

Effect of Using Mathematica on Bachelor's Level Students' Achievement in Limit and Continuity

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Abstract

Article History:

Submitted: 25 October 2025

Reviewed: 21 November 2025

Accepted: 15 December 2025

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Publisher

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The use of mathematical software in teaching and learning has become a growing interest and attention among mathematics scholars and educational researchers. The purpose of this study was to determine the effect of using Mathematica on students' achievement in limit and continuity, and to assess students' perceptions towards the use of software in teaching limits and continuity. A quasi-experimental research design with a pretest-posttest nonequivalent control group was employed, utilizing an achievement test and survey to measure students' achievement and perception of using Mathematica in calculus teaching and learning. Collected data were analyzed using an independent t-test to compare the significance difference between two means. Similarly,

descriptive statistics were used to analyze the data obtained from the questionnaire. The results from the study revealed that the achievement of Mathematica-instructed students was significantly higher than that of the control group. Additionally, the level of perceptions of experimental group students was found to be high towards the use of Mathematica. The findings of the study would be beneficial to mathematics teacher for their professional development. Similarly, the study would be useful to educational administrators and policy makers to make new policies in mathematics education to integrate mathematics with Mathematica software that motivates students towards mathematics subjects.

Keywords: Mathematica, conceptual understanding, computer algebra system, perception

Introduction

There is an emergent and burning issue raised by mathematics scholars and educators on the use of mathematical software in teaching and learning mathematics. This study investigates the impact of teaching mathematics using Mathematica software on students' understanding of limits and continuity in calculus. There are

different kinds of mathematical software: Graphic Calculator, Computer Algebra System, Theorem Provers and Proof Assistant, Optimization Software, Interactive Geometry Software, Numerical Analysis Software, Statistics Software, etc. Among all these, the Computer Algebra System (CAS) is an important software that works with strings of symbols and is used in the manipulation of tedious and difficult mathematical expressions. Mathematica is a powerful CAS used in scientific, engineering, and mathematical fields and in other areas of technical computing. Bataineh et al. (2019) considered Mathematica as one of the most popular CAS that positively impact on learning theoretical and applicable mathematics.

The limit and continuity are fundamental concepts of calculus. This topic was first introduced first in school level in class 9 in additional mathematics in the context of Nepal. The fundamental concept- limits and continuity is the most important part of calculus (Zollman, 2014). Without a good understanding of the limits and continuity, it would be a major challenge to learn derivatives and integration in calculus. The reason behind this is that the concept of limits and continuity is essential to proceed with the concept of instantaneous change rate or derivative of a function. Dlamini (2017) also argues that learners faced challenges in learning calculus due to a lack of conceptual understanding of fundamental concepts such as function, limit, and continuity. According to Maharaj (2010), students find it difficult to understand limits and continuity because they don't have an appropriate mental image of these concepts. This problem arises due to the practice of the traditional approach of teaching limits and continuity, where the teacher, as well as students, emphasize the procedural skill instead of the conceptual understanding of the abstract concepts used. Because of this practice, most of the students give attention to rules and procedures without internalization and focusing on the embedded concepts (Makgakga & Makwakwa, 2016).

Crawford et al. (2018) concluded that the challenges of the calculus are effectively solved by providing a deeper and clearer understanding of fundamental concepts such as function, limit, and continuity in a collaborative environment. The conceptual understanding of students in calculus will not be resolved unless the students are supported to: understand the abstract concepts of limit and continuity, apply the concepts in real models, and change mathematical problems of calculus in real practice (Aspinwall & Shaw, 2002). However, the mathematics teachers have been using the lecture method of teaching (Rawat, 2018) that overemphasizes algebraic manipulation and procedure without exploration and visualization. The mathematics teachers are good at delivering the procedural skill of mathematics, but they lack in explaining the reasons for the procedure. Therefore, our students depend

upon rote memorization of formulas and procedures, lacking the conceptual understanding of the abstract content of mathematics.

