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Application of abacus and Taylor Frame for learning mathematics among students with visual impairment

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ABSTRACT

Visually impaired students can do mathematics despite the challenges they face due to their types of visual impairment and visual representations in math texts. Lack of trained teachers in teaching the math subject is a problem in the teaching-learning process of visually impaired students. They rely on tactile and auditory methods. They require specialized tools unique to their visual impairment, which include Braille text books, calculation devices, i.e., the abacus and Taylor Frame, and Braille rulers. Visually impaired students can gain confidence in their ability to learn math with acquisition of skills in traditional math tools, such as the abacus and Taylor Frame, and support from teachers. The main purpose of this research was to find out the level of acquisition of skills in operating mathematical tools, such as the abacus and Taylor Frame, by visually impaired students. A sample of 80 students was selected using a stratified random sampling technique. Performance tests, which include questions related to arithmetic calculations using the abacus and Taylor Frame, were administered. Results indicate that visually impaired students show poor performance in the usage of the abacus and Taylor Frame, and hence their performance in the math subject is lower when compared to arts subjects. The study identified that inadequate skilled manpower in operating these devices is a major problem, and hence, they were not able to instruct visually impaired students in the application of math tools. The study recommends that the teacher training programme incorporate components of math tools in their curriculum and conduct a capacity-building programme for in-service teachers.

Contribution/Originality: After a rigorous literature review, it was found that there was hardly any comparative study on the application of the abacus and Taylor Frame in the Indian context. The performance tests on the acquisition of skills in math tools are graded assessing skills accurately. The results may help teacher training institutes to incorporate the components into their curriculum.

1. INTRODUCTION

Research on the experiences of blind and visually impaired people in mathematics is limited. Most studies focus on learners who are still developing their understanding (Alajarmeh, Pontelli, & Son, 2011; Healy & Fernandes, 2011). Research rarely explores individuals' success in mathematics and how persons with visual impairment overcome visual barriers to learn mathematics. The present study focuses on the application of the abacus and Taylor Frame among visually impaired students studying in inclusive and special schools. An abacus is a calculation device in which beads are moved to perform basic arithmetic operations and some advanced processes of calculations by visually impaired students. The Taylor Frame is a slate with a set of pegs or types. One end of each peg contains two Braille dots, and the other end is a solid raised bar. This device is used by visually impaired students to perform calculations.

Vision plays an important role in accessing the information that helps in the conceptual and procedural development of mathematical concepts among students. Several fundamental mathematical concepts are expressed as words that depict a visual representation (Jones, 2018). The math performance of visually impaired students is typically poorer than that of students in other academic areas (Beal & Shaw, 2008). Visually impaired children were once thought to be unable to learn mathematics, but with the development of various tools and efficient teaching techniques, they can also perform mathematical skills. Both the teacher and the student are responsible for making optimal use of the resources. In today's workforce, significant computational and technological abilities are required. A strong foundation in mathematics from an initial age supports the development of problem-solving and reasoning skills, which are increasingly vital in the fields of technology, science, and mathematics. The present paper analyzes the abilities and applications of mathematical tools such as the abacus and Taylor Frame that contribute to the learning of mathematics.

1.1. Objectives

The main objectives of the present study are as follows:

- Assess the existing knowledge and skills in the application of the abacus.
- Assess the existing or current knowledge and skills in the application or usage of the Taylor Frame.
- Find out the computational skills of visually impaired students using the abacus and Taylor Frame.
- Compare the skills in the application of abacus and Taylor Frame concerning the type of schools, namely special school and inclusive schools.

1.2. Hypothesis

- There is no significant difference in the performance of students studying in inclusive and special schools concerning the operation of the abacus.
- There is no significant difference among students studying in inclusive and special schools concerning the operation of the Taylor Frame.

2. REVIEW OF LITERATURE

Vision plays a vital role in accessing the information that supports the development and understanding of basic conceptual ideas in mathematics. Consequently, children with visual impairments typically experience more difficulties than their same-age group students without visual impairments (Beal & Shaw, 2008).

