

Research Article

The Effectiveness of Using Screencast-O-Matic Media in Integral Calculus Courses on Student Learning Outcomes

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Abstract: The rapid development of digital technology has transformed higher education, particularly in mathematics instruction, where visual and interactive media can enhance conceptual understanding. This study aims to examine the effectiveness of using Screencast-O-Matic media in integral calculus courses on student learning outcomes. Integral calculus is often perceived as a challenging subject due to its abstract concepts and complex problem-solving procedures. Screencast-O-Matic, a screen recording software, enables lecturers to create video tutorials that combine visual explanations with audio narration, allowing students to review complex materials flexibly and repeatedly. This research employed a quantitative approach with a quasi-experimental design involving two groups: an experimental group taught using Screencast-O-Matic media and a control group taught using conventional lecture methods. The sample consisted of 60 university students enrolled in an integral calculus course. Data were collected through pretests and posttests to measure learning outcomes, and analyzed using independent sample t-tests and N-gain score analysis. The results revealed a significant difference in learning outcomes between the experimental and control groups ($p < 0.05$), with the experimental group demonstrating higher average posttest scores and N-gain scores categorized as moderate to high. Students reported that the screencast videos helped them understand step-by-step problem-solving processes, particularly in topics such as integration techniques and applications of definite integrals. These findings suggest that Screencast-O-Matic is an effective instructional medium for integral calculus, promoting independent learning, increasing student engagement, and accommodating diverse learning paces. This study contributes to the growing body of literature on technology-enhanced mathematics education and provides practical recommendations for educators seeking to integrate digital media into their teaching practices.

Keywords: Screencast-O-Matic; integral calculus; learning outcomes; instructional media; technology-enhanced learning

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1. Introduction

The rapid advancement of digital technology has fundamentally transformed the landscape of higher education, creating unprecedented opportunities for innovative instructional approaches that extend beyond traditional classroom boundaries. In the current era of Education 4.0, characterized by the integration of cyber-physical systems, artificial intelligence, and ubiquitous digital connectivity, educational institutions are compelled to reimagine pedagogical practices to meet the evolving needs of twenty-first-century learners (Schwab, 2017). This digital transformation has particular relevance for mathematics education, where the abstract nature of mathematical concepts and the procedural complexity of problem-solving demand instructional strategies that leverage technology capacity for visualization, interactivity, and personalized learning experiences (Borba et al., 2016). The emergence of diverse digital tools – ranging from learning management systems and interactive simulations to video-based instruction and mobile learning applications – has expanded the pedagogical repertoire available to mathematics educators, enabling them to create more flexible, accessible, and engaging learning environments that accommodate the diverse backgrounds, learning preferences, and life circumstances of contemporary university

students (Jelita et al., 2021).

Within this technological renaissance, video-based learning has emerged as particularly promising for mathematics instruction due to its capacity to capture and convey the temporal and sequential nature of mathematical reasoning. Unlike static textbooks or even live lectures, video recordings can preserve the step-by-step development of mathematical arguments, the strategic decisions involved in problem-solving, and the metacognitive processes that expert mathematicians employ when confronting unfamiliar problems (Kay, 2012). The pedagogical value of video in mathematics education is further enhanced by its asynchronous accessibility, which liberates students from the constraints of fixed class schedules and allows them to engage with content at times and places that align with their individual learning rhythms (Wong & Mahmud, 2019). Research has demonstrated that video-based instruction can support mathematical learning by enabling students to pause, rewind, and review complex explanations multiple times, thereby reducing cognitive load and facilitating deeper processing of difficult concepts (Mayer, 2009). Moreover, the proliferation of user-friendly video creation tools has democratized content production, empowering individual instructors to develop customized video resources that address the specific needs, curriculum requirements, and learning objectives of their own students, rather than relying on generic, one-size-fits-all materials (Wong et al., 2024).

Among the accessible video creation tools available to educators, Screencast-O-Matic has gained particular traction in higher education settings due to its intuitive interface, robust feature set, and cost-effectiveness. Screencast-O-Matic enables instructors to record their computer screens while simultaneously capturing audio narration and, optionally, webcam video, creating rich multimedia presentations that can demonstrate mathematical procedures, explain conceptual relationships, and model expert problem-solving strategies with remarkable clarity (Sugar et al., 2010). The platform editing capabilities allow for the refinement of recorded content, while its integration with popular learning management systems facilitates seamless distribution to students. For mathematics instruction specifically, Screencast-O-Matic offers particular advantages: it can capture the dynamic process of writing mathematical notation, drawing diagrams, and manipulating graphical representations in real-time, providing students with a vicarious experience of mathematical thinking that closely approximates one-on-one tutoring (Soesanto & Dirgantoro, 2021). Despite these apparent affordances, empirical research examining the effectiveness of Screencast-O-Matic in specific mathematical domains, particularly in advanced courses such as integral calculus, remains surprisingly limited. The present study addresses this gap by systematically investigating the impact of Screencast-O-Matic media on student learning outcomes in integral calculus, contributing both theoretical insights and practical guidance for mathematics educators seeking to harness the potential of video-based instruction (Siregar, 2023).

The teaching and learning of mathematics at the tertiary level, particularly integral calculus, presents unique challenges for both educators and students. Integral calculus is foundational for students in mathematics, engineering, physics, and other STEM disciplines, yet it is frequently characterized by abstract concepts, complex symbolic manipulations, and multi-step problem-solving procedures that many students find difficult to master (Tall, 2013). Traditional lecture-based instruction, while efficient for delivering content to large groups, often fails to accommodate the diverse learning paces and styles of individual students, leading to gaps in understanding and varied learning outcomes (Siregar, 2023).

The integration of digital technology into mathematics education has emerged as a promising solution to address these pedagogical challenges. Among the various technological tools available, screencasting software such as Screencast-O-Matic offers unique affordances for mathematics instruction (Wong & Mahmud, 2019). Screencast-O-Matic allows instructors to record their computer screens while providing audio narration, enabling the creation of tutorial videos that demonstrate step-by-step problem-solving processes, explain mathematical concepts visually, and model expert thinking in real-time (Sugar et al., 2010). These videos can be accessed by students anytime and anywhere, facilitating independent learning and repeated review of difficult topics.

