Consolidation and Expansion of knowledge in each subject was achieved through online digital game activities. Indicative activities: http://www.abcya.com/100_number_grid.htm,http://www.abcya.com/one_hundred_number_chart_game.htm

Area: positional value – number comparison and ordering

First Session objectives:

Object grouping and set formation - collection data grouping in tens.

Second Session objectives:

Recognition of tens and units - number decompose in tens and units

Third Session - Structure intervention objectives:

number comparison and ordering

The consolidation and expansion of knowledge in each subject was achieved through online digital game activities. Indicative activities: http://www.abcya.com/base_ten.htm, http://www.abcya.com/base_ten_bingo.ht

Area: mental calculation (addition and subtraction)

First Session objectives:

Acquaintance with the concepts of addition and subtraction (enactive level) - mental estimate and verification of additions and subtractions

Second Session objectives:

Numbers Analysis - maintenance of all within cardinality- automatic enhancement-calculation strategies recollection

Third Session objectives:

mental calculation

The Consolidation and Expansion of knowledge in each subject was achieved through online digital game activities. Indicative activities:

http://www.abcya.com/base_ten_bingo.ht,

http://www.mathplayground.com/ASB_Jumping_Chicks.html

Area: measurements

First Session objectives:

Notion of distance-comparison and ordering of length- basic length measurement unit

Second Session objectives:

Concept of 'weight' - basic measurement unit of weight - correct weight estimation, comparison and verification

Third Session objectives:

Understanding of temporal concepts (awareness of time concepts) -time measurement-proper time reading- period estimation

The Consolidation and Expansion of knowledge in each subject was achieved through online digital game activities. Indicative activities:

http://www.ictgames.com/weight.html,

http://www.topmarks.co.uk/Flash.aspx?b=maths/measures

After completing the program, the two groups (experimental and control) were evaluated, to compare the results between the initial and final evaluation regarding the

degree of mathematical performance of each person in each group (intra-individual control), to identify any performance differences between individuals in the same group (intra - group control) and to detect differences between the two groups (inter - group control). 15 days after the end of the program another assessment followed (final -follow up) to estimate the degree of the improvement's persistence.

Measurements

To assess the initial mathematical performance (Table 1), the "Utrecht Early Numeracy Test " (Barbas, Vermeoulen, Kioseoglou & Menexes, 2008) was used, as well as the diagnostic evaluation procedure proposed by the psychology laboratory - Department of Primary Education - University of Patras (Porpodas, 2005), regarding the basic mathematical concepts. In particular, the oral numbering area includes 15 activities, the positional value - number comparison and ordering area includes 8 activities, the area of mental calculation 8 activities and the area of measurement 7 activities.

The implementation reliability of the pilot project was secured with the greatest possible control of threats to internal and external validity with the method of triangulation (Cohen, Manion & Morrison, 2008). This method can ensure reliability by cross checking various data. For the purposes of methodological triangulation, a multi – methodical approach to the collection and checking of the data was followed:

• Time triangulation through change to the initial designs, feedback from the process and interconnection of new to previous data.

• Methodological triangulation using the different information collection methods (measurement tools, clarifying questions, observation).

• Combined levels of triangulation. The performance of students in the mathematical performance of the two groups was initially graded by the instructor who conducted the intervention in each group, and then, to strengthen its credibility an independent assessment was also conducted by the researcher in collaboration with another assessor, connoisseur of qualitative research procedures.

To test the internal validity of the intervention, the teachers were given written instructions in order to avoid any differences in the experimental procedure that might affect the results. Moreover, the teachers used a list of steps filled step by step during the intervention.