Therefore, it is essential to investigate a new way of teaching using technology to improve the conceptual understanding of students in mathematics. In Nepal, the use of Information and Communication Technologies with different purposes has been seen to be emphasized after the implementation of the National Curriculum Framework for School Education 2005, The School Sector Reformed Plan 2009-2015, and The School Sector Development Plan 2016-2023 (MOE, 2006, 2009 b, 2016). In the context of the use of Mathematica in Nepali universities, Tribhuvan University has introduced Mathematica in a course ICT in Mathematics Education in Master (M. Ed.) program, and Nepal Open University in Master of Philosophy level to enhance mathematics teaching and research. The literature suggests that Mathematica is a powerful interactive and dynamic computer algebra system which enhances the teaching and learning mathematics (Bataineh et al., 2019; Jonassen, 2000).

From the review of literature it was found that Mathematica has been used as teaching tool to enhance the problem solving and interpretation skill of the students' on functions and graph (Bataineh et al., 2019); interest and motivation in mathematics learning (Ardic & Isleyen, 2017); interaction and cognitive development of students (Montoya & Prada, 2019); understanding and problem solving skill in linear algebra (Vorib'ev, 2012); and mathematical abstraction ability, motivation, and independence of students in analytic geometry (Murtianto et al., 2019). But these studies were unable to investigate the effect of Mathematica on learning limit and continuity, so the researcher noted this as an important gap for further study. Researchers found from a literature survey that there are many studies to find the effect of some mathematical software, but no study was seen to find the perception towards the use of Mathematica, so this is another gap for the present study. Thus, this study contributes to filling the above gaps. This study aimed at addressing the following research questions: What is the effect of using Mathematica on students' understanding of limit and continuity as compared to the traditional approach? What are students' perceptions of using Mathematica in the learning of limits and continuity?

Methods and Materials

The researcher used quasi-experimental research with a pretest-posttest non-equivalent group design (Cohen et al., 2018) where experimental and control groups had no pre-experimental sampling equivalence. The researcher took two different intact classes that were taking mathematics in the first-year bachelor level of Butwal Multiple Campus, as it was not practically possible to upset class schedules or

reorganize classes (Koul, 2009). After the selection of two groups, a random procedure was used to determine the intervention for the groups (Koul, 2009). The intervention or the experimental treatment in this study was the use of Mathematica in teaching limits and continuity for a period of two weeks.

Table 1

Pretest-Posttest Non-Equivalent Group Design

Groups	Pretest	Intervention	Posttest
Experimental	T_1	Teaching with Mathematica (X)	T_2
Control	T_3	Conventional method of teaching	T_4

Where,

T_1 =Pre-test given to experimental group, T_2 = Post – test given to experimental group, T_3 =Pre-test given to control group and T_4 = Post – test given to control group

The researcher selected two intact classes: 25 first-year bachelor students majoring in mathematics of the education faculty and 22 first-year bachelor students of science faculty, conveniently for the study of Butwal Multiple Campus, on the basis of number of students, classes shift, qualification of teachers, contents studied in calculus in both classes. The researcher constructed two parallel achievement tests containing 25 items in each test. Both tests were constructed from the chapter limits and continuity of calculus. The tests were constructed on the basis of a specification chart, and validity was established by content validity measured from the expert, teachers, language expert and students.

A survey with 10 items was developed by researcher to find students' perception toward the use of Mathematica used in teaching limit and continuity in experimental group. All items were in the form of Likert Scale as strongly disagree to strongly agree. The scoring technique was 1 for strongly disagree to 5 for strongly agree for positive items and reverse scoring in negative items. Two experts in mathematics education independently reviewed the instrument and indicated that, in their opinion, it had content and construct validity.

Similarly, the researcher developed 14 lessons from the chapter on limits and continuity by the use of Mathematica for the experimental group. Some examples related to concepts of limits and continuity used in the experiment have been given in Figure 1.

