

## **Cognitive Engagement and Technology: The Influence of Wolfram Alpha in Mathematics**

### **Education**

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### **Abstract**

Student cognitive engagement is a multidimensional construct that predicts students' academic performance. In this context, the role of educational technology in enhancing students' cognitive engagement is a major concern among mathematics teachers, educators, and researchers in mathematics education. The purpose of this study was to investigate the effect of using Wolfram Alpha as a teaching and learning tool in mathematics on the cognitive engagement of secondary-level students. The quasi-experimental method with a Pretest-Posttest Non-equivalent Group Design was used to fulfill the purpose of the study. Sixty-four class 11 students studying mathematics from two institutional schools of Butwal Sub metropolitan city were the participants of the study. The study utilized adapted questionnaires: Cognitive Engagement Scale Extended Version (CSE-E) and Students' Opinion Scale (SOS) from earlier studies, with little modification for this context. The independent t-test and ordinal logistic regression analysis were used to analyze the data. The study findings reveal that students who received Wolfram Alpha in teaching and learning have higher cognitive engagement as compared to those who do not receive it. Thus, it is concluded that teaching and learning mathematics using Wolfram Alpha positively impacts students' cognitive engagement. Findings from this study enlighten mathematics teachers, educators, and researchers in enhancing the cognitive engagement of students through the use of Wolfram Alpha in teaching and learning mathematics.

**Keywords:** Wolfram Alpha, engagement, technology, academic performance

### **Introduction**

Student Engagement is an important factor in the learning process, especially in learning mathematics, because it enhances the participation of students in learning. Student engagement involves concepts like active participation, attention, efforts to achieve the intended outcomes, the time spent on tasks, and participation in in-class and out-of-class activities (Gunuc, 2013). Trowler (2017) defined student engagement as the willingness and effort of students to actively participate in school activities that contribute to successful outcomes. In the past, efforts to keep children in school have concentrated on three aspects of student engagement: boosting achievement, encouraging behaviors, and creating a feeling of community (Dunleavy et al., 2012; Parsons & Taylor, 2011). Student engagement has evolved into a purposeful process to improve every student's capacity to acquire the skills necessary to become lifelong learners in a knowledge-based society (Parsons & Taylor, 2011).

There are three widely accepted dimensions of engagement, which are behavioral engagement, cognitive engagement, and emotional engagement (Fredricks et al., 2016). Behavioral engagement indicates active physical participation that is essential for attaining successful academic results and reducing dropouts. Emotional engagement includes positive and negative reactions to classmates, teachers, subject matter, and academic actions that influence willingness to do the work. Cognitive engagement incorporates a willingness to learn and engagement in understanding the content. However, in this study researcher is going to focus on the cognitive engagement of students while using technology in learning mathematics.

The effort shown by students to understand the subject matter reflects cognitive engagement. Cognitive engagement indicates students' willingness and effort to understand the content (Rimm-Kaufman et al., 2015). It means when a child shows willpower to learn the content, he/she shows some effort that supports the learning. Cognitive engagement is concerned with students' diligence and use of cognitive strategies in the learning process (Fredricks et al., 2016). Christenson et al. (2012) state that cognitive engagement refers to learning strategies, independent working, and active self-regulation. My experience as a mathematics teacher asserts that the enhanced cognitive engagement of students positively impacts their mathematics learning. Finn and Zimmer (2012) viewed that when students are cognitively engaged, they start asking questions for more clarification of abstract concepts, continuously engage in difficult tasks, review the source of reading material, search for the required information beyond, and use self-regulation. Further, they concluded that students' high levels of cognitive engagement facilitate students' learning of difficult and abstract concepts of mathematics. Thus, students' cognitive engagement can be considered as an important factor that positively impacts the mathematics learning of students.

Therefore, the cognitive engagement of students in mathematics class can have an impact on the mathematics achievement of students. There are numerous studies on the relationship between cognitive engagement and the mathematics achievement of students. For example, Research has confirmed that higher levels of engagement of students equate to higher levels of student performance (Reeve, 2012). Moreover, the academic success of an entire school depends on the level of student engagement (Rimm-Kaufman et al., 2015). Students with high engagement levels attend school routinely and attain higher grades than their colleagues with low engagement levels (Bear et al., 2018). This means engagement can be enhanced by the manipulation of teaching and learning strategies. This study focuses on the students' cognitive engagement using Wolfram Alpha in teaching and learning derivatives.