Results

The study aimed to assess the effects of interventions in the areas of oral numbering, positional value – number comparison and ordering, mental calculation and measurements. The mathematical performance of the experimental group and the control group in all three measurements (M1, M2, M3) is summarized in table 1(Results of Utrecht Early Numeracy Test) and Graph 1(Mathematical performance-experimental group and control group). Students in both groups, according to the initial assessment, were at about the same learning level. They had a low level of mathematical proficiency (Table 1) and poor performance in all four areas tested (Graph 1). The effectiveness of the teaching intervention arises from the difference in the experimental group's (EG) students achievement compared with that of the control group's students (CG) in the assessment criteria provided. As observed in the results, there is a significant performance difference, with the experimental group's students achieving much better results in the four areas of intervention in relation to

the students in the control group (Graph 1). Indeed, the improved performance was maintained, as evidenced by the final performance control (follow up) taking place fifteen days after the intervention. In particular, the performance of the experimental group's subjects (EG) was significantly improved compared to their starting point in all sectors while also presenting performance homogeneity, as indicated by the results (Graph 2) of intra-group control (comparison of performance of the group's students together). The results were similar during the checking of performance level preservation, since it remained almost the same in the final assessment for the students in the experimental group (EG) which also represents the final result of the teaching intervention (Graph 2).

The performance of the individuals in the control group (CG) was low, as demonstrated by the intra individual control. During the intra-group check, it was shown that in the areas where low performance was experienced (mental calculation, measurements), there was also performance homogeneity, while in the areas where the performance was higher (oral numbering, positional value- number comparison and ordering) homogeneity was not observed (Graph 3). A similar picture also appears in the final evaluation of the performance level preservation (Graph 3).

Discussion

The type of this research is a "case study". Case studies have been increasingly used in education (Tellis, 1997). Case study research allows the exploration and understanding of complex issues. It can be considered a robust research method particularly when a holistic, in-depth investigation is required. By including both quantitative and qualitative data, case study helps explain both the process and

outcome of a phenomenon through complete observation, reconstruction and analysis of the cases under investigation (Tellis, 1997).

The results of this study are consistent with international findings according to which the standard methods of intervention in children with mild intellectual disability based primarily on practicing basic cognitive abilities (e.g. memory, attention, etc.) are ineffective. Despite the initial enthusiasm generated by the launch of such programs (e.g., Head Start, Follow Through), it was quickly found that these programs have not had the expected long-term impact on the cognitive performance of children (Consortium For Longitudinal Studies, 1983). They were not helping in the utilization of skills in different situations. On the contrary, the combination of "high level" procedures such as internal mediation processes (metacognitive) with "low-level" procedures related to fundamental cognitive functions such as perception, attention, memory, are considered more efficient and should be a vital component of intervention programs (Gaskins & Pressley, 2007). Digital games as innovative programs seem to achieve this combination. Innovative programs of new technologies have the potential to help cognitive processes (Jonassen & Reeves, 1996) by providing the stakeholders with critical knowledge to support the construction of dynamic mental models which engage students in even deeper processing and better learning. They help students overcome the limitations of their usually low cognitive abilities. They involve "low level" procedures, such as memory and storing and retrieval of information. However, they serve as footholds that allow the student to think more productively, and participate in significant structural and reflection processes (high level skills), which are the foundations of higher categories of thought and construction of knowledge. When a student uses a cognitive tool effectively, he

participates (actively), thinks (deeply), and structures knowledge properly (Jonassen, 1994).

Based on the results, the teaching intervention applied was successful in improving mathematical performance, since the improvement introduced was important, as recorded by the evaluation results. The results are similar to the corresponding research findings applied to normal students. It is shown that teaching interventions based on the use of technology and digital games are more effective than those of the conventional type (Ke, 2013; Shin, Sutherland, Norris, & Soloway, 2012). Similar are the results of studies related to the use of digital mathematical games (Ke & Grabowski 2007). According to these studies, students participating in groups that used educational digital mathematical games benefited more than those that did not play digital games. Similar are the findings of the few relevant intervention programs for students with intellectual disabilities that incorporate digital games aimed at different areas of mathematics (Singh & Agarwal, 2013)

However, the effectiveness of a teaching intervention also relies on whether the improvement was maintained. The results showed that the students in the experimental group maintained their performance level improvement significantly more compared to the control group students. The students in the experimental group clearly showed higher math performance.

