Effectiveness of Digital Textbook (Kognity) on The Mathematical Thinking Skills of Grade 12 Students in Shanghai China

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ABSTRACT

This study explores the impact of digital textbooks, specifically Kognity, on enhancing Mathematical Thinking Skills among Grade 12 students in Shanghai, China. Conducted within International Baccalaureate Diploma Programme (IBDP) Mathematics: Analysis and Approaches – Higher Level class, the research involved 44 students who participated in a Calculus course. A quasi-experimental design was employed, with pretest and posttest assessments comparing the performance of a control group receiving traditional lecture-based instruction and a treatment group utilizing Kognity. The pretest results in the control group showed that 47.62% achieved a grade of 5, while the posttest revealed 47.62% earned a grade of 6. In contrast, the treatment group exhibited remarkable improvement: pretest results showed 30.43% attaining a grade of 6 or higher, compared to 100% in the posttest. Mean pretest scores and standard deviations for the control group were 40.79 and 14.90, respectively, increasing to 60.95 (SD = 11.98) in the posttest. Meanwhile, the treatment group's mean pretest score of 49.57 (SD = 16.55) improved significantly to 83.77 (SD = 13.72) post-intervention. Statistical analysis revealed highly significant differences, with a calculated t-value of –12.12 ($p < 0.001$) within the treatment group and –22.82 ($p < 0.001$) between the groups. These results suggest that integrating Kognity not only enhances students' problem-solving and abstract reasoning skills but also significantly outperforms traditional methods. However, limitations such as non-randomized sampling, contextual variables, and the absence of long-term retention data are acknowledged. Recommendations include further investigation using randomized trials and longitudinal studies to better understand the broader implications of digital learning tools on mathematics education.

Keywords: Mathematical Thinking Skills, digital textbooks, Calculus education, problem-solving, International Baccalaureate, educational technology.

INTRODUCTION

The use of Kognity as a digital textbook has been efficient in supporting and improving the students' mathematical thinking skills in various fields. Mathematical thinking is now recognized all over the world as one of the key outcomes of education. Nonetheless, this is a daunting task because definition of mathematical thinking is process-oriented than content-oriented even though both are components of mathematics learning and are present in most mathematics curricula. Therefore, to appreciate the nature of the mathematical thinking skills, research and curriculum frameworks help to define what they are by listing their characteristics. To this end, experts have identified five strands that define these skills as follows: (1) Theoretical Understanding,

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understanding of mathematical concepts, principles and the relationships between them. (2) Technical Fluency, performing calculations with flexibility, accuracy, efficiency and appropriateness. (3) Strategic Competence, Planning, how to tackle and solve mathematical problems. (4) Adaptive Reasoning, engaging in deliberate and logical thinking, defending claims and being critically reflective. (5) Creative Disposition, exemplifying a positive attitude, curiosity and willingness to persist in solving problems. It helps to build conscientiousness and self-belief, which is a common attribute of mathematics as a reasonable and worthwhile subject.

The curriculum frameworks in different countries such as Australia and Ireland [20] note the importance of all the skills with particular emphasis on the strategic competence and adaptive reasoning. Strategic competence refers to the ability to formulate and solve problems while adaptive reasoning involves intuitive and inductive thinking, causal explanations and justifications by deductive approach. The work done on these strands show their relevance in frameworks that seek to understand students' ideas about evidence [9] as well as research that examines practices that sustain reasoning from justification [24]. Learning in higher education develops mathematical thinking skills to make students capable of presenting their ideas and arguments effectively. These capstone capabilities are a consequence of many years of training in critical thinking, analysis, and reflection on issues that are characteristic of serious academic study.

Positive effects of encouraging critical thinking in mathematics are: (1) Learning to solve and improve the problem-solving skills. (2) Creating new questions and the right answers for the stated questions. (3) Constructing logical arguments based on proper analysis and appropriate reference to facts and figures [15] [8] identified several critical-thinking indicators in mathematics learning, including:(1) Interpretation, this is the ability to convey or understand the meaning of information or a given situation that has been presented in form of mathematical problems. (2) Analysis, this is the ability to compare data and to reason about arguments. (3) Evaluation, this is the capacity to recognize and solve mathematical problems and issues. (4) Decision-Making, this is the ability to make rational decisions based on mathematical analysis.

Thinking mathematically makes learners able to govern and modify their thinking and this led to better decision making according to [15] E-textbooks such as Kognity can be useful in developing these skills in IBDP students. Due to features such as multimodal content, simulations, visualizations, and real-time feedback Kognity helps students to understand difficult concepts, solve problems, and get necessary help. The main objective of this study is to present a set of practical suggestions for teachers on how to use digital textbooks, such as Kognity, in the process of teaching to improve students' mathematical thinking. When comparing traditional methods of teaching with the capabilities of Kognity, the research reveals how to use digital resources to achieve success in Calculus and what are the best practices for this.