Wolfram Alpha is a valuable tool in teaching and learning mathematics. This search engine is an online tool built on the Wolfram language and launched in 2009 by the Wolfram Research company. It can be used to find information and solve the problems of science, mathematics, technology, and other social science subjects. The interactivity provided by Wolfram Alpha is particularly beneficial in subjects like linear algebra, calculus, and geometry, where abstract concepts

can be understood visually (Campuzano & Crisanto, 2022). I have found that Wolfram Alpha creates an interactive learning environment with step-by-step solutions to mathematical problems, is easy to use without any software installation, and supports diverse mathematical topics. Campuzano & Crisanto (2022) revealed that the step-by-step solution feature provided by Wolfram Alpha helps students understand the processes involved in solving problems instead of just obtaining the final answer.

As a mathematics teacher, the researcher has experienced a great problem of a lack of student cognitive engagement in mathematics class. The major problems of mathematics teachers are to search for a strategy to keep them intellectually busy in learning. It has become increasingly difficult to gain and keep the attention of students in mathematics class. Research studies (Bear et al., 2018; Castro et al., 2017; Lu & Churchill, 2012; Schindler et al., 2017) have given mixed results on the effect of using technology on the cognitive engagement of students. For example, the study by Lu and Churchill (2012) found that social interactions using technology did not lead to higher cognitive engagement. Furthermore, several studies have found that the technology used in blended-mode classes can pressure students to learn, thereby reducing their cognitive engagement (Asoodar et al., 2014). Further, the researcher found that few studies on cognitive engagement using search technology exist, so a large number of studies are required in this construct (Schindler et al., 2017).

There are various studies related effect of Wolfram Alpha, for instance, Campuzano and Crisanto (2022) on geometry achievement, Barba-Guaman et al. (2018) on reading comprehension in mathematics, Cassel (2016) as a search engine, Compunzano and Gonzabay (2022) on performance of linear algebra, and Dimiceli et al. (2010) as a teaching tool. It can be seen that the existing studies show the positive effects of Wolfram Alpha on student performance, but several gaps remain, particularly in the context of Nepal. Most studies have been conducted in a setting of Western educational. However, to my knowledge, there are too limited studies on the effect of Wolfram Alpha on cognitive engagement in teaching and learning mathematics in the context of Nepal. Therefore, the researcher was interested in using Wolfram Alpha to see its effect on the cognitive engagement of students in mathematics classrooms in the Nepali context. The purpose of this study was to examine the effect of using Wolfram Alpha in teaching and learning mathematics on the cognitive engagement of secondary-level students. The researcher reviewed the literature that supports a better understanding of the previous studies related to technology use and their effect on different dimensions of Students' cognitive engagement. As a mathematics teacher, the researcher has realized that cognitive engagement of students plays a crucial role in their learning mathematics. It involves the extent to which students use their mental effort in mastering mathematical concepts, ranging from deep comprehension to superficial involvement. The integration of educational technology in mathematics teaching has shown promise in shaping different dimensions of cognitive engagement, influencing how students connect with mathematical content.

### **Technology Use and Deep Engagement**

Deep cognitive engagement refers to a student's meaningful interaction with mathematical content, characterized by intentional efforts to understand underlying principles and solve problems creatively. Multiple studies underscore that technology, such as dynamic mathematics software and interactive computational tools, fosters deep engagement by enabling students to visualize abstract concepts and explore mathematical relationships actively (Attard & Holmes, 2020). Tools like Wolfram Alpha encourage students to investigate multiple problem-solving strategies, promoting conceptual comprehension rather than rote memorization. When students interact with technology that supports inquiry-based learning, they develop metacognitive skills and critical thinking, which are hallmark features of deep engagement (Duterte, 2024). Thus, technology transforms passive reception into active construction of knowledge, aligning with the deep engagement subscale of cognitive engagement, such as measured by Charsha (2013) CSE-E.