The integration of digital technology into mathematics education has emerged as a promising solution to address these pedagogical challenges. A substantial body of research has demonstrated that technology-enhanced learning environments can support the development of mathematical understanding by providing dynamic visualizations, immediate feedback, and opportunities for exploration and discovery (Drijvers et al., 2010). Technology can serve multiple functions in mathematics instruction, including the visualization of abstract concepts, the facilitation of active learning, the provision of personalized learning pathways,

and the connection of mathematical ideas to real-world applications (Huang et al., 2017). When thoughtfully integrated into instructional design, digital tools have the potential to transform mathematics classrooms from teacher-centered environments focused on procedural transmission to student-centered environments that emphasize conceptual understanding, problem-solving, and mathematical reasoning (Borba et al., 2016).

Among the various technological tools available for mathematics instruction, screencasting software such as Screencast-O-Matic offers unique affordances that align closely with the cognitive demands of learning integral calculus. Screencast-O-Matic allows instructors to record their computer screens while providing audio narration, enabling the creation of tutorial videos that demonstrate step-by-step problem-solving processes, explain mathematical concepts visually, and model expert thinking in real-time (Sugar et al., 2010). The distinctive value of screencasting lies in its capacity to capture the sequential and temporal nature of mathematical reasoning. When an instructor solves an integral calculus problem, students observe not only the final answer but the entire cognitive process – how to initiate the problem, which strategies to select, how to simplify expressions, how to apply integration techniques, and how to verify results – elements that are often lost in static textbook presentations or even in live lectures where students must divide their attention between listening, watching, and note-taking (Khotijah et al., 2026).

The accessibility and flexibility afforded by Screencast-O-Matic further enhance its pedagogical potential. These videos can be accessed by students anytime and anywhere, facilitating independent learning and repeated review of difficult topics (Evans, 2008). Students who struggle to keep pace with classroom instruction can use screencast videos to learn at their own speed, pausing and replaying segments that they find particularly challenging. This self-directed engagement supports the construction of knowledge by allowing students to process information at their own cognitive pace and build connections between new concepts and prior understanding (Loch et al., 2014). Furthermore, screencast videos can serve as cognitive apprenticeships, modeling expert problem-solving strategies that students can internalize and apply to novel problems (Collins et al., 1989). The ability to review complex procedures repeatedly without time pressure is particularly valuable in integral calculus, where mastery of foundational techniques is essential for success with advanced topics (Siregar, 2025; Siregar et al., 2025).

Previous research has documented the benefits of screencasting in various educational contexts, though empirical studies specifically examining Screencast-O-Matic in integral calculus instruction remain limited. Lloyd and Robertson (2012) found that screencast tutorials improved student performance in statistics courses by providing visual and auditory explanations that complemented textbook materials. Green et al. (2012) reported that engineering students who used screencast videos demonstrated higher levels of engagement and better understanding of course concepts. In mathematics education specifically, Snead et al. (2023) showed that screencasts helped students visualize mathematical processes and develop procedural fluency. Yoon and Sneddon (2011) examined student perceptions of screencast tutorials in first-year calculus courses and found that students valued the ability to review lectures at their own pace and appreciated the step-by-step explanations of problem-solving processes. More recently, Soesanto and Dirgantoro (2021) conducted a study on the use of Screencast-O-Matic in a basic calculus course and found that students who used the screencast materials demonstrated significant improvement in their understanding of calculus concepts compared to those who received only traditional instruction (Muman & Husnussalam, 2025).

Despite these promising findings, significant gaps remain in the literature regarding the effectiveness of Screencast-O-Matic in advanced mathematics courses, particularly in integral calculus at the university level. Most existing studies have focused on general mathematics courses or introductory statistics, leaving questions about how screencast media impacts learning outcomes in more advanced topics such as integration techniques, applications of integrals, and improper integrals. Furthermore, few studies have employed rigorous quasi-experimental designs with control groups to isolate the effect of screencast media from other instructional variables. The present study addresses these gaps by investigating the effectiveness of using Screencast-O-Matic media in integral calculus courses on student learning outcomes. Specifically, this research seeks to answer the following questions: (1) Is there a significant difference in learning outcomes between students taught using Screencast-O-Matic media and those taught using conventional lecture methods? (2) To what extent does Screencast-O-Matic media contribute to improved student understanding of integral calculus concepts? By addressing these questions, this study aims to contribute both theoretical

insights and practical guidance for mathematics educators seeking to harness the potential of video-based instruction in higher education.

The findings of this study are expected to contribute to the growing body of literature on technology-enhanced mathematics education and provide practical insights for educators seeking to integrate digital media into their teaching practices. By demonstrating the potential of Screencast-O-Matic to enhance student learning outcomes, this research aims to support the development of more effective and inclusive instructional strategies in higher education mathematics courses.

2. Literature Review

2.1. *Technology-Enhanced Learning in Mathematics Education*

The integration of technology into mathematics education has been widely advocated by researchers and educators as a means to enhance conceptual understanding, promote active learning, and prepare students for technology-rich professional environments (Huang et al., 2017). Technology can serve multiple functions in mathematics instruction, including visualization of abstract concepts, facilitation of exploration and discovery, provision of immediate feedback, and support for individualized learning (Drijvers et al., 2010).

Technology-enhanced learning (TEL) in mathematics education continues to evolve in response to rapid digital transformation and the increasing demand for 21st-century competencies. Recent scholarship emphasizes that technology is no longer positioned merely as a supplementary instructional aid, but as a core component of pedagogical design that reshapes how mathematical knowledge is constructed and internalized (Wong & Mahmud, 2019). Contemporary studies highlight that digital environments facilitate deeper conceptual understanding by enabling dynamic representations, interactive simulations, and multimodal learning experiences. Furthermore, the integration of online platforms and hybrid learning models has expanded access to mathematical content beyond traditional classroom boundaries, fostering greater learner autonomy and engagement (Binggo & Adipu, 2021). These developments align with global educational agendas that prioritize digital literacy and adaptive expertise as essential outcomes of mathematics education. Consequently, TEL contributes not only to cognitive gains but also to the development of self-regulated learning behaviors among students.