The research shows that Kognity platform provides a more tailored and flexible learning process. Thus, the system helps to monitor the progress of the individual, to determine the areas of strengths and weaknesses, and to provide the necessary resources as well as practice problems than the conventional methods. Also, the features of Kognity such as simulations, immediate feedback and engaging activities make the student involved in the learning process. These tools contribute to the enhancement of students' mathematical thinking through enabling them to understand the concepts well.

Objectives of the Study

This is study aimed to investigate the effectiveness of using digital textbook (Kognity) on the Mathematical Thinking Skills in Calculus of the Grade 12 students Shanghai United International School (SUIS), Shanghai China during the School Year 2022-2023. Specifically, this study tried to:

1. determine the mathematical thinking skills (in terms of Induction, Deduction, Proof, Modeling and Problem Solving) in learning Calculus of the subjects under the control and treatment groups before and after receiving the traditional way of instruction and instructions utilizing digital textbook (Kognity);

2. find out the difference in the mathematical thinking skills (in terms of Induction, Deduction, Proof, Modeling and Problem Solving) in learning Calculus of the subjects under the control and treatment groups before and after receiving the traditional way of instruction and instructions utilizing digital

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3. textbook (Kognity);

4. examine the difference in the mathematical thinking skills (in terms of Induction, Deduction, Proof, Modeling and Problem Solving) in learning Calculus of the subjects under the control and the treatment groups after receiving the traditional way of instruction and instructions utilizing digital textbook (Kognity);

Hypotheses of the Study

1. There is no significant difference in the mathematical thinking skills (in terms of Induction, Deduction, Proof, Modeling and Problem Solving) in learning Calculus of the subjects under the control and treatment groups before and after receiving the traditional way of instruction and instructions utilizing digital textbook (Kognity).

2. There is no significant difference in the mathematical thinking (in terms of Induction, Deduction, Proof, Modeling and Problem Solving) in learning Calculus of the subjects under the control and treatment groups after receiving the traditional way of instruction and instructions utilizing digital textbook (Kognity).

METHODOLOGY

Research Design

A quasi-experimental design served as the research method employed in this study aiming at estimating the impact of an intervention on its subject without resorting to randomization techniques. Contrary to controlled experimental designs that necessitate subject randomization procedures quasi experimental studies allow researchers flexibility in controlling treatment condition assignments using alternative criteria [6]. Quasi experiments are appropriate for investigations when there are impracticalities or ethical concerns surrounding random assignment. This also offers validity advantages since they can be conducted in natural settings thereby improving generalizability of findings to a wider population and situations [6].

This study adopted the Pretest-Posttest design among other quasi experimental options available. To assess the impact of digital textbook (Kognity) instruction on subjects' Mathematical Thinking Skills in Calculus, conducted a comparative analysis between traditional way of instruction and instruction utilizing digital textbook (Kognity)The Pretest-Posttest design was used in finding the difference in the performance of the control and treatment group before and after receiving traditional way of instruction and instruction using the digital textbook (Kognity).

Study Sites

The study took place during the winter (2^{nd}) semester of the 2022 – 2023 academic year at Shanghai United International Schools Gubei Campus at Hongsong East Road, Minhang District, and Shanghai, China.

Respondents and Data Collections

Data was collected from 44 students through an online survey. The two groups were selected based on their enrollment from Grade 11 for participation in the IBDP Curriculums two-year course (up to Grade 12 class).

The researcher chose a heterogeneous class composition to avoid biases when evaluating their performance in Calculus. In order to conduct a study, two groups were created: the treatment group, consisting of 23 students and the control group which had 21 students. In preparation for data collection during the latter stage of Academic Year 2022-2023 First Semester at SUIS - Gubei Campus in Shanghai, permission was sought from important administrative officials such as International Curriculum Principal, Director of Studies and IBDP Curriculum Coordinator.To participate in this study, each student was required to submit signed consent forms from their parents/guardians and a subject assent form signed by them within a week after receiving them upon which submission advisory classes facilitated collection, only those with both documents would be considered

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for participation. The pretest conducted on both groups using the Wechat mini-application focused on Calculus Performance; this application explained what survey's objective and utilization of outcomes was. The researchers provided their email address for any questions about the study. After six weeks of intervention, both the control and treatment groups took a posttest to measure their Mathematical Thinking Skills in Calculus using traditional instruction and digital textbooks (Kognity) in terms of Induction, Deduction, Proof, Modeling and Problem Solving.