Figure 1*Image of lesson limit using Mathematica*

Wolfram Mathematica 9.0 - [Concept of Limit.nb]

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Concept of Limit.nb

Limit and Continuity

concept of Limit

Define a function

$$f[x_] := \frac{x^2 - 9}{x - 3};$$

suppose we are going to find out the limit of $f[x]$ at $x=3$.

$f[2.9]$
5.9

$f[3.1]$
6.1

$f[2.999]$
5.999

$f[3.1111]$
6.1111

Let us make a table where we can see the different values of x very less than 3 (say $L[h]$) and the values of x whose values are greater than 3 by very less (say $L[ph]$) to all values of $L[h]$ and $L[ph]$ and their corresponding values in a single table. for tha we need to define these two functions $L[h]$ and $L[ph]$ as given below

$uv[h_] := 3 - 0.1^h;$

Activate Windows
Go to Settings to activate Windows

100

Wolfram Mathematica 9.0 - [Concept of Limit.nb]

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Concept of Limit.nb

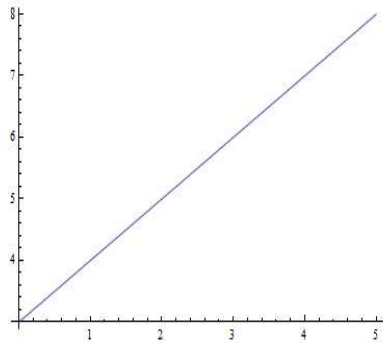
```
uv[h_] := 3 - 0.1^h;
```

```
lv[h_] := 3 + 0.1^h;
```

```
TableForm[Table[{uv[h], f[uv[h]], lv[h], f[lv[h]]}, {h, 1, 5}], TableHeadings -> {None, {"x", "f[x]", "x", "f[x]"}}]
```

x	f[x]	x	f[x]
2.9	5.9	3.1	6.1
2.99	5.99	3.01	6.01
2.999	5.999	3.001	6.001
2.9999	5.9999	3.0001	6.0001
2.99999	5.99999	3.00001	6.00001

```
Plot[f[x], {x, 0, 5}]
```



```
Manipulate[Show[ListPlot[{{2.999999999, f[2.999999999]}}, PlotRange -> {{a, 6 - a}, {0, 9 - a}}, Plot[f[x], {x, 0, 5}], {{a, 0}, 0, 3}]
```

Alt

Wolfram Mathematica 9.0 - [Important Concept in Limit.nb]

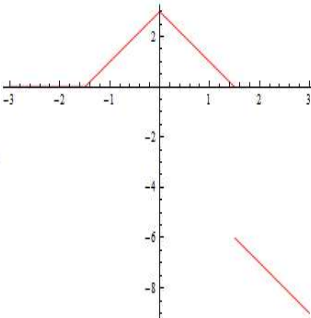
File Edit Insert Format Cell Graphics Evaluation Palettes Window Help

Important Concept in Limit.nb

Discuss the continuity and discontinuity of the given function $t[x] = \begin{cases} 3 + 2x & -3/2 \leq x < 0 \\ 3 - 2x & 0 \leq x < 3/2 \\ -3 - 2x & x \geq 3/2 \end{cases}$ at $x=3/2$

In[3]: $t[x_] := \begin{cases} 3 + 2x & -3/2 \leq x < 0 \\ 3 - 2x & 0 \leq x < 3/2 \\ -3 - 2x & x \geq 3/2 \end{cases}$

In[4]: `Plot[t[x], {x, -3, 3}, PlotStyle -> Red]`



Out[5]:

Let's find left hand limit of $t[x]$ at $x=3/2$ (from the left)

In[7]: `Limit[t[x], x -> 3/2, Direction -> 1]`

Out[7]: 0

Thus, when we approach $3/2$ to from left side in the given fiuge, the value of the function is near to 0.