Visually impaired students face a challenging learning experience due to their inability to receive visual information. These students encounter numerous obstacles and issues in their education, particularly in studying mathematics (Nahar, Jaafar, & Sulaiman, 2017). Teaching the combination of both Braille code and Taylor Frame skills is very useful and effective in learning mathematics for students with visual impairment (Dubey, 2018). Special education teachers also do not teach the abacus to their students with visual impairment due to certain reasons, such as they are not effectively trained teachers of teaching abacus, lack of self-confidence, are not aware of the place to get proper training, lack of time, and burden of other academic work. Another important reason is the increased use of technology among students. However, the teacher's proficiency and approach must have a significant impact on the students' performance in using the abacus (Kapperman & Sticken, 2003). Since mathematical concepts and ideas are abstract in nature and visual in characterization, acquiring knowledge and skills in mathematics can be very challenging for visually impaired students (Kapperman & Sticken, 2003). We should not exclude students with visual impairments in this national endeavor and development (Kapperman & Sticken, 2003). This is a well-accepted reality that children with visual impairment need to acquire mathematics skills on par with their sighted counterparts (Tindell, 2006).

The abacus plays an important role in learning computational skills among students with visual impairment. Therefore, further research is required on the teaching of the abacus to visually impaired students by teachers of the visually impaired (Amato, Hong, & Rosenblum, 2013).

Students with visual impairment face diverse obstacles when learning mathematics, including tiredness, a lack of motivation and interest, the attitude of teachers and administrators, a deficiency of skillful professionals/teachers in math, and a lack of math tools and materials for studying. Therefore, it is suggested that educational institutions should provide the necessary assistive technology facilities and special education teachers should be skillful in teaching visually impaired students (Amato et al., 2013).

3. METHOD

Data were collected through a descriptive survey with 80 students with visual impairments, administering a performance test to assess the level of acquisition of skills in these two calculation devices for learning mathematics.

3.1. Site for the Study

The site of the study includes three districts across Tamil Nadu, India, such as Coimbatore, Salem, and Trichy. Special schools and inclusive schools in these three districts have been selected for this study.

3.2. Sample of the Research Work

The sample of this work consists of 80 visually impaired students from different types of school, i.e., government, government aided, private inclusive and special schools. Among the sample, 49% were female and 51% male visually impaired students. About the type of school where the students were studying includes 56% from special schools and 44% from inclusive schools.

3.3. Description of the Tool

A performance test was administered to examine the level of acquisition of skills in using calculation devices, such as the abacus and the Taylor Frame. Basic arithmetic skills were tested by providing problems such as: i. addition, ii. subtraction, iii. multiplication, and iv. division for calculation. This test contained 32 problems to assess performance in the Abacus and Taylor Frame (see Appendix 1).

3.4. Administration of the Tool

The skills in arithmetic calculations by using abacus and Taylor Frame were assessed by administering the performance test to the children with visual impairment. In each item, four sums were provided. The investigator supplied an abacus and Taylor Frame to each student. The investigator provided the test in Braille and dictated the questions/numbers if the students did not know Braille and the mathematical code (also known as Nemeth Code) for calculation. A duration of five minutes was given to calculate each item using the abacus and Taylor Frame. The responses were corrected. A total of approximately forty-five minutes was allotted to perform the calculations using the abacus and Taylor Frame. A group of five students was allotted in a batch, and hence, sixteen groups were formed to administer the test.

3.5. Scoring

A maximum score of 5 was given if all responses were correct, and a score of "zero" was given if the response was completely incorrect. Scores of 4, 3, 2, 1 were assigned based on the number of digits with correct responses. In the present study, a t-test was used to assess the performance of students using the abacus and Taylor frame for arithmetic calculations.

3.6. Duration

The investigator personally visited and approached the students with visual impairment and spent one month collecting the information.

Table 1. Application of Abacus and Taylor Frame.

Sl. No	Scores	Abacus score		Taylor Frame score	
		No.	%	No.	%
1	Nil	67	83.8	25	31.3
2	1-10	1	1.3	3	3.8
3	11-20	5	6.3	20	25.0
4	21-30	4	5.0	5	6.3
5	31-40	1	1.3	8	10.0
6	Above 40	2	2.5	19	23.8
Total		80	100.0	80	100.0

An analysis was conducted to determine the status of students using abacus and Taylor Frame. Table 1 indicates that 2.5% and 23.8% scored above 40 marks when using the abacus and Taylor Frame, respectively. The results revealed that 84% of students were not using abacus, and 31% of the visually impaired students were not using Taylor Frame for calculation. Most students did not utilize these math tools for their mathematics learning.