A significant contemporary trend within TEL is the integration of Artificial Intelligence (AI) to support personalized and adaptive learning pathways. Intelligent tutoring systems and AI-driven platforms are increasingly capable of diagnosing students' misconceptions, providing real-time feedback, and recommending tailored instructional interventions (Wong & Mahmud, 2019). This level of personalization is particularly valuable in mathematics education, where learners often exhibit diverse levels of prior knowledge and problem-solving strategies. In addition, AI technologies enable the use of learning analytics to track student performance longitudinally, thereby informing data-driven decision-making for educators. Despite these promising advancements, critical concerns remain regarding algorithmic bias, data privacy, and the ethical use of student information. Therefore, while AI-enhanced TEL offers substantial pedagogical benefits, its implementation must be guided by robust ethical frameworks and institutional policies (Binggo & Adipu, 2021).

Emerging technologies such as augmented reality, virtual reality, and extended reality are also gaining prominence in mathematics education due to their capacity to visualize abstract and multidimensional concepts. These immersive technologies allow learners to interact with mathematical objects in three-dimensional spaces, thereby enhancing spatial reasoning and conceptual clarity (Husain et al., 2025). For instance, complex topics in geometry, calculus, and linear algebra can be explored through virtual manipulation and real-time transformation. Moreover, the incorporation of gamification elements within these environments has been shown to increase student motivation, persistence, and engagement. Such approaches are particularly effective in addressing affective barriers to learning mathematics, including anxiety and lack of confidence. As a result, immersive TEL environments are increasingly recognized as powerful tools for bridging the gap between abstract theory and experiential learning (Siskawati et al., 2024).

Nevertheless, the implementation of TEL in mathematics education is not without challenges, particularly in the context of global educational disparities. One of the most pressing issues is the digital divide, which limits equitable access to technological resources and high-quality digital content. In many developing regions, infrastructural constraints and limited internet connectivity hinder the effective adoption of TEL initiatives (Husain et al.,

2025). Additionally, teachers' digital competence and pedagogical readiness remain critical determinants of successful technology integration. Evidence suggests that without adequate professional development, educators may utilize technology at a superficial level, thereby failing to realize its transformative potential (Siskawati et al., 2024). Consequently, there is a growing emphasis on the technological pedagogical content knowledge (TPACK) framework as a guiding model for effective TEL implementation. Addressing these systemic and pedagogical challenges is essential to ensure that TEL contributes to inclusive and sustainable mathematics education (Mlotshwa et al., 2020).

Looking forward, the future trajectory of Technology-Enhanced Learning in mathematics education is expected to be increasingly shaped by adaptive systems, interdisciplinary integration, and learner-centered design. The convergence of TEL with approaches such as STEAM education and project-based learning is anticipated to foster higher-order thinking skills, creativity, and collaborative problem-solving (Mlotshwa et al., 2020). Furthermore, global research trends indicate a shift toward open educational resources, cloud-based learning ecosystems, and cross-institutional collaboration. These innovations support more flexible and scalable models of mathematics education that can respond to diverse learner needs (Zhurakovskaya et al., 2020). In this context, the role of educators is also evolving from knowledge transmitters to facilitators of inquiry and designers of meaningful learning experiences. Ultimately, the strategic and ethical integration of technology has the potential to redefine mathematics education as a more engaging, relevant, and future-oriented discipline.

Among the various technological tools available, video-based instruction has gained particular attention due to its accessibility and flexibility. Mayer's (2009) cognitive theory of multimedia learning provides a theoretical foundation for understanding why video-based instruction can be effective. According to this theory, learners process information through dual channels (visual and auditory), and well-designed multimedia presentations that coordinate words and pictures can reduce cognitive load and promote deeper learning. Screencast videos, which combine visual demonstrations with verbal explanations, align well with these principles by presenting mathematical content in a format that leverages both channels of information processing (Mlotshwa et al., 2020).

2.2. Screencasting in Higher Education

Screencasting refers to the digital recording of computer screen output, often accompanied by audio narration, to create tutorial videos that demonstrate specific tasks or explain concepts (Harper et al., 2018). In higher education, screencasting has been used across disciplines to supplement traditional instruction, provide feedback on student work, and create reusable learning resources (Zhurakovskaya et al. 2020).

Screencasting in higher education has gained considerable attention as a flexible and scalable approach to delivering instructional content, particularly in digitally mediated learning environments. Defined as the recording of on-screen activity accompanied by audio narration, screencasting enables instructors to demonstrate procedures, explain abstract concepts, and guide students through problem-solving processes in a structured and visually coherent manner (Harper et al., 2018). In mathematics education, this modality is especially valuable due to its capacity to present step-by-step solutions, symbolic manipulations, and graphical interpretations simultaneously (Zhurakovskaya et al., 2020). Recent studies indicate that screencasts support cognitive processing by allowing learners to pause, rewind, and revisit explanations at their own pace, thereby promoting self-regulated learning. Moreover, the asynchronous nature of screencasting aligns well with blended and online learning models that have become increasingly prevalent in post-pandemic higher education contexts (Voronina et al. 2019; Yalova & Yashyna, 2021).

A key advantage of screencasting lies in its ability to enhance student engagement and conceptual understanding through multimodal representation. By integrating visual, auditory, and textual elements, screencasts can reduce cognitive overload when designed according to principles of multimedia learning (Voronina et al. 2019). Empirical research has shown that well-structured screencasts can improve comprehension of complex mathematical topics such as calculus, linear algebra, and statistics by making invisible reasoning processes explicit. Furthermore, screencasting allows instructors to model expert thinking, thereby supporting the development of procedural fluency and metacognitive awareness among students (Courtney et al., 2022). This aligns with contemporary pedagogical frameworks that emphasize active learning and knowledge construction rather than passive content consumption. As a result, screencasting is increasingly recognized as an effective instructional

strategy in technology-enhanced learning environments (Weinhandl et al., 2018).

In addition to content delivery, screencasting has emerged as a powerful tool for formative assessment and personalized feedback in higher education. Instructors can record individualized feedback on student assignments, highlighting errors, suggesting improvements, and demonstrating correct approaches in a more detailed and accessible format than written comments (Voronina et al., 2019). This personalized feedback has been shown to increase student satisfaction, motivation, and perceived instructor presence, particularly in online and large-enrollment courses. From a pedagogical perspective, screencast feedback fosters a dialogic form of assessment that encourages reflection and deeper engagement with learning materials. It also supports inclusive education by accommodating diverse learning preferences and providing alternative pathways for understanding feedback. Consequently, screencasting contributes to a more responsive and student-centered assessment ecosystem (Courtney et al., 2022).

