



Generative AI in Teaching and Learning: Benefits and Challenges

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Abstract. Recent advancements in Artificial Intelligence (AI), particularly Generative AI (GenAI), have brought both transformative opportunities and significant challenges to the future of teaching and learning practices. This article provides an overview of popular GenAI tools and explores strategies for integrating them into classroom instructions, their ethical considerations, and challenges. This work includes narratives of implementation demonstrating how specific GenAI tools were utilized by the authors, including the use of ChatGPT for drafting an assignment, NotebookLM for curating content, developing formative assessments, and providing study materials for students, and the application of AI-integrated assessment tools like Gradescope to streamline grading in large classes. In addition, we present a summary of guidelines for educators and institutions to ensure the responsible and effective use of GenAI in educational settings. While GenAI offers powerful possibilities for enhancing teaching and learning, the human element remains irreplaceable. The role of the teacher must shift from being the *sage on the stage* to the *guide on the side*, providing authentic, AI-enhanced learning experiences. To succeed in this evolving educational landscape and prepare for the future workforce, students require intrinsic motivation, emotional intelligence, and meaningful human connections, in addition to their technical skills.

Received: August 10, 2025 ; **Revised:** October 23, 2025; **Accepted:** October 30, 2025

Keywords: GenAI in teaching and learning, Transformative opportunity and challenges, Learning mechanism, Research-based instructional strategies, Irreplaceable human component in teaching, Holistic competency for future workforce, GenAI embedded classroom, ChatGPT, NotebookLM, Gradescope as an AI-assisted grading tool

INTRODUCTION

The rapid advancement of artificial intelligence (AI), particularly Generative AI (GenAI), is transforming industries and reshaping the job market in various ways. In education, GenAI offers both unprecedented opportunities and significant challenges, prompting a potential paradigm shift in how we teach, learn, and assess knowledge [1, 2]. Tools such as ChatGPT and NotebookLM, which are capable of generating text, images, code, podcasts, and other media like humans, are increasingly influencing classroom practices [3–5]. GenAI can be used to address students' diverse learning needs and styles, design interactive lesson plans, automate assessments, and bridge the digital resource gap for geographically and economically disadvantaged communities. However, it also has limitations, including biases, misinformation, data privacy concerns, and the risk for AI dependency [6]. While these innovations have the potential to enhance ed-

ucational access and personalization, they also require educators and institutions to address complex ethical, pedagogical, and assessment-related challenges. This article explores the mechanisms of learning, the evolution of teaching pedagogy, strategies for integrating GenAI into future classrooms, and the importance of the human element in an AI-enhanced educational landscape.

HOW DO WE LEARN?

Learning is a complex cognitive process, especially in academic settings [8]. In the early stage of human evolution, knowledge was transmitted to learners by oral communications, which evolved over time with significant advances driven by technologies such as the printing press. Formal education, which dates back over 5,000 years, has continually evolved to shape modern learning systems. Despite this progress, many universities

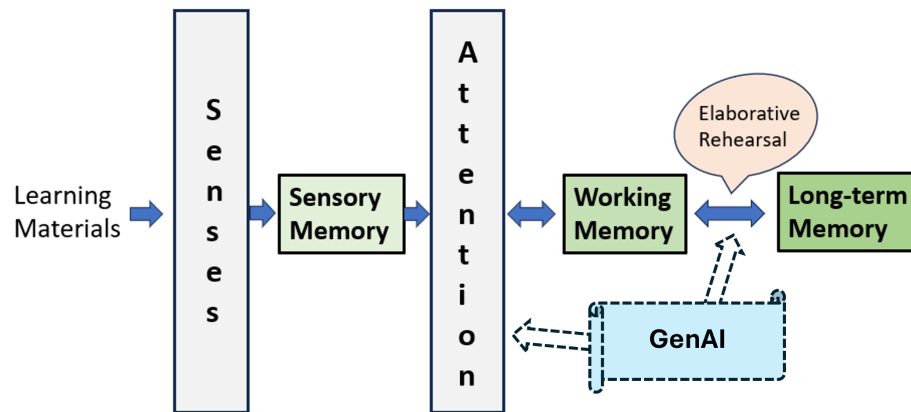


FIGURE 1: The key stages of learning mechanism adapted from Refs. [7, 9] with an added GenAI tool.