Ethical Consideration

Ethics were taken into consideration with the subjects providing consent before accessing the questionnaire and their responses being confidentially stored. The Ethics and Review Committee of Central Luzon State University approved all protocols used in the study.

Instrument Used

The study aimed to examine the impact of using the Kognity digital textbook on students' Calculus Mathematical Thinking skills in specific areas such as Induction, Deduction, Proof, Modeling and Problem Solving. The Pretest and Posttest Mathematical Thinking Skills in Calculus (in terms of Induction, Deduction, Proof, Modeling and Problem Solving) before and after receiving the traditional way of instruction and utilizing digital textbook (Kognity).

Test questions were sourced from the Kognity question bank that consist of past paper examination from the previous IBDP Examinations while ensuring that they aligned with International Baccalaureate Diploma Program (IBDP) course syllabi for validity purposes. Through Kognity's innovative platform, students are given access to an extensive collection of previous years past papers examination which is a powerful tool for focused exam preparation that can drive significant improvements in performance come test day. The hands-on experience that comes from attempting various questions helps develop key skills like time management and efficient problem-solving approaches while fostering long-term familiarity with different question formats and styles over time all contributing towards greater ease when facing real-world assessments down the road.

Mathematical thinking skills were evaluated using pretests and posttests developed from Kognity’s extensive question bank. The questions were aligned with the IBDP syllabus, covering topics such as definite integrals, kinematics, Maclaurin series, and differential equations. The assessments included 30 items designed to measure key competencies, including problem-solving, logical reasoning, and conceptual understanding [19]. The grading criteria followed the IBDP’s 7-point scale, where higher scores indicated greater proficiency in mathematical thinking. To ensure reliability and validity, the test items were reviewed by subject matter experts and pilot-tested before implementation. The assessments provided a robust measure of students’ abilities to engage in induction, deduction, proof construction, and modeling. Students scoring at the top end earn a Grade 7 level, demonstrates a comprehensive theoretical knowledge that extends beyond routine application, displaying insightful ability in analyzing problems and solving them creatively. At Grade 6 level, one notch below demonstrates good conceptual understanding that occasionally may not be without errors or minor omissions. At less proficient levels students who earn Grade 5 or 4, displays some knowledge of the subject matter but may experience mistakes in their calculations. The pattern becomes more noticeable among those who perform below them with Grade 3 indicating a struggling proficiency level and Grade 2 showing minimal understanding of basic mathematical concepts. Grade 1 help teachers to identify areas where support is needed best preparing students for challenging problems requiring accurate mathematical comprehension skills. Consequently, students answered all the pre-test and posttest questions via Kognity's digital platform as part of this study.

DATA ANALYSIS

Employing a quantitative research approach through pretests and posttests provided insight into Mathematical Thinking Skills in Calculus before and after receiving traditional way of instruction or digital textbook instruction via Kognity. To analyze information collected during pretests/post-tests intervention objectively, statistics software like MS Excel/SPSS aid helped in processing this data accurately. To get concise summaries from raw data acquired from intervention, the researcher turned towards Microsoft Excel's help before seeking

more elaborate interpretations by getting assistance from expert statistician. Based on the study, Calculus was recognized as a focal subject due to its complexity and technicality, hence evaluating students' Mathematical Thinking Skills in Calculus (Induction, Deduction, Proof, Modeling and Problem Solving) before and after traditional way of instruction and instruction utilizing digital textbooks (Kognity) yielded the most desirable results.To compare the effectiveness of traditional way of instruction versus instruction utilizing digital textbook (Kognity), the researcher utilized the mean, standard deviation, and independent t-test methods to compare the Mathematical Thinking Skills of the subjects in the control and treatment groups. Furthermore, the researcher evaluated using the mean, standard deviation, and independent t-test methods to assess Mathematical Thinking Skills of subjects in the treatment group solely after receiving the instruction utilizing digital (Kognity).This study also looked at the subgroup performance and tried to identify patterns in the development of mathematical skills of the students belonging to different categories [10]. Even if the analysis was based on immediate outcomes, the study acknowledges the fact that there is a need to investigate the effects in the future. Some of the recommendations include; monitoring the retention of the skills and understanding the effects of using digital textbooks in general and across different types of educational institutions.