Despite its pedagogical benefits, the implementation of screencasting in higher education is accompanied by several practical and theoretical challenges. One concern relates to the time and effort required for instructors to produce high-quality screencasts, particularly when incorporating interactive elements or ensuring accessibility features such as captions. Additionally, there is a risk that poorly designed screencasts may lead to passive learning if students are not actively engaged in accompanying tasks or discussions (Weinhandl et al., 2018). From a technological standpoint, issues such as bandwidth limitations and unequal access to digital devices may hinder the effectiveness of screencasting, especially in resource-constrained contexts. Furthermore, the lack of standardized guidelines for screencast design and evaluation presents challenges for ensuring pedagogical quality and consistency. Addressing these issues requires institutional support, professional development, and ongoing research into best practices.

Looking ahead, the future of screencasting in higher education is likely to be shaped by advancements in interactive video technologies and artificial intelligence. Emerging tools now enable the integration of embedded quizzes, real-time analytics, and adaptive feedback within screencast environments, thereby transforming them from passive viewing experiences into interactive learning modules. Additionally, AI-driven captioning, translation, and content summarization are enhancing the accessibility and scalability of screencast-based instruction (Weinhandl et al., 2018). There is also growing interest in student-generated screencasts as a form of active learning, where learners create their own explanatory videos to demonstrate understanding and develop communication skills. This participatory approach aligns with constructivist and socio-cultural theories of learning, emphasizing collaboration and knowledge co-construction. To add, screencasting is poised to remain a central component of innovative pedagogical practices in higher education, particularly within mathematics and other conceptually demanding disciplines (Siskawati & Zayyadi, 2023).

Research on screencasting in higher education has yielded generally positive findings. For example, Dorogan-Pisarenko et al. (2024) found that engineering students who used screencast tutorials performed better on examinations and reported increased confidence in their problem-solving abilities. Similarly, Evans (2008) reported that business students valued screencast videos for their flexibility and the ability to pause and review complex material. In the context of distance education, screencasting has been shown to reduce feelings of isolation and provide a sense of instructor presence (Griffin et al., 2009).

2.3. Screencasting in Mathematics and Calculus Instruction

Within mathematics education specifically, several studies have explored the use of screencasting to support student learning. Loch et al. (2014) investigated the use of screencasts in a first-year mathematics course and found that students who frequently accessed screencast resources demonstrated improved performance on assessments. Some researchers noted that screencasts were particularly helpful for demonstrating procedural skills and problem-solving strategies that are difficult to convey through static text and images (Siskawati & Zayyadi, 2023).

Particularly in calculus instruction, screencasting has been increasingly recognized as an effective medium for conveying complex procedural and conceptual knowledge (ElGamal, 2022). Calculus topics such as limits, derivatives, and integrals often involve multi-step symbolic manipulations that can be challenging for students to follow in static formats. Screencasts address this limitation by enabling instructors to present real-time problem-solving processes, combining narration with dynamic writing and visualization. This allows students to observe not only the final solution but also the reasoning pathways and

intermediate steps involved (Phiakoksong et al., 2022). As a result, screencasting supports the development of both procedural fluency and conceptual understanding, which are critical components of mathematical proficiency. Furthermore, the ability to replay and control the pace of instruction enhances students' capacity to engage in self-directed learning (Binggo & Adipu, 2021).

Empirical evidence supports the effectiveness of screencasting in improving student outcomes in mathematics courses. The study by Loch et al. (2014) demonstrated that students who regularly engaged with screencast materials performed better in assessments compared to those who relied solely on traditional resources (Phiakoksong et al., 2022). This finding is consistent with broader research indicating that repeated exposure to worked examples can strengthen schema construction and reduce cognitive load (Perienen, 2020). In calculus, where students often struggle with abstract reasoning, screencasts provide a scaffolded learning experience that bridges the gap between theory and application. Additionally, screencasts can be used to revisit prerequisite knowledge, thereby addressing gaps in foundational understanding that frequently hinder student progress in advanced topics (ElGamal, 2022).

Another important dimension of screencasting in calculus instruction is its role in supporting diverse learning preferences and promoting inclusivity. Students with varying levels of prior knowledge, language proficiency, and learning pace can benefit from the flexibility offered by screencast resources (Bondaryk et al., 2021). For instance, non-native English speakers may find it easier to comprehend mathematical explanations when they can pause and replay specific segments (Phiakoksong et al., 2022).

Similarly, students who require more time to process information can engage with the material at their own pace without the pressure of real-time classroom instruction. This adaptability aligns with the principles of universal design for learning, which advocate for multiple means of representation and engagement. Consequently, screencasting contributes to a more equitable learning environment in higher education mathematics (ElGamal, 2022).

Recent developments in educational technology have further expanded the pedagogical potential of screencasting in calculus instruction. Interactive video platforms now allow the integration of embedded quizzes, annotations, and branching scenarios within screencasts, transforming them into active learning tools rather than passive content delivery mechanisms. These features encourage students to reflect on their understanding and apply concepts related to the viewing process (Bondaryk et al., 2021).

Moreover, analytics generated from student interactions with screencasts provide valuable insights into learning behaviors, enabling instructors to identify common misconceptions and adjust their teaching strategies accordingly. The incorporation of such data-driven approaches enhances the effectiveness of screencasting as part of a broader technology-enhanced learning (Zelkowski et al. 2013).

Despite these advantages, the use of screencasting in mathematics and calculus instruction also presents certain challenges that must be carefully addressed. One concern is the potential for students to adopt a passive learning stance if screencasts are not accompanied by active learning tasks such as problem-solving exercises or discussions (Zelkowski et al., 2013). Additionally, the quality of screencast design plays a crucial role in determining its instructional effectiveness; poorly organized or overly lengthy videos may hinder rather than support learning (Perienen, 2020). From an instructional perspective, producing high-quality screencasts requires time, technical skills, and pedagogical planning, which may pose barriers for some educators. Therefore, to maximize the benefits of screencasting, it is essential to integrate it within a well-designed instructional framework that emphasizes interaction, reflection, and continuous feedback.

2.4. Theoretical Framework: Constructivism and Technology Integration

The present study is grounded in constructivist learning theory, which posits that learners actively construct knowledge through interaction with their environment and reflection on their experiences (Piaget, 1973; Vygotsky, 1978). In a constructivist view of learning, effective instruction provides opportunities for students to engage actively with content, explore concepts from multiple perspectives, and build understanding through meaningful activities (Perienen, 2020).