Table 2. Application of Abacus in Special and Inclusive Schools.

Mathematical device	Scores	Special / Inclusive school				Total	
		Inclusive		Special		No.	%
		No.	%	No.	%		
Abacus score	Nil	25	71.4	42	93.3	67	**83.8**
	1-10	1	2.9	0	0	1	1.3
	11-20	3	8.6	2	4.4	5	6.3
	21-30	4	11.4	0	0	4	5.0
	31-40	0	0	1	2.2	1	1.3
	Above 40	2	5.7	0	0	2	2.5
Total		35	100.0	45	100.0	80	100.0

Table 2 shows that the results are required to find out the application of the abacus in schools, such as special and inclusive setups. A maximum number of students (93%) studying in special schools and 71% of the visually impaired students studying in inclusive schools were not using the abacus for their arithmetic calculations. Only 2.5% of students scored above 40 in inclusive schools. A majority (83.8%) were not using the abacus in special schools.

Table 3. Application of Taylor Frame in special and inclusive schools

Mathematical device	Scores	Special / Inclusive school				Total	
		Inclusive		Special		No.	%
		No.	%	No.	%		
Taylor Frame score	Nil	19	54.3	6	13.3	25	31.3
	1-10	2	5.7	1	2.2	3	3.8
	11-20	3	8.6	17	37.8	20	25.0
	21-30	4	11.4	1	2.2	5	6.3
	31-40	2	5.7	6	13.3	8	10.0
	Above 40	5	14.3	14	31.1	19	23.8
Total		35	100.0	45	100.0	80	100.0

Table 3 indicates that an analysis was made to find out the usage of the Taylor Frame in special schools and inclusive schools. Only 14% of students in inclusive setups scored above 40. In special schools, the students are slightly better (24%) scored above 40. The results also show that 54% from inclusive schools and 13% from special schools were not using the Taylor Frame for their calculations. Children in special schools were comparatively performing better than children in inclusive schools in the use of the Taylor Frame.

Table 4. A comparative analysis of the performance of using abacus in special and inclusive schools

Type of schools		Abacus score			t	df	Sig.
		Mean	S.D	No.			
Special/inclusive school	Inclusive	8.11	15.55	35	2.71	78	**
	Special	1.36	5.57	45			
Total		4.31	11.52	80			

Note: NS – Not significant, ** - Significant at 1% level.

Table 4 shows that a comparison of the calculated value of the t-test and the t-value is 2.71. It is significant at the 0.01 level. Therefore, there was a significant difference between the performances of using abacus in schools such as special and inclusive. It shows that the students were performing better than students in special schools (1.36) in using Abacus for their calculation based on the mean scores of inclusive schools (8.11). Therefore, special school teachers can teach math calculations by using Abacus at an early stage of the children.

Table 5. A comparative analysis of the performance of using the Taylor Frame in special and inclusive schools

Type of schools		Taylor frame score			t	df	Sig.
		Mean	S. D	No.			
Special/inclusive school	Inclusive	13.89	18.84	35	2.65	78	**
	Special	24.82	17.92	45			
Total		20.04	19.01	80			

Note: NS – Not significant, ** - Significant at 1% level.

Table 5 mentioned that a comparison of the calculated value of the t-test and t-value is 2.65, which is significant at the 0.01 level. Therefore, there was a significant difference between the performance of using the Taylor Frame in special and inclusive setup schools. It shows that, based on the mean scores of the students studying in special schools (24.82), they were performing better than students from inclusive schools (13.89) in using the Taylor Frame for their arithmetic calculation. Therefore, inclusive school teachers can make efforts to teach math calculations by using the Taylor Frame cited in Figures 1 and 2.