### **Technology Use and Shallow Engagement**

Shallow cognitive engagement typically involves surface-level learning strategies, such as memorization or task completion with minimal cognitive investment. While technology can unintentionally reinforce shallow engagement when used primarily as a computational shortcut or drill tool, research suggests that its design and implementation critically determine its effect (Smiley & Anderson, 2011). For example, when technology is used merely for answer verification or speed without interpretative dialogue, students may adopt shallow engagement strategies. However, adaptive platforms and gamified mathematics applications that provide immediate feedback and scaffolded challenges can help reduce tendencies toward superficial processing by keeping students cognitively engaged within their zone of proximal development (Wahid & Shahrill, 2014). Therefore, assessing shallow engagement in technology-aided settings is crucial to ensure instructional goals prioritize understanding over speed or correctness alone.

### **No Engagement and Distractive Effects of Technology**

No cognitive engagement denotes a state where students mentally disengage from learning tasks altogether, which can manifest as distraction or disinterest. When technology is not used effectively in teaching and learning, it can also become a source of disengagement when students multitask or shift attention away from academic content (Charsha et al., 2013). Some studies report that unmonitored access to non-educational content on devices leads to lowered cognitive engagement and poorer comprehension outcomes (Joshi et al., 2020). Effective technological interventions, therefore, require deliberate structuring to minimize distractions and support sustained focus through interactive, goal-oriented tasks that promote re-engagement when attention lapses.

### **Technology Integration and the Importance of Task**

The perceived importance of tasks, a motivational dimension from Sundre's (1997) Students' Opinion Scale, influences how much effort and cognitive resources students dedicate to a mathematics assignment. Technology-mediated tasks that clearly articulate relevance or practical applications of

mathematics tend to enhance students' perceived importance. For instance, simulation software that connects algebraic functions to real-world engineering problems enhances task relevance and motivates students to deeply engage cognitively (Lo & Hew, 2021). Similarly, technologies that allow students to explore mathematical modeling or data analysis foster appreciation of mathematics as a valuable tool, increasing both cognitive investment and motivational importance (Lo & Hew, 2021).

### **Effort Investment in Technology-Supported Learning**

Effort relates to the actual energy students devote to learning tasks and can be influenced positively by engaging technological environments. According to Sundre and Moore (2002), when students use educational technologies that provide adaptive challenges and just-in-time support, they often report higher effort levels due to increased motivation and manageable cognitive load. Interactive platforms that include gamification elements, real-time feedback, and collaborative problem-solving opportunities stimulate students to sustain effort over time (Attard & Holmes, 2020). In mathematics education, effortful learning mediated by technology has been linked to improved persistence in tackling complex problems and higher overall achievement (Cevikbas & Kaiser, 2022). Thus, effort as a cognitive engagement dimension is enhanced when technology creates an engaging, supportive learning atmosphere that balances challenge and skill.

In summary, I realized the multidimensional nature of cognitive engagement requires measurement tools that capture diverse mental and motivational behaviors. Adapting the Cognitive Engagement Scale Extended Version (CSE-E) alongside the Students' Opinion Scale (SOS) provides a comprehensive framework to evaluate these dimensions in technology-rich mathematics classrooms. Research consistently shows that well-integrated technology supports deeper engagement and effort by promoting inquiry, relevance, and interactive learning. However, caution is necessary to avoid encouraging shallow engagement or disengagement due to distraction. The balanced application of technology aligned with pedagogical principles can thus foster holistic cognitive engagement, enhancing both motivation and learning outcomes in mathematics education.

### **Methodology**

The philosophical view of this study is the post-positivist paradigm. Quasi-experimental research with a pretest-posttest non-equivalent control group design was used (Cohen et al., 2018). The cognitive engagement of students and the relation between technology (Wolfram Alpha) and cognitive engagement are considered as a single reality in the research. The causal relationship between the use of Wolfram Alpha and cognitive engagement was found through the use of quasi-experiments. The researcher selected two intact classes of Grade 11 mathematics students from Deep High School and Canon Secondary School in Butwal sub-metropolitan city due to the impracticality of random assignment, consistent with Koul's (2009) guidelines on quasi-experimental design and intact group sampling. Both schools are institutional and were chosen because they exhibit characteristics representative of the broader population of institutional schools in Butwal. This purposive sampling ensures that the selected schools mirror the demographic, academic, and

institutional features prevalent across Butwal's institutional schools, thereby making them a valid sample for the study context. Hence, sampling these schools supports the external validity and generalizability of the study findings to the population of secondary-level institutional schools in the city. This approach aligns with Koul's (2009) emphasis on selecting samples that are representative to enhance the relevance and applicability of research outcomes. After that, the treatment in the form of Wolfram Alpha in teaching derivatives was applied for the experimental group only. The experimental duration was three weeks.