still rely on traditional lecture-based models where instructors remain dominant as a conveyor of information. While this approach has some advantages, research consistently shows that it limits deep learning. In traditional classrooms, students often sit passively and listen to the instructor, and lose attention after the first 10 minutes of a lecture. After about 20 minutes, their attention to detail decreases dramatically. As a result, material presented beyond that point will be ineffective, making both instruction and learning inefficient [7, 8].

To implement effective teaching and learning strategies, we must first understand the learning mechanism. The commonly accepted key stages in a learning process are identified as illustrated in Fig. 1. The information first enters sensory memory and, depending on the learner's attention, either moves into working memory (WM) or it is instantly lost. Through a process called iterative rehearsal, i.e., actively thinking about and applying new knowledge, information in WM can be transferred into long-term memory (LTM) [9]. Authentic learning occurs when learners can retrieve and apply this stored knowledge automatically and effortlessly across different contexts.

Two major challenges in this process are sustaining students’ attention and supporting effective rehearsal. These challenges can be addressed by implementing active learning strategies, such as short, Research-Based Instructional Strategies (RBIS) [10, 11], every 10 to 15 minutes, which have been shown to enhance student engagement and retention [8]. With GenAI, instructors can design class activities, link them to everyday examples, while students can generate practice exams and quizzes, debate answers, simplify course content for different learning levels, and translate learning materials into the language of their choice. These GenAI capabilities can enhance attention and foster elaborative rehearsal (see Fig. 1), increasing the likelihood of transferring information from WM to LTM. Thus, integrating GenAI

into teaching and learning (GenAI-TL) can strengthen authentic learning.

Expertise develops through sustained effort and practice. John Biggs' 3P model of learning (presage – process – product) highlights that students' perceptions play a key role in shaping their learning approaches and outcomes [12]. Therefore, understanding how students are increasingly using GenAI and integrating these insights into policy is essential in higher education.

EVOLUTION OF TEACHING PEDAGOGY WITH GENERATIVE AI

For the instructor to be an effective guide in the learning process, the blending of content knowledge, pedagogical knowledge, and technological knowledge is required, as described by the framework of technological pedagogical content knowledge (TPACK) [13, 14]. In other words, an instructor’s knowledge on what to teach, how to teach, and which instructional tools to use, are equally important. Recent technological advancements in AI, especially in GenAI, have offered tremendous opportunities in streamlining the teaching and learning process. GenAI is no longer just a tool; it can generate original content on request, act as a tutor, and collaborate with both students and teachers. In addition to the creation of the content knowledge (CK) and technological knowledge (TK), as shown in the left diagram of Fig. 2, GenAI is also capable of supporting the pedagogical knowledge (PK) of the TPACK model [15], as illustrated in the right diagram of Fig. 2. This means that GenAI can be used as an overarching tool to enhance the TPACK framework.