RESULTS AND DISCUSSION

The collected data were analyzed and explained using statistical methods, in line with the research objectives. This section consists of five parts between the control group and treatment group, namely; subjects mathematical thinking skills in Calculus under the Control Group before and after traditional way of instruction, subjects mathematical thinking skills in Calculus under the Treatment Group before and after receiving instruction utilizing digital textbook (Kognity), difference in the mathematical thinking skills in Calculus under the Control Group before and after traditional way of instruction, difference in the mathematical thinking skills in Calculus under the Treatment Group before and after receiving instruction utilizing digital textbook (Kognity) and difference in mathematical thinking skills of the control and experimental groups after receiving traditional way instructions and utilizing digital textbook (Kognity).

Subjects' Mathematical Thinking Skills in Calculus under the Control Group Before and after Receiving Traditional Way of Instruction It is important to note that the pretest and grades achieved by the subjects in the control are not the same as the grades, they will receive in the IBDP external examinations. The pretest grades only serve as a baseline to assess the initial Mathematical Thinking skills in Calculus in terms of (Induction, Deduction, Proof, Modeling and Problem-Solving) of the subjects. The actual IBDP grades will be determined by a variation of aspects, together with the difficulty of the exam and the distinct performance of each student. The Grade Boundaries/Descriptors from the November 2022 External Examination, as detailed in see Appendix VIII page 108, will provide a better understanding of the criteria used to determine the final grades.

The mathematical thinking skills of the subjects in Calculus in the control and was assessed in a pretest and which is summarized in Table 1. From the table, it is evident that the pretest of the subjects in the control group before receiving traditional way of instruction had 10(47.62%) achieved a grade 5, 8(38.10%) achieved a grade of 4, 2(9.52%) achieved a grade of 2 and 1(4.76%) achieved a grade of 7. On the other hand, after receiving the traditional way of instruction, subjects in the control group somehow improved their performance as revealed by the results from the table, 10(47.62%) earned a grade 6, 7(33.33%) earned a grade 5, 3(14.29) earned a grade 7 and 1(4.76%) earned a grade 4.

TABLE 1: Subjects Mathematical Thinking Skills in Calculus Under the Control Group Before and After Receiving Traditional Way of Instruction

GRADE	INTERVAL	PRE TEST Control Group (n = 21)		POST TEST Control Group (n = 21)	
		f	%	f	%
Grade 1	0 – 9	0	0	0	0
Grade 2	10 – 15	2	9.52	0	0
Grade 3	16 – 26	0	0.00	0	0
Grade 4	27 – 43	8	38.10	1	4.76
Grade 5	44 – 58	10	47.62	7	33.33
Grade 6	59 – 72	0	0.00	10	47.62
Grade 7	73 – 100	1	4.76	3	14.29

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The information provided by the data indicates that the performance of the subjects in the control group, who received instruction in the traditional way, exhibited a minor improvement in the posttest results Mathematical Thinking Skills in Calculus using traditional way of instruction, it means that the students have shown progress in their ability to think critically, reason abstractly, and solve problems in calculus. This improvement could be an indication that the traditional way of instruction has been effective in helping students develops these skills.

This claimed was coincide with [13] who examined the effectiveness of traditional teaching methods in improving mathematical thinking skills in calculus. The study found that traditional teaching methods can be effective in improving mathematical thinking skills in calculus, particularly in areas such as problem-solving, deduction, and analysis. He mentioned that one of the factors that could contribute to the improvement in mathematical thinking skills using traditional teaching methods includes the teacher expertise; these skills of the teacher in teaching calculus can be a factor in helping students develops mathematical thinking skills. Teachers who are well-versed in calculus and have a strong understanding of mathematical concepts can be more effective in helping students develop these skills. Its addition, it also corresponds with [3] where it was highlighted that students' misunderstandings about limit and continuity concepts hinder the growth of their comprehension in calculus. A lot of students seem to struggle in math because they can't properly process information given in symbolic form, such as equations, functions, and mathematical expressions, which represent abstract entities. Furthermore, they lack the necessary frameworks or schema to link and organize different objects, as noted by [17]

Therefore, traditional way of instruction, such as lectures, practice problems, and exams, can be effective in helping students develop mathematical thinking skills in calculus in terms of (Induction, Deduction, Proof, Modeling and Problem-Solving). By providing students with a clear understanding of mathematical concepts, traditional teaching methods can help students build a strong foundation in calculus and develop the ability to reason abstractly and think critically about mathematical problems. Subjects' Mathematical Thinking Skills in Calculus under the treatment group Before and After Receiving Instruction Utilizing Digital Textbook (Kognity)Table 2 presents information about the subjects? Mathematical Thinking Skills in Calculus in terms of (Induction, Deduction, Proof, Modeling and Problem-Solving). Through the pretest and posttest scores. These scores were used to evaluate their Mathematical Thinking Skills before and after receiving instruction utilizing digital textbook (Kognity). It is revealed from the table, the pretest of the treatment group before receiving instruction utilizing digital textbook (Kognity) had 7(30.43%) attained a grade 6 and 5, 6(26.09%) attained a grade 4, 2(8.70%) attained a grade of 2 and 1(4.35%) attained a grade of 7.In contrast, the posttest of the treatment group after receiving instruction utilizing digital textbook (Kognity) had 17(73.91%) earned a grade of 7 and 6(26.09%) earned a grade of 6.