**Table 1**

*Pretest-Posttest Non-equivalent Group Design*

Groups	Pretest	Intervention	Posttest
Experimental	CES-E	Teaching with Wolfram Alpha	CES-E
Control	CES-E	Conventional teaching without Wolfram Alpha	CES-E

The researcher selected 32 and 34 students of class 11 who were studying mathematics at Deep Boarding School ( $n_1 = 34$ ) and Canon Secondary School ( $n_2 = 32$ ) of Butwal Sub metropolitan city for the academic year 2079/80. Two sections of both schools were selected based on similarity in internal exam scores, IT skills, number of students, and teacher factors. The study utilized a combined form of the Cognitive Engagement Scale Extended Version (CSE-E) adapted from Charsha et al. (2013) and the Students' Opinion Scale (SOS) adapted from Donna Sundre (1997), with little modification for this context. It consisted of twelve items from CSE-E and 10 items from SOS, both measured on a five-point Likert scale. It has five subscales: deep, shallow, no engagement, importance, and effort. Two educational experts in construct and instrument development independently reviewed to establish the content and construct validity. Cronbach's Alpha Reliability of the questionnaire in the Nepali context was found to be  $\alpha = .79$  for deep construct,  $\alpha = .70$  for non-engagement,  $\alpha = .71$  for shallow construct,  $\alpha = .80$  for the importance construct, and  $\alpha = .56$  for the effort construct and  $\alpha = .87$  for the total scale. Similarly, teaching lessons with 18 episodes using Wolfram Alpha was prepared for the experimental group, and a lesson plan without using any of the software was prepared for the control group.

The researcher visited both schools and clarified the purpose of the study. Before deciding on the experimental and control groups, a pretest of the Cognitive Engagement Survey (SCE-E and SOS) was given to both groups to see whether their cognitive engagement was equal. The experimental and control groups were identified using the coin-tossing method. The experimental group was given an orientation on using Wolfram Alpha. The researcher taught them derivatives for three weeks by using the interactive lesson plan for derivatives. The students in the experimental group used Wolfram Alpha in the computer lab for visualization, manipulation, and step-by-step

solutions for the problems of derivatives. They were allowed to use Wolfram Alpha for classwork and homework. The control group was taught the same chapter using the usual teaching method without Wolfram Alpha. The researcher taught both groups to control the teacher bias present in the experiment. As soon as the experiment was over, both groups were given the same tool as the posttest.

The test of normality was carried out by using the Shapiro-Wilk test to decide the parametric or non-parametric test to be used in analyzing the data (Ardıç & İşleyen, 2018). Similarly, an independent t-test was used to compare two mean cognitive engagement scores of two unrelated groups (experimental and control) on the same test (Field, 2009; Cohen et al., 2018). Logistic regression analysis was used to determine the extent of the impact of using Wolfram Alpha on student cognitive engagement.

## Results

### Effectiveness of Using Wolfram Alpha on Students' Cognitive Engagement

**Table 2**

*Independent sample t-test result of the pretest scores according to the group*

Groups	N	Mean	SD	t	d f	Sig.
E G	34	3.30	.41	1.35	64	.18
CG	32	3.18	.32			

Table 2 shows that on average, participants experienced greater cognitive engagement in the experimental ( $M = 3.30$ ,  $SD = .41$ ) group than in the control group ( $M = 3.18$ ,  $SD = .32$ ). This difference was not significant,  $t(64) = 1.35$ ,  $p > .05$ . Thus, it is concluded that students in experimental and control groups were assumed to have a similar level of cognitive engagement in mathematics class before the intervention.