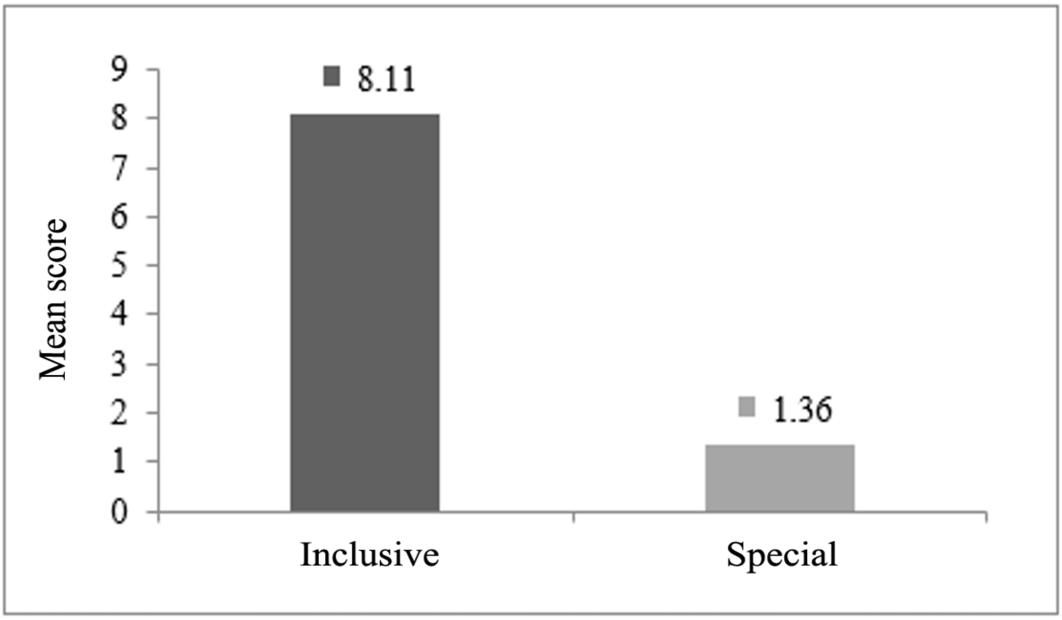

Figure 1. A comparative analysis of the performance of using the abacus in special and inclusive schools.

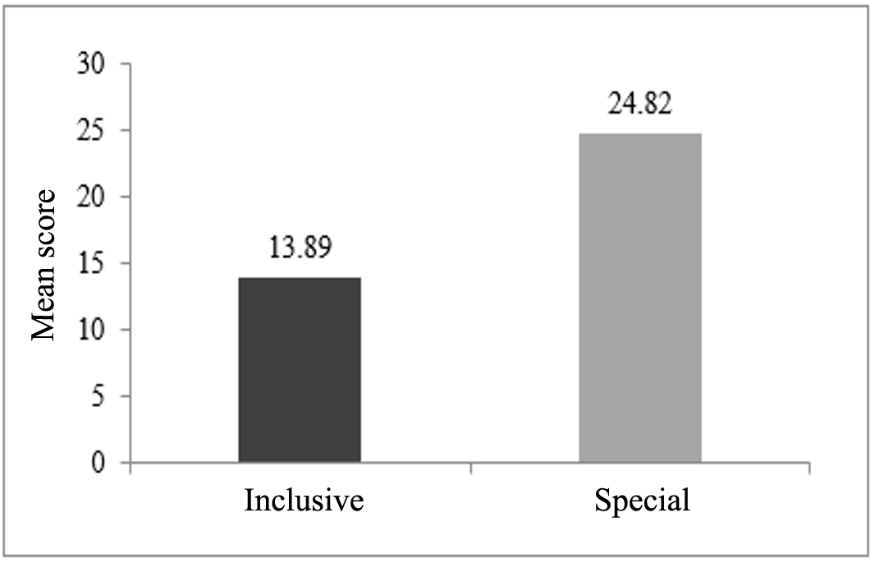

Figure 2. Analysis of the performance of using the Taylor frame in special and inclusive schools

4. DISCUSSION

The main purpose of this research was to determine the level of skill acquisition in operating mathematical tools such as the abacus and Taylor Frame by visually impaired students.

The findings of the study demonstrate that visually impaired students are facing more difficulties in learning basic arithmetic skills. The main reason is that only around 6% of the students were using the abacus and Taylor Frame for computation in arithmetic calculation. The usage of the abacus and Taylor Frame is still considered a potential learning aid for students in the Indian context. This study reports that students in special schools prefer the Taylor Frame, and on the other hand, students in inclusive setups opt for the abacus.