Let's find the limit of $t[x]$ at $x=3/2$ from the right

In[8]: `Limit[t[x], x -> 3/2, Direction -> -1]`

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100%

Before deciding on the experimental and control groups, a pretest was given to both groups to see whether the two groups were equal in mathematical ability or not. Then, coin tossing was used to decide the experimental and control groups. Experimental treatment was used in the form of using Mathematica in teaching limits and continuity for two weeks, and control group was taught the same chapter conventionally. The researcher taught both groups to control the teacher variables. As soon as the experiment was over, both groups were given a posttest. At the time of the posttest, the students of the experimental group who experienced the use of Mathematica were exposed to the survey to measure their perception.

The test of normality was carried out by using the Shapiro-Wilk test in order to decide the parametric or non-parametric test to be used in analyzing the data (Ardic & Iseleyan, 2018). Similarly, an independent t- test was used to compare the two mean scores of two unrelated groups (experimental and control) on the same test (Field, 2009; Cohen et al., 2018). In evaluating the effect size, $r = .10$ (small effect), $r = .30$ (medium effect), $r = .50$ (large effect) criteria specified by Cohen (1992) were consulted. While percentage, mean, and standard deviation were calculated under descriptive statistics to analyze the perception of students towards the use of Mathematica in teaching limits and continuity.

Results

Effectiveness of Using Mathematica on Students' Achievement of Limits and Continuity

Table 2

Independent t-Test Result of the LCDRT Scores on Pretest according to the Group

Groups	N	Mean	SD	T	d f	Sig.
E G	25	12.84	1.97			
CG	22	12.68	2.10	.27	47	.79

Table 2 shows that on average, participants experienced significantly greater achievement in the experimental group ($M = 12.84$, $SD = 1.97$) than in the control group ($M = 12.68$, $SD = 2.10$). This difference was not significant, $t(46) = .27$, $p > .05$. Thus, the researcher concluded that students in experimental and control groups were assumed to have a similar level of mathematical ability on limits, continuity, and derivative concepts before the experimental treatment of the control group.

Table 3

Independent sample t-test result of the posttest scores according to the groups

Group	N	Mean	SD	t	d f	Sig.	r
EG	25	14.44	2.06				
CG	22	13.05	2.08	2.30	45	.026	.61

Table 3 shows that on average, participants experienced significantly greater achievement in experimental group ($M = 14.44$, $SD = 2.06$) than in the control group ($M = 13.05$, $SD = 2.08$). This difference was significant, $t(44) = 2.30$, $p < .05$. Further, this effect was of a large size, $r = .61$. Thus, it was concluded that the use of Mathematica in teaching mathematics for the experimental group had a positive effect on the mathematics achievements of the students.

Students' Perception Toward Using Mathematica in Learning Limits and Continuity

Table 4 showed that the level of students' perception towards the use of Mathematica in teaching limit and continuity was found to be high. The result also indicates that the Mathematica software is helpful to learn mathematical concepts, visualize mathematical content, and make students more creative, enjoyable, and confident. Additionally, it is essential for mathematics learning.

Table 4

Perception of Students Towards Using Mathematica in the Experimental Group

Items	SA	A	N	D	SD	Mean	SD	Level
I felt confident in solving problems of limit and continuity using Mathematica	40	16	28	12	4	3.8	1.12	High
I enjoyed learning limits and continuity much more using Mathematica.	32	40	24	4	0	4.0	0.87	High
Mathematica assisted in thinking more creatively.	24	40	20	12	4	3.68	1.11	High
Mathematica helped me a lot to learn the difficult concept of limit and continuity.	32	36	24	8	0	3.92	0.95	High
I was very engaged in the learning process using Mathematica.	24	40	20	12	4	3.68	1.11	High
I was in confusion while using Mathematica.	0	16	32	32	20	2.44	1.00	Low