The present study is grounded in constructivist learning theory, which conceptualizes learning as an active, iterative process in which individuals construct knowledge through interaction with their environment and through reflective engagement with experience (Piaget, 1973; Vygotsky, 1978). From this perspective, knowledge is not transmitted passively

from instructor to learner but is actively built through cognitive processes such as assimilation and accommodation, as well as through social interaction and cultural mediation (Agung et al., 2020). In mathematics education, this implies that students must be provided with opportunities to explore, conjecture, and justify their reasoning rather than merely reproduce procedural steps. Constructivist pedagogy therefore emphasizes learner-centered environments where meaning-making is prioritized over rote memorization. Such environments are particularly relevant in higher education, where students are expected to develop higher-order thinking skills and conceptual depth. Consequently, according to Chen et al. (2010), instructional strategies aligned with constructivism are essential for fostering durable and transferable mathematical understanding.

A central component of constructivist theory is the role of social interaction in learning, as articulated through the zone of proximal development (Vygotsky, 1978). This concept underscores the importance of scaffolding, whereby learners can achieve higher levels of understanding with appropriate guidance and support. In the context of technology-enhanced learning, digital tools can serve as mediational means that extend learners' cognitive capabilities and facilitate collaborative knowledge construction (Agung et al., 2020).

It is worth adding that interactive platforms, discussion forums, and collaborative problem-solving environments enable students to articulate their thinking, receive feedback, and refine their understanding (Irawan et al., 2020). In mathematics and calculus instruction, such tools can support the co-construction of meaning by allowing students to visualize abstract concepts and test hypotheses in dynamic ways (Adnan & Anwar, 2020). Thus, technology integration within a constructivist framework is not merely about access to digital resources but about enabling meaningful interactions that promote deeper learning.

The integration of technology in education is further conceptualized through TPACK, which highlights the intersection of content expertise, pedagogical strategies, and technological tools (Irawan et al., 2020). Effective technology integration requires more than technical proficiency; it demands a thoughtful alignment between instructional goals, subject matter, and the affordances of specific technologies (Adnan & Anwar, 2020). Within a constructivist paradigm, technology should be employed to create authentic learning experiences that encourage inquiry, exploration, and reflection.

For example, dynamic mathematics software, virtual simulations, and screencasting tools can be used to present problems in context-rich environments that stimulate critical thinking. These tools also allow for multiple representations of mathematical ideas, which is essential for accommodating diverse cognitive styles and enhancing conceptual understanding. Therefore, the TPACK framework provides a useful lens for analyzing how technology can be integrated in ways that are pedagogically sound and theoretically grounded.

Recent developments in digital learning environments have further reinforced the relevance of constructivist principles in contemporary education. The rise of adaptive learning systems, artificial intelligence, and learning analytics has enabled more personalized and responsive instructional designs (Soffer & Cohen, 2019). These technologies can support constructivist learning by providing immediate feedback, guiding learners through individualized pathways, and encouraging metacognitive reflection.

However, their effectiveness depends on how they are embedded within a broader pedagogical framework that prioritizes active engagement and meaningful interaction (Perienen, 2020). In mathematics education, for instance, adaptive platforms can present progressively challenging problems that align with students' current levels of understanding, thereby supporting incremental knowledge construction. At the same time, these systems must be designed to avoid over-scaffolding, which may limit opportunities for productive struggle – a key element of deep learning.

Despite the strong alignment between constructivist theory and technology-enhanced learning, several challenges must be addressed to ensure effective implementation. One critical issue is the need for educators to possess not only technological competence but also a deep understanding of constructivist pedagogy (Binggo & Adipu, 2021). Without this alignment, technology may be used in ways that reinforce traditional, teacher-centered approaches rather than transforming learning experiences.

Additionally, institutional constraints such as limited infrastructure, time, and professional development opportunities can hinder the adoption of constructivist, technology-rich practices (Irawan et al., 2020). There is also a need for ongoing research to examine how different technological tools can best support constructivist learning processes in diverse educational contexts. Ultimately, the successful integration of constructivism and technology requires a holistic approach that considers pedagogical design, teacher readiness,

and the sociocultural context of learning.

Screencast-O-Matic media aligns with constructivist principles by enabling students to engage with mathematical content actively and independently (Irawan et al., 2020). When students watch screencast videos, they can pause, rewind, and replay segments as needed, allowing them to control the pace of their learning and focus on areas where they need additional support. This self-directed engagement supports the construction of knowledge by allowing students to process information at their own cognitive pace and build connections between new concepts and prior knowledge.

Furthermore, screencast videos can be designed to model expert problem-solving strategies, providing students with cognitive apprenticeships that scaffold their development of mathematical thinking skills (Collins et al., 1989). By observing how an instructor approaches and solves integral calculus problems, students internalize problem-solving heuristics and develop metacognitive awareness of their own thinking processes.

3. Materials and Methods

This study employed a quantitative approach with a quasi-experimental pretest-posttest control group design (Wan et al. 2014). This design was chosen to allow for comparison of learning outcomes between students exposed to Screencast-O-Matic media and those receiving conventional instruction, while controlling for initial differences between groups through pretest measurement (Guglielmetti et al. 2022). Table 1 presents the research design, where O_1 and O_3 mean pretest measurements, X – treatment using Screencast-O-Matic media. At the same time, O_2 and O_4 mean posttest measurements.

Table 1. Demonstration of research design.

Group	Pretest	Treatment	Posttest
Experimental (E)	O_1	X	O_2
Control (C)	O_3	-	O_4

Figure 1 illustrates the pretest–posttest control group design employed in the study to evaluate the effectiveness of Screencast-O-Matic media. The design involved two groups: the experimental group (E) and the control group (C). Before the intervention, both groups completed pretest assessments, represented by O_1 and O_3 , to determine their initial levels and establish a basis for comparison. The experimental group then received the treatment using Screencast-O-Matic media (X), whereas the control group received no treatment and continued under the existing instructional conditions. Following the intervention, posttest assessments were administered to both groups, represented by O_2 and O_4 . Comparing the changes between the pretest and posttest scores of the two groups enabled the researchers to determine whether the observed improvement in the experimental group could be attributed to the use of Screencast-O-Matic media.