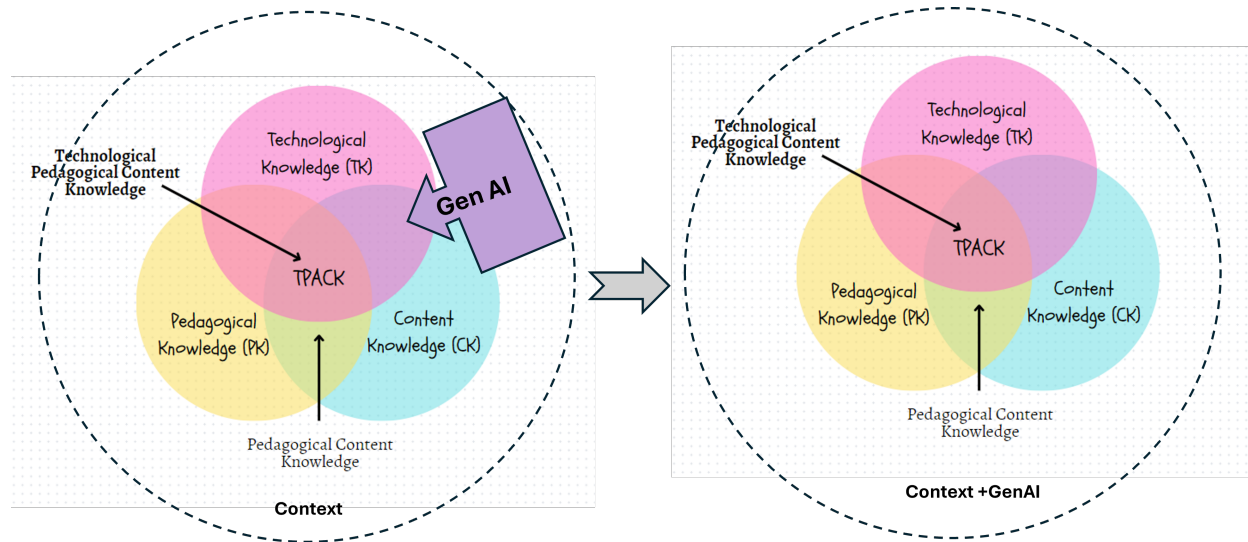


FIGURE 2: Technological Pedagogical Content Knowledge (TPACK) framework adapted from Ref. [16], modified to illustrate the inclusion and collaborative capacity of Generative AI.

GENERATIVE AI AND ITS PERCEPTIONS IN THE COMMUNITY

GenAI is capable of creating original content and producing human-like responses across various formats, including text, images, speech, videos, code, and so on [17, 18]. It leverages advanced deep learning architectures such as Generative Adversarial Networks (GANs), Variational Autoencoders (VAEs), and transformer-based models [19–21]. For example, ChatGPT is built on a transformer architecture that recognizes patterns and statistical relationships within language, enabling it to predict and generate coherent, contextually appropriate responses [6]. The capabilities and accuracy of GenAI-generated content depend on the number of parameters used during training. For example, ChatGPT-1 used 110 million parameters, whereas ChatGPT-4 is estimated to use around 1.75 trillion parameters [22]. For perspective, the human brain contains roughly 100 billion neurons and trillions of synaptic connections [23]. If future GenAI models improve by 100x, they may approach a level of sophistication comparable to certain aspects of human cognition [22].

Some people perceive GenAI as a modern version of the calculator, mentioning that when calculators were first introduced, educators were worried that they might negatively impact the computational skills [22]; however, calculators have since become an integral part of everyday classrooms. In contrast, we believe GenAI is fundamentally different and should not be taken in the same way. GenAI does not follow fixed rules and can generate varying responses depending on the details of the prompt, model, and context. Their outputs may contain inherent

biases, inaccuracies, and outdated information based on the prompts from the users and other variables. Consequently, GenAI-generated educational content might include misinterpretations of facts, cultural insensitivity, stereotypes, and hallucinations [6]. Without proper oversight, this variability poses serious challenges to the reliable and effective use of GenAI in education, which is essential for modern society.

GENERATIVE AI IN TEACHING AND LEARNING PRACTICES

Several GenAI tools are becoming increasingly common in education. Some frequently used GenAI include ChatGPT, Gemini, Claude, NotebookLM, Perplexity AI, DALL-E, Midjourney, Co-pilot, Stable Diffusion, etc. These tools are not only transforming how students learn, but they are also helping educators plan, deliver, and assess their instruction [24].

The traditional role of educators as primary sources of information is rapidly changing. With GenAI tools, students can instantly access learning resources and complete assignments, including essays, multiple-choice questions, and complex problem-solving tasks. GenAI has also shown it can pass advanced professional exams [25–28]. As a result, it is time for educators to rethink instructional design and assessment methods [1].