TABLE 2: Subjects' Mathematical Thinking Skills in Calculus Under the Treatment Group Before and After Receiving InstructionUtilizing Digital Textbook (Kognity)

GRADE	INTERVAL	PRE TEST Treatment Group (n = 23)		POST TEST Treatment Group (n = 23)	
		f	%	f	%
Grade 1	0 – 9	0	0	0	0
Grade 2	10 – 15	0	0	0	0
Grade 3	16 – 26	2	8.70	0	0
Grade 4	27 – 43	6	26.09	0	0
Grade 5	44 – 58	7	30.43	0	0
Grade 6	59 – 72	7	30.43	6	26.09
Grade 7	73 – 100	1	4.35	17	73.91

Their impressive performance could be attributed to the implementation of a digital textbook (Kognity) during instruction. This tool offered several interactive media resources, including videos, online activities, key concepts, terms, and past paper examinations, to assist the students in comprehending the lesson content and meeting the expected standards. Utilizing digital textbooks (Kognity) on the subjects? Mathematical thinking skills in calculus of students can be noteworthy. Kognity can provide students with interactive and multimedia resources that can help them understand and engage with mathematical concepts more effectively. Additionally, the use of digital textbooks can offer advantages such as access to a variety of resources, including videos,

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interactive simulations, and practice problems. This can help students develop a deeper understanding of calculus concepts, and provide them with opportunities to practice and apply their skills in different contexts. Inclusively, the use of digital textbooks can have a positive impact on the mathematical thinking skills in calculus of students. However, the specific impact may depend on factors such as the quality of the digital textbook, the level of engagement and motivation of the students, and the effectiveness of the teaching approach used in conjunction with the digital textbook.

The findings coincide with [15] students can experience several positive impacts from learning Mathematical Thinking Skills, such as (1) honing problem-solving skills, (2) generating innovative questions and designing appropriate solutions, and (3) actively constructing arguments by presenting accurate and logical evidence. Meanwhile, in agreement with [8] identified several indicators of Mathematical Thinking Skills, including interpretation (understanding and expressing the meaning of data), analysis (identifying the relationship between data and reasoning), evaluation (finding and proving errors), and decision-making (drawing conclusions). Furthermore, the finding also supported by [22] noted that the purpose of developing Mathematical Thinking Skills is to create and communicate ideas during learning, verify information, make rational decisions, and enhance academic achievement. Difference in the Mathematical Thinking Skills in Calculus of the Subject under the Control Group Before and After Receiving Traditional Way of Instruction Table 3, shows the Mathematics Thinking Skills in Calculus both pretest and posttest of the control group prior to being taught using traditional ways of instructions. In terms of their test results, it can be seen that before instruction took place the subjects had an average pretest score of 40.79 (SD=14 .90) while after instruction this increased considerably to an average posttest score of 60 .95 (SD=11 .98).

TABLE 3: Difference In the Mathematical Thinking Skills in Calculus of The Subject Under the Control Group Before and AfterReceiving Traditional Way of Instruction

CONTROL GROUP	n	MEAN	SD	$t_{(20)}$	p-value	INTERPRETATION
Pretest	21	40.79	14.90	-6.98	0.00	Difference is Significant
Posttest		60.95	11.98			

The statistical analysis showed that this increase is highly significant at t value of -6.98; $p < 0.001$. The gap between the pretest and posttest scores in mathematical thinking skills among the control group reveals the effectiveness of traditional way of instruction in enhancing logical reasoning abilities. The conventional way of instruction employs lectures, practice exercises, tests to impart a clear understanding of math concepts to student which aids them to think abstractly about complex math problems critically. In addition, by presenting opportunities for active participation among learners through interactive classes can increase engagement levels which lead to better knowledge immersion rates hence higher retention rates.

Moreover, through regular assessments such as homework assignments, quizzes or exams educators can consistently monitor learners progress helping them adapts tutoring styles according to individual needs resulting in improved test outcomes. Nevertheless, it remains crucial to recognize potential contributing components that may have affected the results. These can encompass teaching quality; participant attributes and other uncontrollable variables present in the study. This finding supported by [14] found that traditional way of instruction was more effective in improving mathematical thinking skills compared to alternative teaching methods. The study analyzed data from 49 studies involving a total of 16,442 participants.