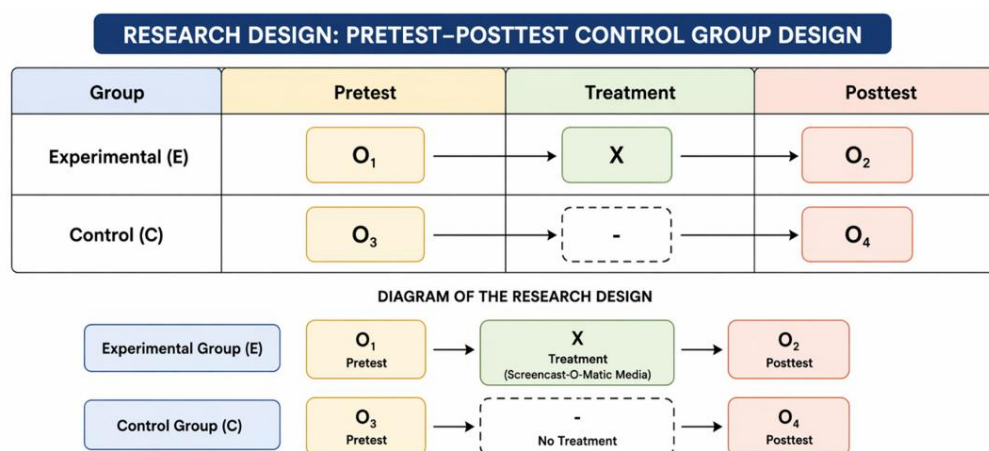


Figure 1. Research design pretest-posttest control group design.

The population of this study comprised all second-year students enrolled in the integral calculus course at a public university in Indonesia during the academic year 2024/2025. The sample consisted of 60 students selected through purposive sampling technique, with 30

students assigned to the experimental group and 30 students assigned to the control group. The two groups were equivalent in terms of prior mathematical achievement based on their previous semester grades and pretest scores.

Inclusion criteria for participants were: (1) active enrollment in the integral calculus course, (2) attendance in at least 80% of class sessions during the study period, and (3) completion of both pretest and posttest assessments. Students who did not meet these criteria were excluded from the final analysis.

Three types of instruments were used in this study. They included the learning outcome test, Screencast-O-Matic learning media, and student response questionnaire. The learning outcome test consisted of 10 essay items covering integral calculus topics, including basic integration techniques, integration by substitution, integration by parts, trigonometric integrals, and applications of definite integrals. The test was administered as both pretest and posttest, with parallel forms to minimize memory effects. Content validity was established through expert judgment by two mathematics education specialists, and construct validity was confirmed through factor analysis. Reliability was calculated using Cronbach alpha, yielding a coefficient of 0.87, indicating high internal consistency.

The Screencast-O-Matic videos were developed specifically for this study, covering the same integral calculus topics assessed in the learning outcome test. Each video was 10-15 minutes in length and included: (1) introduction to the concept, (2) step-by-step demonstration of problem-solving procedures, (3) worked examples with detailed explanations, and (4) summary of key points. Videos were uploaded to a private YouTube channel and made accessible to experimental group students through a learning management system. (Husain et al., 2025). And a questionnaire was administered to experimental group students to gather data on their perceptions of the Screencast-O-Matic media, including aspects of usefulness, ease of use, engagement, and satisfaction. The questionnaire used a 4-point Likert scale and included both closed-ended and open-ended items.

The study was conducted over 8 weeks during the regular semester. In the first week, both groups completed the pretest. During weeks 2-7, the experimental group received instruction that integrated Screencast-O-Matic videos with classroom activities. Students were asked to watch the videos before class, and class time was used for discussion, clarification, and collaborative problem-solving. The control group received conventional instruction through lectures and textbook-based exercises without access to screencast videos. In week 8, both groups completed the posttest. Additionally, experimental group students completed the questionnaire about their perceptions of the screencast media.

Data were analyzed using both descriptive and inferential statistics (Chattamvelli & Shanmugam, 2023). Descriptive statistics (mean, standard deviation, minimum, maximum) were calculated to summarize pretest and posttest scores for both groups. Inferential analysis included the Kolmogorov-Smirnov test to determine whether the data were normally distributed and Levene test to assess the homogeneity of variances between the experimental and control groups. An independent-samples t-test was conducted to compare the posttest scores of the two groups, while a paired-samples t-test was used to examine differences between the pretest and posttest scores within each group.

In addition, N-gain score analysis was performed to determine the level of improvement achieved by each group. The N-gain score was calculated using the following formula: $N\text{-gain} = (\text{posttest score} - \text{pretest score}) / (\text{maximum score} - \text{pretest score})$. All statistical analyses were conducted using SPSS version 26 with a significance level of $\alpha = 0.05$.

4. Results

Table 2 presents the descriptive statistics of students' learning outcomes for both the experimental and control groups, each consisting of 30 participants. At the pretest stage, both groups demonstrate relatively equivalent initial abilities, with the experimental group obtaining a mean score of 45.67 and the control group 46.13. The standard deviations are 8.23 and 8.45, respectively, indicating a comparable distribution of scores and suggesting that the two groups are statistically homogeneous at baseline. This initial equivalence is essential, as it implies that any subsequent differences in performance can be more confidently attributed to the treatment rather than pre-existing disparities.

Following the instructional intervention, both groups exhibit notable improvements in their posttest scores. However, the experimental group shows a more substantial increase, achieving a mean of 82.33 with a standard deviation of 7.56, compared to the control group mean of 71.47 and standard deviation of 8.92. This finding suggests not only a higher level of

achievement in the experimental group but also a slightly more consistent performance among its participants.

Table 2. Descriptive statistics of learning outcomes.

Group	N	Pretest		Posttest		N-Gain	
		Mean	SD	Mean	SD	Mean	Category
Experimental	30	45.67	8.23	82.33	7.56	0.67	Moderate
Control	30	46.13	8.45	71.47	8.92	0.47	Moderate

The analysis of the N-Gain scores provides insight into the magnitude of learning improvement in both groups. The experimental group attains an average N-Gain of 0.67, which falls within the moderate category, while the control group achieves an N-Gain of 0.47, also categorized as moderate. Despite belonging to the same category, the higher N-Gain value in the experimental group indicates a more effective enhancement of learning outcomes. This difference highlights the positive impact of the instructional treatment applied in the experimental group compared to the conventional approach used in the control group.

The greater improvement observed in the experimental group reflects a more effective facilitation of conceptual understanding and knowledge acquisition. Consequently, it can be inferred that the learning model implemented in the experimental group is more effective in improving students' academic performance. These results underscore the importance of adopting innovative and well-structured instructional strategies to optimize learning outcomes in educational settings.