Students can use GenAI to brainstorm ideas, draft essays, simulate real-world scenarios, simplify complex topics, generate practice quizzes, create flashcards, and translate materials into different languages. Meanwhile, teachers can use GenAI to prepare lesson plans, write

emails, create quizzes, grade assignments, provide feedback, summarize content, and design engaging activities [1, 6].

Benefits of Generative AI in Education

In general, instructors spend about 90% of their time on content creation and only about 10% on revision and feedback [29]. This pattern holds true across all disciplines and professions. This trend can be remodeled with GenAI. Educators can spend less time generating content and more time providing individualized support for students, focusing on critical thinking and problem-solving skills that GenAI cannot replicate. For example, as mentioned previously, instructors can leverage GenAI to reduce their non-teaching administrative burdens, such as writing emails, sending announcements, creating quizzes, and grading assignments.

Traditional education systems often follow a one-size-fits-all approach, which fails to accommodate individual learning styles and paces. Effective use of GenAI can bridge these gaps by creating educational content tailored to diverse student needs and analyzing progress to adapt materials. This enhances engagement, improves comprehension, and makes learning more enjoyable [6]. Furthermore, GenAI provides instant, real-time feedback, enabling students to identify mistakes and correct them immediately, which fosters continuous improvement in learning [1, 6].

Additionally, GenAI can serve as a tutor at any time, offering personalized assistance to learners with diverse backgrounds, making the digital education accessible and affordable. Many students already have benefited from rich digital resources like *YouTube* and *Khan Academy* [30, 31], even in remote areas of the world. Students report that sometimes they learn more from these platforms than from traditional classroom instruction. GenAI further enhances this accessibility by making education more inclusive, flexible, and tailored to individual learning needs. The language translation capabilities of GenAI are breaking communication barriers for second-language learners and hold great potential to help dismantle the digital divide [6]. In the United States, students usually pay \$20 to \$50 per hour for tutoring. In comparison, some GenAI services offer full-year subscriptions for less or are even free, making learning resources more accessible. This means that students in low-income or remote areas can leverage their learning with GenAI by getting extra teaching-learning resources, which can help close educational equity gaps [1, 6]. Furthermore, in the future, there is potential to use GenAI to predict student performance, enabling instructors opportunities for early intervention, and helping students reduce churn and dropout rates [32, 33].

Limitations and Risks of Generative AI in Education

Despite the numerous advantages of GenAI, it also presents significant challenges. One major concern is the generation of misinformation. GenAI-produced content can appear convincing but sometimes they can be factually incorrect or outdated. This requires an essential critical evaluation of GenAI-produced materials before they are further used. Another risk is students overreliance on GenAI. Learning involves a continuous effort and struggle. Taking a shortcut through GenAI can reduce students' motivation to engage and learn deeply [32]. Prompting without understanding often leads to superficial learning, as highlighted by a popular Nepali proverb '*ghokante bidhya, dhawanti kheti*', which refers to the rote-learning without comprehension. True learning should be an adventure of exploration and discovery. However, by providing instant answers, GenAI can diminish deep learning, reduce the '*aha*' moments, and may erode the excitement of discovery.

Overuse of GenAI may also reduce human interaction, which is crucial for developing emotional intelligence and fostering a sense of community in learning [6]. A recent research shows that the performance of the learners who use AI frequently in their learning is impacted negatively [34]. Academic integrity is another huge concern, as GenAI can be misused to plagiarize or bypass genuine effort [4]. Off-campus assessments lose reliability when GenAI can complete tasks on behalf of students. Additionally, unequal access to advanced GenAI tools may widen educational disparities, especially between students using free versions and/or paid premium versions of the technology [6].

GenAI-driven personalized learning requires access to student data, their learning behaviors, and performance metrics. Improper handling of this information risks violating privacy protections such as those covered under the Family Educational Rights and Privacy Act (FERPA) [35]. Moreover, AI lacks emotional intelligence, contextual understanding, and mentorship capabilities, which are qualities fundamental to education. Thus, while AI can serve as an assistant, maintaining the human connection in teaching is essential.