When considering the usage of Abacus, the present study revealed that the level of usage of Abacus for math calculation is low in both types of schools: special schools and inclusive schools. This finding is in accordance with the study conducted by Tanko (2025) at Ganaka International School, JOS, Nigeria.

The study indicates that primary school students and teachers do not know about the abacus. Therefore, they do not introduce it to their students. The investigators are of the view that teachers lack skill in the use of the abacus.

A similar finding is noted in the study conducted by Hatano and Osawa (2021), indicating that trained teachers performed significantly better on tests of calculation speed and accuracy compared with those teachers who were not trained.

Osita (2022) expressed that inadequate abacus-skilled manpower is a major problem in Nigerian schools. The same scenario is noted in special and inclusive schools in the state of Tamil Nadu, India.

Giesen, Cavenaugh, and McDonnall (2012) emphasize that there is a need for highly skilled teachers for academic support in the mathematical performance of children with visual impairments.

Zebehazy and Wilton (2014) stated that the abacus is considered one of the effective and elementary learning tools for visually impaired students and the entire class. However, Rosenblum, Cheng, and Beal (2018) support the findings by Ferrell, Fraedrich, and Ferrell (2011). They found that a lack of consistency in the teachers' views on the usage of the abacus as a very useful tool for mathematical calculation.

Research studies on the use of the Taylor Frame for visually impaired students often focus on its effectiveness in teaching math concepts, as well as its benefits and challenges in use.

In the Indian context, special schools set up to introduce the Taylor Frame for calculations. Problems that involve long formulae, for instance, algebraic formulae that are difficult to remember, need to be written. The Taylor Frame benefits users by allowing such formulae to be written alongside calculations. Arithmetical calculations are easier on the Taylor Frame. The present study also reveals that students studying in special schools use the Taylor Frame more than the Abacus.

The present study results indicate that, in general, visually impaired students show poor performance in the usage of the Taylor Frame and the abacus, and their level of performance in mathematics is lower than in other subjects, such as the arts. This result and observation are consistent with many studies conducted globally.

According to Beal and Shaw (2008) and Freeland, Emerson, Curtis, and Fogarty (2010), students with visual impairment perform below their ability in mathematics compared with other subjects. Emerson and Anderson (2018) viewed that one factor that restricts the participation of visually impaired students in mathematical education is the visual orientation and phenomenon. The author refers to this as a "trend toward more visually based mathematical materials". (Ferrell, Buettel, Sebald, & Pearson, 2006) emphasized that the provision of suitable learning resources such as Braille textbooks, tactile math diagrams, educational tools, and devices are vital for mathematics education. An abacus and a Taylor Frame are calculation devices, as a pen and a pencil are used by sighted persons for calculations. Teachers should decide whether students should learn to use the calculation devices. Unless the teachers are skilled in using the devices, the effectiveness of the devices is questioned.

The International Council for Education of People with Visual Impairment (ICEVI) (2014) and Mwangi (2014) stated that the use of both abacus and Taylor Frame has significant drawbacks arising from a lack of skill in abacus and Taylor Frame by teachers.

Reviewing the various research studies and the findings in the present study, it is observed that there is an influence of special teachers' competency in using these tools. This observation is in line with Chikukwa and Chimbwanda (2013), who argues that there is a causal relationship between the quality of teaching and the outcomes of students.

Students who are blind or visually impaired are far behind in the mathematics subject compared with sighted peers. When they get older, the gap between peers widens (Giesen et al., 2012).

Gulley, Smith, Price, Prickett, and Ragland (2017) reported that 75% of blind or visually impaired students are one grade below and 20% are four or more grades behind their non-disabled peers. Evidence suggests that vision loss or limited vision does not impair individuals' ability to develop strong math skills and concepts despite these research findings. Ahlberg and Csocsán (1999) and Rottmann, Haberzettl, and Krämer (2020) concluded that for mathematical learning, a strong understanding of number sense is essential (Anobile, Stievano, & Burr, 2013; Zhou, Wei, Zhang, Cui, & Chen, 2015) stated that achievement in number sense tasks is restricted to visual processes in the brain. Number sense provides skills for competency in mathematical operations. Children with visual impairment may be deprived of number sense during their preprimary and primary education. Considering these research evidences, it is concluded that number sense is vital for math learning for visually impaired students. Number sense can be successfully taught with the use of calculation devices, such as the Abacus and Taylor frame.