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Interaction with peers and the teacher was increased in the Mathematica class.	24	40	20	12	0	3.68	1.11	High	
I was able to visualize and answer the questions after each activity.	40	16	28	12	4	3.76	1.23	High	
I enjoyed learning mathematics much more using Mathematica.	32	40	16	8	4	3.88	1.01	Low	
Using Mathematica was challenging to learn limits and continuity.	4	4	24	44	24	2.20	1.00	Low	

Results indicated high positive perceptions across most dimensions (M range = 3.68–4.00, SD range = 0.87–1.23), with Mathematica enhancing confidence, enjoyment, creativity, conceptual understanding, engagement, visualization, and interaction. The highest mean (M = 4.00, SD = 0.87) for enjoyment in learning limits and continuity suggests a strong motivational impact. Low means on reverse-scored items (confusion: M = 2.44, SD = 1.00; challenge: M = 2.20, SD = 1.00) confirmed minimal barriers, supporting tool accessibility.

Discussion

The findings of this research indicated that the impact of using Mathematica in teaching and learning limits and continuity has a significant effect on students' achievement. The significant change in achievement was due to the construction and improvement in abstract concepts through visualization and interactive features while using Mathematica software (Tersian & Chparova, n.d.). Another reason for improvement in achievement in the experimental group is due to the manipulative feature present in Mathematica, which assisted in linking abstract ideas present in the lesson with the interactive model provided (Kamina & Iyer, 2009).

The result of this study is consistent with the findings of similar studies on the utilization of software GeoGebra in teaching linear equations at eight grade students in Nepal (Joshi & Singh, 2020), In teaching coordinate geometry to low visual-spatial ability secondary school students (Saha et al., 2010), in teaching circle among senior high school students (Tay and Wonkyi, 2018), , in teaching function to high school students in Indonesia conducted by Zulnaldi & Zakaria (2012), in teaching triangle (Ozcakir et al., 2015), in teaching definite integral among perspective secondary teachers in Turkey (Tatar & Zengin, 2016), in teaching fraction at primary level (Bulut et al., 2016), and in teaching geometry to secondary level (Kushwaha et al., 2014). Similarly, the present result is consistent with the study of Bataineh et al. (2019), demonstrated that utilizing Mathematica software in teaching derivative and its application in the experimental group found to be more effective than control group in developing student's problem-solving skills by supporting students with

multiple representations of the derivative concepts, and also motivate the students to think in critical and innovative ways.

The students who were exposed to the perception survey showed high agreement that the Mathematica used in teaching limits, and continuity is a supportive tool for learning mathematics, understanding abstract concepts used in the lesson, increases their confidence in solving problems, makes them more interactive, makes learning more enjoyable, and visualizes mathematical content. This is supported by the conclusion of Barkatsasa and Shamoil (2011) that the students were very positive about the use of CAS in learning mathematics due to the use of mathematical software in learning mathematics. A similar result was found by Shadaan and Eu (2013) in a learning circle using GeoGebra and Arbain and Shukor (2015) in the perception of students. Similarly, the finding is similar to the finding of Dikovic (2009), Ocal (2017), and Zulnaidi and Zamri (2017) showed that the software is very good for developing conceptual understanding. Hence, the study verifies that Mathematica is a supportive tool for students to enhance conceptual understanding and visualize the mathematical content.

Conclusion

The result of this study demonstrated that Mathematica is an effective tool for teaching mathematics, which assisted students in enhancing their understanding of the concept of limits and continuity. The increase in understanding of the concept enhances students' achievement in this topic. The students who were instructed with the help of Mathematica in teaching and learning agreed that the software increased their understanding of the subject, increase the confident, created an environment to be more creative, make learning more enjoyable by visualizing the concept of limit and continuity. The research was limited to a small group of students, so additional research is needed to include different classes with similar content. Therefore, mathematics teaching will be meaningful if all the teachers use Mathematica in limit and continuity. In addition, the study also suggests that mathematics experts and policy maker to framework for the mathematics curriculum incorporating Mathematica software at the college and university level.

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