Noteworthy is the fact that the second person of the experimental group (EG2) has achieved impressive results in the performance improvement preservation measurement (3rd measurement - follow up) as there was no drop in performance in any sector. On the contrary, a rise in the performance level was observed in two areas during the final assessment. It seems that the two areas of basic mathematical

concepts (oral numbering, mental calculation) where the phenomenon was observed are interdependent and interrelated. As a result, the teaching intervention in one area influences the other. It should also be noted that in the mental calculation field, the first student of the control group (CG1) showed a drop in relation to the baseline performance during the two subsequent measurements. It seems that conventional interventions tire and burden students and occasionally brings about the known phenomenon, which is often observed in the education of children with intellectual disabilities, known as "sensory overload". This is the encumbrance of the child by the inability to process the amount of information provided to him resulting in confusion and decline in performance.

The performance of the experimental group's students was high as was recorded in the second and third measurements, as well as homogeneous. The possibility that the significant improvement that was observed in the students of the Experimental Group was achieved due to either higher maturity, the positive effects of formal schooling or both was eliminated, since both groups followed exactly the same intervention program with the only difference being the digital game activities that were added in the experimental group's intervention program. Therefore our research questions were verified, since adding digital game activities in a typical educational intervention program contributed to the understanding of mathematical concepts by students with mild mental disabilities, improving their performance.

Significance of the Study

While the contribution of digital games in the teaching of mathematics to children with typical development is well established, research focusing on children with

intellectual disabilities is extremely limited. This research is important because, for the first time, the use of online games in teaching mathematics to students with mild mental disabilities is examined. The rapid growth of technology, and the increasing number of students qualifying for special education services, constitute a challenge for special educators, who are faced with the need to use the new, innovative teaching methods in the most effective way possible.

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Figure captions

Table 1: Results of Utrecht Early Numeracy Test

Graph 1: Mathematical performance-experimental group and control group

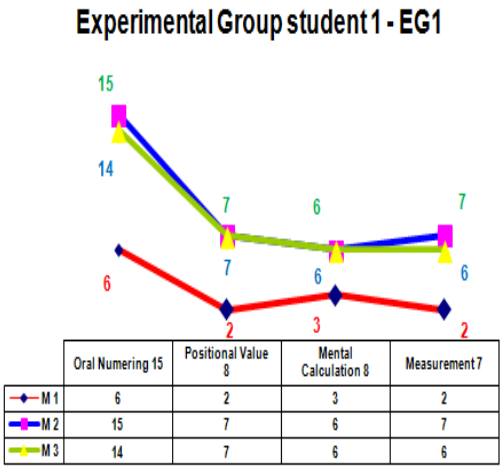
Graph 2: Mathematical Performance of the experimental group students – intra group Control

Graph 3: Performance of Control Group students-intra group control

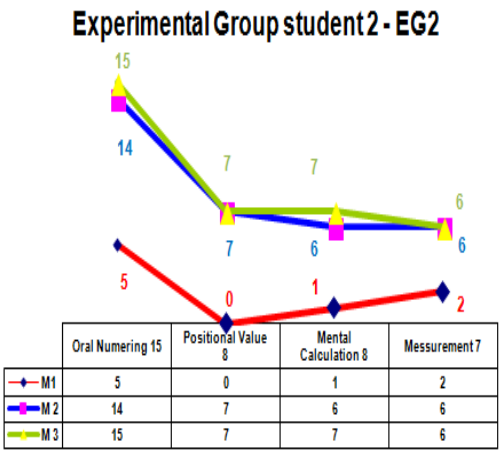
Table 1: Results of Utrecht Early Numeracy Test

Student	Mathematical Performance	Characterization
EG 1	**62<69**	**Level E**
EG 2	**61<69**	**Level E**
CG 1	**62<69**	**Level E**
CG 2	**64<69**	**Level E**