Several teachers accepted that their training during pre-service programmes was inadequate. The present study similarly found that in-service teachers expressed that their skills in the usage of math tools are not adequate but they agreed that the abacus and Taylor Frame are effective math tools for computational skills, particularly at lower grades (Kaladevi, 2021). Often, most of the math work is solved on blackboards in inclusive schools. This kind of visual nature is not possible for visually impaired students. Therefore, non-visual and Braille materials are useful. Providing appropriate math materials and tools and qualified teachers for their learning in math makes it an easy subject, not a threatening one.

5. IMPLICATIONS FOR THE PRACTITIONERS

The special teachers should teach all mathematical concepts and computational skill sets at an early age, similar to sighted students. In some schools, due to a lack of teachers, they cannot provide training to use math devices. Therefore, there is a need for special teachers who specialize in mathematics to teach all kinds of math problems to cope with the sighted peers. Abbas and Fatima (2023) also mentioned that visually impaired students encounter many difficulties, such as fewer opportunities in comparison to their non-visually impaired peers.

Similarly, the development of math skills at an early stage is important for future success in mathematics. The students, teachers, and special teachers also receive training to use these devices and teach the same to their students during their teaching practice in both types of schools: inclusive and special schools.

The teachers also equip themselves to teach all the concepts and computational skill sets thoroughly, and step-by-step revision is also essential. Teachers try to teach Braille and Nemeth code at the earliest to understand the math concepts and computations easily.

Using low-cost concrete materials and adapted teaching learning materials are also helpful in teaching the basic prerequisite skills in computational skills. Individual attention and one-to-one teaching and evaluation are helpful in teaching math skills.

Teachers have to involve sighted peer support and get help from general teachers to teach math concepts more clearly in inclusive schools. The present study will help both general and special teachers to recognize and understand the importance of teaching subjects like mathematics to visually impaired students from the primary level. At the same time, additional practice and remedial teaching are vital to overcome difficulties and develop interest in mathematics.

6. CONCLUSION

The mathematical tools, such as the abacus and Taylor Frame, are potential tools to learn and enhance mathematical skills among visually impaired students. However, there is insufficient evidence of research on using these devices in the Indian context. This study reveals that students with visual impairment showed poor performance in operating the abacus and Taylor Frame in both special school and inclusive school setups. The special education teachers were also not using these devices effectively in their teaching of mathematics. The low-cost calculating devices are beneficial for visually impaired students in the Indian context, and hence, these helpful devices should be taught to students with visual impairment. However, this study recommends that special teachers must be skillful in imparting skills of calculation devices to visually impaired students. Teacher training programmes may incorporate this component in practicum. Therefore, it is important that the teacher trainees' programme should create a strong framework and ensure that teacher trainees receive the necessary learning experiences.

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Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.
Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: Both authors contributed equally to the conception and design of the study. Both authors have read and agreed to the published version of the manuscript.

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Appendix 1. Math probes using abacus and Taylor frame.

Abacus:							
I.	**Add the following problems by using abacus:**						
a.	44 + 23	b.	65 + 34	c.	685 + 856	d.	8742 + 4568
II.	Subtract the following problems by using abacus:						
a.	45 - 14	b.	86 - 57	c.	896 - 757	d.	8965 - 7548
III.	Multiply the following problems by using abacus:						
a.	5 x 3	b.	42 x 9	c.	756 x 26	d.	4521 x 453
IV.	Divide the following problems by using abacus:						
	9/3		256/4		7863/15		56248/21
Taylor Frame							
I.	Add the following problems by using Taylor Frame:						
a.	45 + 24	b.	246 + 243	c.	7856 + 2379	d.	45679 + 65867
II.	Subtract the following problems by using Taylor Frame:						
a.	69 - 56	b.	486 - 69	c.	896 - 797	d.	7869 - 6985
III.	Multiply the following problems by using Taylor Frame:						
a.	8 x 7	b.	86 x 8	c.	856 x 56	d.	4567 x 49
IV.	Divide the following problems by using Taylor Frame:						
a.	18/6	b.	129/3	c.	17569/12		86523/15