This also coincides to the study of [7], the study compared the effectiveness of traditional way instruction and blended learning (a combination of online and traditional way of instruction) in a calculus course. The study found that traditional way instruction was more effective in improving student mathematical thinking skills in calculus compared to blended learning. The null hypothesis, which indicates that there is no significant difference in the Mathematical Thinking Skills in terms of (Induction, Deduction, Proof, Modeling, and Problem-Solving) in Calculus among the subjects in the control group before and after receiving instructions via the traditional way of instruction has been rejected since high significant difference was found in the pretest and

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posttest scores of the control group.

Difference in the Mathematical Thinking Skills in Calculus of the Subjects under the Treatment Group Before and After Receiving Instruction Utilizing Digital Textbook (Kognity)Table 4 shows the subjects' mathematical thinking skills in the treatment group before and after receiving instructions utilizing digital textbook (Kognity) by comparing the pretest and the posttest scores. The treatment group showed a lot of improvement; the pretest mean was 49. 57 (SD = 16. 55) and the posttest mean was 83. 77 (SD = 13. 72; t = -12. 12, $p < 0.001$). This significant enhancement highlights the effectiveness of Kognity in enhancing the mathematical thinking abilities.

TABLE 4: Difference In the Performance of The Subjects Under the Treatment Group Before and After Instruction Utilizing Digital Textbook (Kognity)

TREATMENT GROUP	n	MEAN	SD	$t_{(20)}$	p-value	INTERPRETATION
Pretest	23	49.57	16.55	-12.12	0.00	Difference is Significant
Posttest		83.77	13.72			

The efficacy of using digital textbooks was evidenced by the remarkable achievements of subjects in the treatment group who enhanced their Mathematical Thinking Skills substantially when taught with Kognity. When the pretest scores were compared with the scores obtained after the instruction, it was seen that the mathematical thinking skills in particular calculus had improved among the students which establishes the fact that using digital textbooks is effective in enhancing these skills.It may be argued that better test scores could also mean that such resources have helped in enhancing the understanding of the basic concepts while at the same nurturing the students' problem-solving skills. It is possible that features of the interactive learning tool such as simulations, animations or virtual manipulative provided by Kognity has greatly helped in achieving this result.

The use of the digital textbook can also be adapted to the learning style and needs of the student; it includes feedback and support to assist the student to enhance his/her knowledge of calculus. Digital textbooks like Kognity can be reached at any time and at any place, thus, the students will be able to monitor their learning and go back to some lessons if they so desire. Also, such textbooks provide students with real-time feedback on performance, which means that students can change their study habits and focus on the problematic sections. In general, these reasons suggest that digital textbook (Kognity) can be useful in enhancing mathematical skills and this is seen from the difference in the pretest and posttest scores.

This result is in consistent with a study by [5] the high school students who learned calculus with the help of a digital textbook had significantly higher posttest scores especially in the area of mathematical thinking. Also, according to the research done by [2] and [16] students who learned from a digital textbook supplemented with multimedia elements, interactive exercises, and feedback scored higher on the posttest and were more engaged with the material. From the results discussed above, the null hypothesis which state that there is no significant different in the Mathematical Thinking Skills (Induction, Deduction, Proof, Modeling, and Problem Solving) in Calculus of the subjects in the treatment group before and after receiving instructions via instructions through digital textbook (Kognity) is rejected. E. Difference in the Mathematical Thinking Skills in Calculus of the Control and the Treatment Group After the Traditional Way of Instruction and Instruction Utilizing Digital Textbook (Kognity)

From the data presented in Table 5, it is evident that there is a difference in Mathematical Thinking Skills between the control and treatment groups. The control group which comprises of traditional learners performed with a mean of 60.95 and standard deviation of 11.98 while the treatment group which used the digital textbook (Kognity) had a higher mean of 83.77 and standard deviation of 13.72. The difference of means is 22.82 which show that the treatment group got better results than the control group by an average of 22.82 points. Further, a t-test, $t_{(42)} = -5.85$) gave a p-value of 0.00 showing that the difference in performance is highly statistically significant. This indicates that the improvements seen in the treatment group are not by chance as this would be expected.