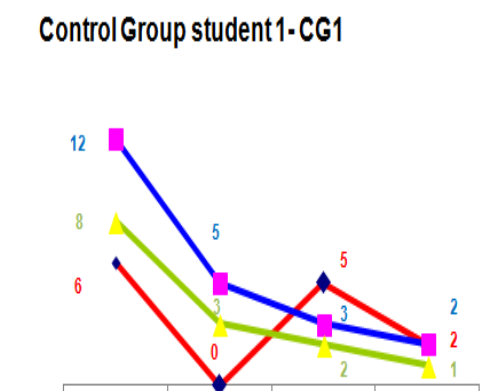
Graph 1: Mathematical performance-experimental group and control group



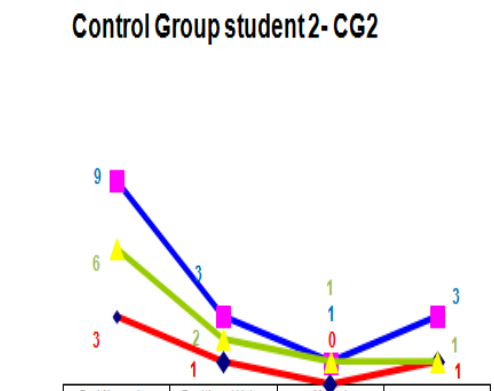
	Oral Numering 15	Positional Value 8	Mental Calculation 8	Measurement 7
M 1	6	2	3	2
M 2	15	7	6	7
M 3	14	7	6	6



	Oral Numering 15	Positional Value 8	Mental Calculation 8	Messurement 7
M1	5	0	1	2
M 2	14	7	6	6
M 3	15	7	7	6

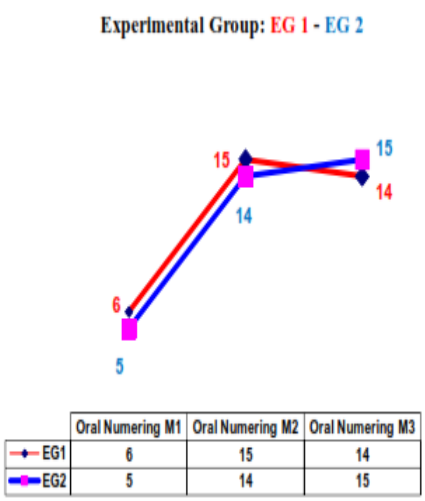


	Oral Numering 15	Positional Value 8	Mental Calculation 8	Messurement 7
M 1	6	0	5	2
M 2	12	5	3	2
M 3	8	3	2	1

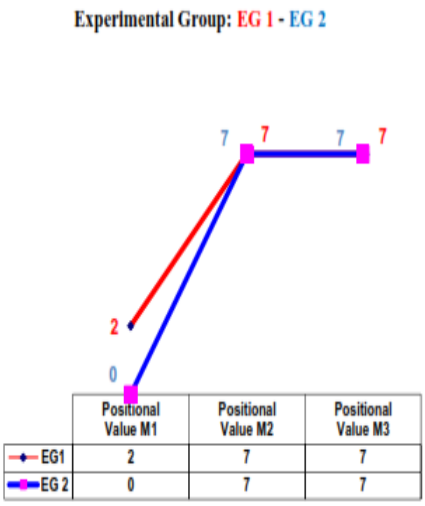


	Oral Numering 15	Positional Value 8	Mental Calculation 8	Messurement 7
M 1	3	1	0	1
M 2	9	3	1	3
M 3	6	2	1	1

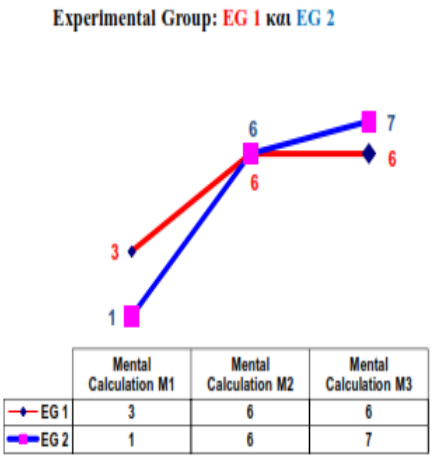
Graph 2: Mathematical Performance of the experimental group students - intragroup Control