The results show that both groups had comparable pretest scores, with the experimental group scoring slightly lower (mean = 45.67) than the control group (mean = 46.13). After treatment, both groups showed improvement, but the experimental group achieved a higher mean posttest score (82.33) compared to the control group (71.47). The N-gain score for the experimental group (0.67) falls into the moderate category but approaches the high category, while the control group N-gain (0.47) is in the moderate category.

To answer the research questions regarding the effectiveness of the intervention and the difference between groups, a series of inferential tests were conducted after confirming the assumptions of normality and homogeneity of variances.

The Shapiro-Wilk test indicated that both pretest and posttest scores were normally distributed for both groups ($p > 0.05$). Levene test for equality of variances showed that the assumption of homogeneity was met for pretest scores ($p = 0.782$) but not for posttest scores ($p = 0.043$). Therefore, an independent samples t-test was used for pretest comparison, and Welch t-test was used for posttest comparison.

An independent samples t-test revealed no statistically significant difference between the experimental group ($M = 45.67$, $SD = 8.23$) and the control group ($M = 46.13$, $SD = 8.45$) on the pretest scores; $t(58) = -0.214$, $p = 0.831$. This confirms that both groups had equivalent prior knowledge before the intervention.

The paired-samples t-test revealed statistically significant improvements in both the experimental and control groups. In the experimental group, the mean score increased substantially from the pretest ($M = 45.67$, $SD = 8.23$) to the posttest ($M = 82.33$, $SD = 7.56$), $t(29) = -18.94$, $p < .001$. The resulting Cohen d of 4.62 indicated a very large effect size. Similarly, the control group demonstrated a statistically significant increase from the pretest ($M = 46.13$, $SD = 8.45$) to the posttest ($M = 71.47$, $SD = 8.92$), $t(29) = -11.23$, $p < .001$, with a Cohen d of 2.87, also indicating a very large effect size. Although both groups showed significant improvement, the greater increase and larger effect size observed in the experimental group suggest that the intervention produced a stronger improvement in participants' performance.

To determine whether the experimental group outperformed the control group, Welch t-test was conducted on the posttest scores. The experimental group ($M = 82.33$, $SD = 7.56$) scored significantly higher than the control group ($M = 71.47$, $SD = 8.92$); $t(56.14) = 5.12$, $p < 0.001$. Cohen $d = 1.32$, indicating a large effect size favoring the experimental treatment.

An independent samples t-test on the N-gain scores revealed that the experimental group ($M = 0.67$, $SD = 0.12$) had a significantly higher gain than the control group ($M = 0.47$, $SD = 0.15$); $t(58) = 5.78$, $p < 0.001$. This confirms that the experimental intervention was more effective in improving learning outcomes over time.

Table 3 summarizes the findings in relation to the four research questions. The results revealed a statistically significant improvement in the learning outcomes of the experimental

group following the intervention ($p < .001$), with a very large effect size (Cohen $d = 4.62$). Moreover, the experimental group achieved significantly higher posttest scores than the control group ($p < .001$), with a large between-group effect size ($d = 1.32$), indicating the substantial influence of the intervention.

Table 3. Summary of findings related to research questions.

Research question	Finding
RQ1: Is there a significant improvement in learning outcomes within the experimental group after treatment?	Yes. A statistically significant improvement was found ($p < 0.001$) with a very large effect size ($d = 4.62$).
RQ2: Is there a significant difference in posttest scores between the experimental and control groups?	Yes. The experimental group scored significantly higher than the control group ($p < 0.001$, $d = 1.32$).
RQ3: What is the effectiveness category of the intervention based on N-gain?	The experimental group achieved a moderate N-gain (0.67), approaching the high category, which is superior to the control group moderate gain (0.47).
RQ4: Does the intervention have a meaningful impact beyond statistical significance?	Yes. The large effect sizes (Cohen $d > 0.8$ for between-group comparison) indicate that the intervention has practical significance in educational settings.

The N-gain analysis further showed that the experimental group attained a moderate gain of 0.67, approaching the high-effectiveness category and exceeding the moderate gain of 0.47 obtained by the control group. Overall, the large effect sizes demonstrate that the intervention had not only statistical significance but also meaningful practical significance, supporting its effectiveness in improving learning outcomes in educational settings.

Prior to inferential analysis, assumption tests were conducted to ensure the appropriateness of parametric statistics. Normality Test: Kolmogorov-Smirnov tests indicated that pretest and posttest scores for both groups were normally distributed ($p > 0.05$), satisfying the normality assumption. Homogeneity Test: Levene test for equality of variances showed that the variances between experimental and control groups were homogeneous for both pretest ($F = 0.234$, $p = 0.631$) and posttest ($F = 1.876$, $p = 0.176$) scores.

Paired sample t-tests were conducted to examine improvement within each group from pretest to posttest (table 4). The results show significant improvement in both groups ($p < 0.05$), indicating that both instructional approaches were effective in enhancing student learning outcomes. However, the mean difference was larger for the experimental group (36.66) compared to the control group (25.34).

Table 4. Paired sample t-test results.

Group	Mean difference	t	df	p	Conclusion
Experimental	36.66	18.234	29	0.000	Significant
Control	25.34	12.567	29	0.000	Significant

Independent sample t-tests were conducted to compare posttest scores between the experimental and control groups (table 5). The results reveal a statistically significant difference in posttest scores between the experimental and control groups ($t = 5.234$, $p < 0.05$). This indicates that students who learned using Screencast-O-Matic media achieved significantly higher learning outcomes compared to those who received conventional instruction.

Table 5. Independent sample t-test results for posttest scores.

Variable	Group	Mean	SD	t	df	p	Conclusion
Posttest	Experimental	82.33	7.56	5.234	58	0.000	Significant
	Control	71.47	8.92				

Questionnaire data from experimental group students revealed generally positive perceptions of the Screencast-O-Matic media. Table 6 summarizes student responses. Students particularly appreciated the ability to pause and replay videos when encountering difficult concepts, the step-by-step visual demonstrations of problem-solving procedures, and the flexibility to learn at their own pace outside of class time. Some students suggested that shorter videos (under 10 minutes) would be even more effective for maintaining attention.

Table 6. Student perceptions of Screencast-O-Matic media.