**Table 3**

*Independent sample t-test result of the post-test scores according to the group*

Groups	N	Mean	SD	t	d f	Sig.
E G	34	3.61	.35	3.02	64	.004
CG	32	3.38	.25			

Table 3 shows that on average, the participants experienced greater cognitive engagement in the experimental group ( $M = 3.61$ ,  $SD = .35$ ) than in the control group ( $M = 3.38$ ,  $SD = .25$ ). This difference was significant,  $t(64) = 3.02$ ,  $p < .05$ . Thus, it was concluded that the use of Wolfram Alpha in teaching and learning for the experimental group had a positive effect on the students' cognitive engagement.

**Table 4**

*Ordinal Logistic Regression Test Showing Parameter Estimates with Odds Ratios*

Location	Estimate	S E	d f	Sig.	Odd Ratio
Experimental	1.31	.45	1	.004	3.71
Control	0		0		

Table 4 shows that students who receive Wolfram Alpha as a treatment have higher cognitive engagement than those who do not, as the estimated value is 1.31. Similarly, the odds ratio value (3.71) indicates that when there is a unit change in the independent variable (teaching and learning with or without Wolfram Alpha), the students' cognitive engagement increases by 3.71 units.

### Discussion

It was found from the study that the use of Wolfram Alpha in teaching and learning for the experimental group had a positive effect on the students' cognitive engagement. Further, the change in one unit in the independent variable resulted in a 3.71 unit increase in the dependent variable. The significant change in cognitive engagement was due to the construction and improvement in abstract concepts through visualization while using Wolfram Alpha (Tersian & Chparova, n.d.). Technology can facilitate intellectual engagement and learning through customization and personalization (Hsieh & Chen, 2016). The technology used helped to engage learners in supporting a constructivist learning environment by activating their prior learning (Isik, 2018). Further, Wolfram Alpha's step-by-step solutions support the learners to explore the reasoning behind derivative calculations, providing a deeper understanding of abstract concepts of derivatives. My results confirmed that using Wolfram Alpha in the classroom helped students understand material through visualization, so their cognitive participation was increased. The result of the study is similar to the findings of Wallace-Spurgin, M. (2020), who found that the students using technology fully facilitated cognitive engagement, leading to overall positive learning experiences for students. The finding of this study also aligns with the findings of the study conducted by Campuzano and Crisanto (2021), which stated that the use of Wolfram Alpha positively impacts students' performance. They found that the user-friendliness of technology further facilitates intellectual engagement by reducing their distractions from unrelated things.

Despite its advantages, being fully dependent upon Wolfram Alpha presents challenges. Besides the study's findings, I noticed few students used Wolfram Alpha to complete their assignments rather than develop their conceptual understanding and problem-solving skills. My experience proclaims that if students use Wolfram Alpha as an aid without understanding the underlying concepts of differentiation results in struggling with more difficult problems. The blind dependency on the software could hinder their ability to perform manual calculations of mathematical problems. Thus, teachers need to care whether they are searching for answers superficially. Before

using of search engine, why and how to use this properly for a deeper understanding and enhance the procedural knowledge of mathematical problems? The researcher realized that mathematics teachers are required to encourage students to use Wolfram Alpha as an instructional aid without neglecting the fundamental skills required in mathematics learning.

### Conclusion

The result of this study demonstrated that Wolfram Alpha is an effective tool for teaching mathematics. It assisted students in enhancing their cognitive engagement level in teaching and learning the concepts of function, limit, and continuity. As the researcher was involved in the experiments, he observed students in the experimental group who were more active, creative, satisfied, had increased confidence, and enjoyed learning. In addition, the study also suggests that the Wolfram experts and policymakers' framework for mathematics curriculum incorporates the software. Further research is also invited on the topic with qualitative or mixed methods at different levels of the educational system. The study was limited to a small group of students, so additional research is needed at various levels of college and university in similar content. The study was limited to grade 11, with only two institutional schools, with a short intervention period of two weeks on the derivative topic of calculus, which may affect the generalizability of the findings. Thus, Future research could extend the study by including larger and more diverse samples across multiple educational levels and institutions to enhance generalizability.

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