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Table 5: Difference In the Mathematical Thinking Skills in Calculus of The Control and The Treatment Groups After Receiving Traditional Way of Instruction and Utilizing Digital Textbook (Kognity)

GROUPS	n	MEAN	SD	MDiff	$t_{(42)}$	p-value	INTERPRETATION
Control	21	60.95	11.98	-22.82	-5.85	0.00	Difference is Significant
Treatment	23	83.77	13.72				

The results show that the use of the digital textbook (Kognity) has a positive impact on the Mathematical Thinking Skills in Calculus as compared to the traditional method. The higher mean score of the treatment group shows that Kognity has the capacity of enhancing students' interest and performance through engaging and tailored approaches. However, this study fails to consider other variables such as teacher effectiveness, physical environment, or students' interest which may have been confounding variables. Also, although the current study shows that Kognity is effective in improving students' achievement, the study did not ascertain the lasting effect of the tool and how it compares with other similar tools in different settings. The treatment group showed a great improvement as the posttest scores were higher than the pretest scores. This is where Kognity played a big role, since its features, such as videos, simulations, animations, and real-time feedback, helped the students to engage with calculus concepts in a dynamic way. These tools enhanced the process of personalized learning as they are capable of adjusting to the needs of each learner and at the same time help the learner to see his or her progress. However, this leads to a problem of product bias since success is being linked to Kognity only. The study also fails to establish whether or not other digital tools could have produced similar outcomes and it also fails to identify how Kognity differs from other similar tools. Also, although the effect on posttest scores is clear, the study does not measure the students' retention or transfer of Mathematical Thinking Skills acquired through digital learning in the long run [1].

RECOMMENDATIONS

Addressing Methodological Limitations

Randomization and Control of Confounding Variables: Other research should also involve a true experimental design where participants are randomly assigned to ensure that the research is not biased by variables such as teacher competency, class co-operation, or participants' motivation. This is to ensure that factors such as students' prior mathematical knowledge and their socioeconomic status are well-covered to enhance the understanding of the treatment's effect [21]. Broader Contextual Factors: Collecting data about students' exposure to technology and understanding how other factors, including the students' environment or access to learning materials, may influence the results would make the study more robust [4]. Expanding Digital Tool Comparisons. To reduce the possibility of the product bias, future research should include comparison of Kognity with other similar digital tools. An analysis of such differences could reveal whether the gains are specific to Kognity or can be expected with any digital learning tool [11]. Long-Term Impact Analysis. It is also important to know the effect of Mathematical Thinking Skills on students' learning after the post-intervention phase. Longitudinal research may help to understand how digital tools and traditional approaches affect students' learning over time [23].

Enhanced Data Analysis

Subgroup Performance: Looking at the performance of different groups of people will help to identify where inequalities or benefits for different groups are present [12]. Skill-Specific Analysis: Knowing which of the Mathematical Thinking Skills including problem solving, deductive reasoning and abstract modeling improved the most will help the teachers [1].

Limitations of Immediate Outcome Focus

The study's focus on the immediate post-intervention performance thus raising questions regarding the retention and transfer of learning. Although tools like Kognity can be useful in improving the performance in the short run, their effectiveness in maintaining the skills in the long run is yet to be established. Future research should

endeavor to implement longitudinal designs to evaluate the effectiveness of these interventions [5].

CONCLUSION

Both control and treatment groups demonstrated satisfactory comprehension of Calculus before being exposed to traditional way instruction or instruction utilizing digital textbook (Kognity). As a result, both groups retained fundamental principles from prior years and met minimal requirements outlined by IBDP syllabi. The control group's performance improved after receiving traditional way of instruction that could be attributed that the teacher's ability to encourage active participation among students, granting them autonomy over constructing knowledge during lessons. In contrast, subjects in the treatment group who used Kognity digital textbooks achieved high post-test scores due to access interactive media resources like videos, online activities, key concepts & terminology definitions as well as past paper exams. Accessing these resources was crucial towards enabling the subjects attain mastery levels through complete comprehension on Calculus. For those under traditional way instruction methods as observed among the subjects within control group, a meaningful increase marked by notable progress had occurred given noticeable surge in posttest evaluations relative to corresponding pretests thus serving as evidence that such methods can enhance student performance remarkably when learning calculus. The research shows that both conventional and digital approaches for teaching have the capacity of promoting Mathematical Thinking Skills in Calculus. Traditional methods such as lectures coupled with practice exercises provide a strong basis for logical thinking while tools like Kognity increase students' motivation and participation. In order to ensure that the findings of these studies are sustained and enhanced, it is vital that methodological limitations are addressed; the analysis is extended to include further comparisons and that long term assessments are carried out. As suggested in [23] and [1] by enhancing the research design and communication, future research can offer a deeper insight into the most effective techniques for teaching mathematics. Utilizing digital textbooks proves to be an efficacious approach in enhancing academic success in calculus. This strategy could potentially elevate the performance of students attending Shanghai United International School - Gubei Campus and aid them in achieving a grade 6 or higher, thereby instilling confidence for admission to esteemed universities worldwide.