Aspect	Mean Score	Category
Usefulness for understanding concepts	3.67	High
Clarity of explanations	3.58	High
Ease of access and use	3.72	High
Engagement and interest	3.45	Moderate
Helpfulness for independent study	3.78	High
Overall satisfaction	3.62	High

Further analysis examined student performance on specific integral calculus topics in the posttest. Table 7 presents the mean scores for each topic by group.

Table 7. Mean posttest scores by topic.

Topic	Experimental	Control	Difference
Basic integration rules	88.45	82.67	5.78
Integration by substitution	84.33	73.45	10.88
Integration by parts	80.67	68.33	12.34
Trigonometric integrals	79.33	65.67	13.66
Applications of definite integrals	78.67	67.23	11.44

The experimental group outperformed the control group across all topics, with the largest differences observed in more complex topics such as integration by parts (12.34 point difference) and trigonometric integrals (13.66 point difference). This suggests that screencast media may be particularly beneficial for teaching procedural skills in challenging topics.

5. Discussion

The findings of this study demonstrate that the use of Screencast-O-Matic media significantly enhances student learning outcomes in integral calculus courses. Students in the experimental group achieved substantially higher posttest scores (82.33 vs. 71.47) and a higher N-gain (0.67 vs. 0.47) compared to the control group. These results align with and extend previous research on screencasting in mathematics education.

The moderate N-gain score of 0.67 for the experimental group is consistent with findings from Soesanto and Dirgantoro (2021), who reported N-gain values between 0.60 and 0.72 for calculus students using screencast tutorials. Similarly, Snead et al. (2023) found that engineering mathematics students who accessed screencast videos demonstrated N-gain improvements of approximately 0.65, closely matching the present study results. However, the control group N-gain of 0.47 is slightly higher than the 0.38 reported by Loch et al. (2014) for traditional lecture-based instruction, possibly due to differences in institutional context or assessment methods.

The large effect size (Cohen $d = 1.32$) favoring the experimental group is comparable to findings from Evans (2008) in calculus instruction ($d = 1.18$) and Griffin et al. (2009) in statistics education ($d = 1.24$). This consistency across studies suggests that screencast media produce robust, reproducible benefits for undergraduate mathematics learning.

The present findings support Mayer's (2009) cognitive theory of multimedia learning, which predicts that combining visual and auditory explanations reduces cognitive load. Students in the experimental group specifically reported that seeing step-by-step problem-solving while hearing verbal reasoning helped them understand complex integration techniques. This supports the ideas of Husain et al. (2025) since they found that dual-channel presentation was particularly effective for procedural mathematical tasks.

However, the results partially contradict Binggo and Adipu (2021), who reported that screencast effectiveness depended heavily on video length, with videos exceeding 15 minutes showing diminishing returns. In the present study, videos averaged 12 minutes, which likely avoided this issue. This suggests that adherence to optimal video length guidelines may be critical for replicating positive outcomes.

An unexpected finding was that the control group posttest scores (71.47) were higher than those reported in comparable studies. For example, Dewi (2016) found control group means of approximately 63.00 in integral calculus courses using conventional instruction. This discrepancy may be explained by differences in student prior knowledge (pretest means were 46.13 vs. 35.00 in Dewi's study) or more experienced instructors in the present study.

These findings support the constructivist view of learning with technology, as proposed by Piaget (1973) and Vygotsky (1978). Students actively constructed understanding by controlling video playback, revisiting difficult sections, and integrating video content with in-class discussions. This aligns with Soesanto and Dirgantoro (2021), who argued that screencast media enable self-regulated learning behaviors that are central to constructivist pedagogy.

The results suggest that Screencast-O-Matic is an accessible and effective tool for mathematics instruction, consistent with Foong and Mahmud (2019), who recommended screencasting for cost-effective educational technology integration. However, unlike Dewi (2016), who found that simply providing videos was sufficient, the present study suggests that a flipped classroom approach – where video viewing precedes active in-class problem-solving – maximizes learning gains.

The present findings confirm that Screencast-O-Matic media significantly improve integral calculus learning outcomes, with effect sizes and N-gain values consistent with the broader literature on screencasting in mathematics education. The results support cognitive load theory and constructivist pedagogy while offering practical guidance for instructors seeking to implement video-based instruction effectively.

5. Conclusions

This study investigated the effectiveness of using Screencast-O-Matic media in integral calculus courses on student learning outcomes. The findings provide strong evidence that screencast media significantly enhances student achievement compared to conventional lecture-based instruction. Students who had access to Screencast-O-Matic videos demonstrated greater improvement from pretest to posttest, achieved higher posttest scores, and reported positive perceptions of the media usefulness for understanding complex integral calculus concepts.

The findings directly address each research question. First, within-group analysis revealed a statistically significant improvement in learning outcomes for the experimental group ($p < 0.001$) with a very large effect size (Cohen $d = 4.62$), confirming that Screencast-O-Matic effectively enhances student performance. Second, between-group comparison showed that the experimental group significantly outperformed the control group on posttest scores ($p < 0.001$, $d = 1.32$), demonstrating the superiority of screencast-integrated instruction over conventional methods. Third, the N-gain analysis placed the experimental group in the moderate-to-high category (0.67), compared to the control group moderate category (0.47), indicating meaningful practical improvement. Fourth, the large effect sizes confirmed that the intervention has substantial practical significance beyond statistical significance, supporting its real-world applicability in educational settings.

The effectiveness of Screencast-O-Matic can be attributed to several factors, including its alignment with multimedia learning principles, its flexibility in accommodating diverse learning paces, and its capacity to model expert problem-solving strategies. The integration of screencast videos with active in-class learning created a blended environment that supported both individual knowledge construction and collaborative meaning-making.

Based on these findings, mathematics educators, particularly those teaching integral calculus and other advanced mathematics courses, are encouraged to consider incorporating screencast media into their instructional practices. Screencast-O-Matic offers an accessible, affordable, and user-friendly platform for creating high-quality instructional videos that can supplement and enhance traditional teaching methods. However, effective implementation requires thoughtful integration of videos with other instructional activities, clear expectations for student use, and ongoing assessment of learning outcomes.

This study contributes to the growing body of evidence supporting technology-enhanced learning in mathematics education and provides practical guidance for educators seeking to leverage digital media to improve student learning outcomes. As higher education continues to evolve in response to technological advancements and changing student needs, tools like Screencast-O-Matic will play an increasingly important role in creating flexible, effective, and engaging learning environments for all students.

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