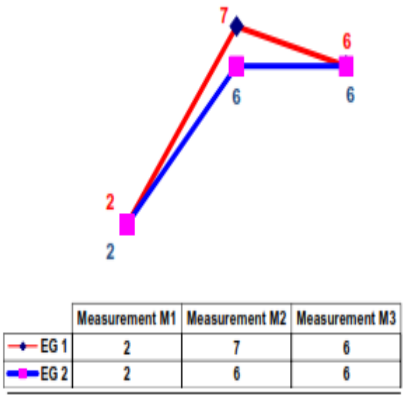
	Oral Numering M1	Oral Numering M2	Oral Numering M3
EG1	6	15	14
EG2	5	14	15



	Positional Value M1	Positional Value M2	Positional Value M3
EG1	2	7	7
EG 2	0	7	7

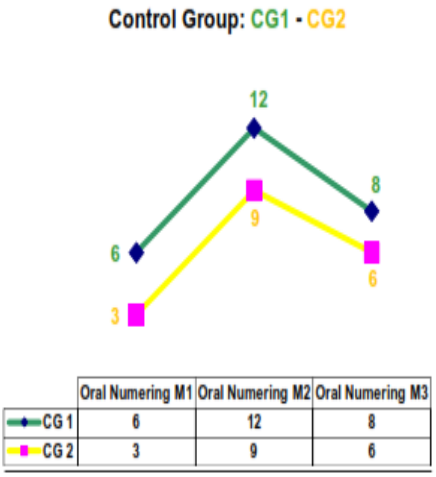


	Mental Calculation M1	Mental Calculation M2	Mental Calculation M3
EG 1	3	6	6
EG 2	1	6	7

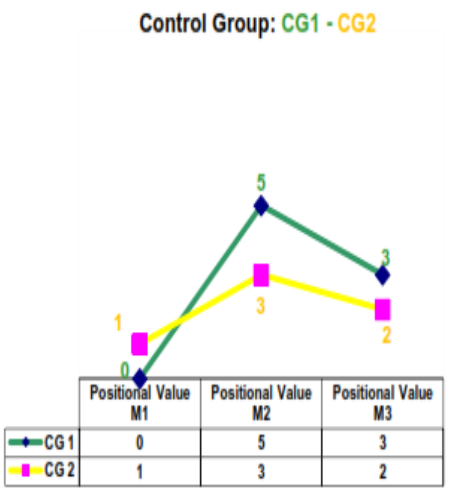


	Measurement M1	Measurement M2	Measurement M3
EG 1	2	7	6
EG 2	2	6	6

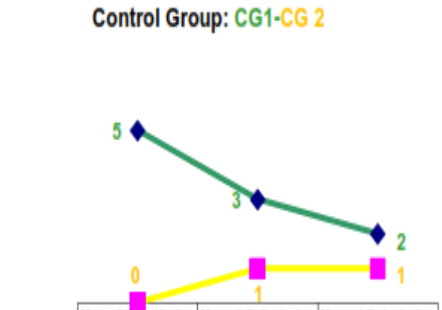
Graph 3: Performance of Control Group students-intra group control



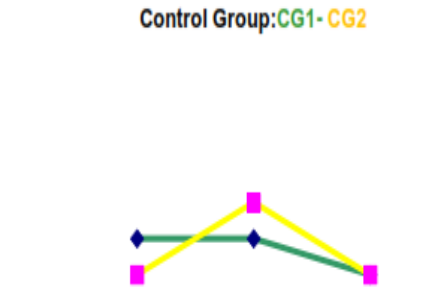
	Oral Numering M1	Oral Numering M2	Oral Numering M3
CG 1	6	12	8
CG 2	3	9	6



	Positional Value M1	Positional Value M2	Positional Value M3
CG 1	0	5	3
CG 2	1	3	2



	Mental Calculation M1	Mental Calculation M2	Mental Calculation M3
CG 1	5	3	2
CG 2	0	1	1



	Measurement M1	Measurement M2	Measurement M3
CG 1	2	2	1
CG 2	1	3	1