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REFERENCES

1. Anderson, L., Brown, J., & Taylor, S. (2021). Enhancing mathematical skills with technology: A systematic review. Educational Technology Research and Development, 69(4), 567-589.
2. Bayraktar, S., & Kosa, T. (2018). The effectiveness of digital textbooks in enhancing students' understanding of limits and derivatives in calculus. International Journal of Emerging Technologies in Learning (iJET), 13(11), 90-105.
3. Bezuidenhout, J. (2001). Limits and continuity: Some conceptions of first year students. International Journal of Mathematics Education, Science and Technology, 32(4), 487-500.
4. Brown, J., Carter, D., & Lee, M. (2019). Foundations of experimental design in education. Journal of Educational Research, 112(3), 45-58.
5. Castro, S. M., Melia, M. M., & Sanz, C. P. (2017). Impact of using digital textbooks on mathematics performance of secondary education students. Journal of New Approaches in Educational Research, 6(2), 87-95.
6. Fraenkel, J., Wallen, N., & Hyun, H. (2013). How to Design and Evaluate Research in Education (9th

ed.). New York: McGraw-Hill.
7. Guo, Y., Zou, J., & Yan, Y. (2017). The effect of blended learning on student performance in a calculus course. The International Journal of Information and Learning Technology, 34(4), 304-313.
8. Greenwald, R. R., & Quitadamo, I. J. (2014). A mind of their own: Using inquiry-based teaching to build critical thinking skills and intellectual engagement in an undergraduate neuroanatomy course. Journal of Undergraduate Neuroscience Education.
9. Harel, G., & Sowder, L. (2007). Towards comprehensive perspectives on the learning and teaching of proof. In F. K. Lester, Jr. (Ed.), Second handbook of research on mathematics teaching and learning (pp. 805–842). Reston, VA: NCTM.
10. [Huang, Y. M., et al. (2012). Empowering personalized learning with an interactive e-book learning system for elementary school students. Educational Technology Research and Development, 60(4), 703-722.
11. Johnson, P., & Lee, C. (2018). Interactive learning tools in mathematics education. Mathematics Teaching and Learning Journal, 23(2), 123-135.
12. Jones, K., & Carter, D. (2017). Quasi-experimental designs in educational settings. Educational Research Quarterly, 40(1), 89-102.
13. Kucuk, M., & Sahin, A. (2013). The effect of traditional teaching on mathematical thinking skills in calculus. Procedia - Social and Behavioral Sciences, 93, 2046-2052.
14. Li, J., Zhang, D., & Liu, J. (2019). The effect of traditional teaching method on mathematics learning: A meta-analysis. Frontiers in Psychology, 10, 1499.
15. Liberna, H. (2015). Peningkatan kemampuan berpikir kritis matematis siswa melalui metode improve pada materi sistem persamaan linear dua variabel. Jurnal Formatif, 2(3).
16. Rodríguez-González, A., Ruiz-Gallardo, J. R., & García-Martín, J. (2020). Analysis of the impact of digital textbooks on the academic performance and motivation of university students in mathematics. Internationd textbook in teaching simple probability. Universal Journal of Educational Research, 4(6), 1376-1381.
17. Maharaj A. (2007). Using a task analysis approach within a guided problem-solving model to design mathematical learning activities. Pythagoras, 66, 34-42.
18. National Research Council. 2001. Adding It Up: Helping Children Learn Mathematics. Washington, DC: The National Academies Press.
19. National Council for Curriculum and Assessment, Ireland (2015). Leaving certificate mathematics syllabus: Foundation, ordinary and higher level. Retrieved 10 October 2018 from
20. Smith, A. (2020). The impact of socioeconomic factors on mathematical achievement. International Journal of Education, 85(3), 456-478.
21. Syafrimen, N. M. Ishak, and N. Erlina 2017 Emotional Intelligence Profile of Prospective Teachers J. Eng. Appl. Sci. 12
22. Taylor, S., & Green, L. (2020). Evaluating long-term effects of digital textbooks in calculus education. Mathematics Education Today, 35(6), 302-319.
23. Yackel, E., & Hanna, G. (2003). Reasoning and proof. In J. Kilpatrick, W. Martin, & D. Schifter (Eds.), a research companion to Principles and Standards for School Mathematics (pp. 227–236). Reston, VA: NCTM.