Furthermore, AI-generated content raises concerns about academic dishonesty, plagiarism, and the decline of original student work. Clear guidelines are needed to define what proportion of AI-generated content, if any, is acceptable in academic submissions. In addition, students from underprivileged communities may face technological and financial barriers that limit their access to AI-enhanced education, further widening the social gap [1, 6].

SAMPLE USE OF GENERATIVE AI IN CLASSROOMS

The authors of this article have already utilized GenAI in their classes. Silwal encouraged students to use GenAI to draft their *Statement of Teaching Philosophy* (SoTP) assignment. Dhungana has been using Google's NotebookLM to generate course content, share practice questions with students, and even produce lecture note-based podcasts that enhance student engagement. Kifle has been using AI-integrated assessment tools like Gradescope to streamline grading in large classes, freeing up time for deeper student engagement. These real-world examples demonstrate that GenAI, when used thoughtfully, supports both teaching and learning effectively.

In the following sections, we will briefly describe the implementations of these tools.

1. GENERATIVE AI FOR ASSIGNMENT

Silwal co-instructs the *fundamentals of teaching physics* course as a part of the Teaching Assistant (TA) training program at the Department of Physics and Optical Science at *University of North Carolina at Charlotte*. This course covers effective teaching and learning practices and explores the strategies to make this process both effective and enjoyable. As an assignment, students are required to write an SoTP at the end of the semester. The instructor covers the essential components of this assignment in class and encourages students to use GenAI for drafting their SoTPs. Students then use the AI-generated draft as a skeleton and modify it to reflect their own perspectives and experiences. For the assignment, students submit three components: the prompt they used, the GenAI-generated draft, and their final, personalized version. This approach allows students to leverage the capabilities of GenAI while practicing ethical and responsible use of the technology. Fig. 3 shows a sample SoTP generated by ChatGPT-4. The first paragraph of the SoTP is the revised version.

For online and at-home lab courses, Silwal includes a sign-in section where students indicate whether they used GenAI to complete the assignment (see Fig. 4). If they did, they would be asked to submit both the prompt they used and the GenAI-generated content, thereby encouraging the responsible use of GenAI.

2. NOTEBOOKLM TO ENHANCE INTERACTIVE LEARNING

When considering AI tools for academic applications, NotebookLM (<https://notebooklm.google/>) demon-

strates better functionality compared to ChatGPT, particularly when users can provide adequate source material. ChatGPT, developed by OpenAI, is a general-purpose conversational model trained on extensive internet data, making it effective for tasks such as content creation, coding assistance, and creative brainstorming. However, its broad training data contributes to a higher susceptibility to hallucinated or inaccurate responses, which poses a challenge for scholarly integrity [36]. In contrast, NotebookLM, developed by Google, is purpose-built for analyzing and synthesizing user-supplied documents, including PDFs, Google Docs, websites, and multimedia transcripts, offering responses grounded directly in the source content. This document-oriented approach significantly reduces the risk of misinformation and enhances citation accuracy, often including detailed references to page numbers and document titles [37]. For academics who prioritize traceability and factual reliability, NotebookLM emerges as a more robust alternative when appropriate content is made available. NotebookLM is available for free and supports up to 50 uploaded sources per notebook, each containing up to 500,000 words or 200MB of data. Users also enjoy unlimited chat functionality. Premium tiers offer expanded limits and additional features.

(a) Integration of NotebookLM in Physics Instruction

Dhungana utilizes the free version of NotebookLM as a pedagogical tool to curate and structure instructional materials for his undergraduate physics courses. By integrating content from prior class notes, recorded lecture videos hosted on YouTube, and open-access textbooks available through OpenStax, NotebookLM serves as a dynamic platform for organizing diverse instructional resources into a coherent and accessible repository. These curated materials are subsequently distributed to students via the Canvas learning management system, ensuring streamlined access and alignment with course objectives. In addition to content delivery, NotebookLM facilitates the development of formative assessments; Dhungana employs the platform to design multiple-choice quizzes embedded with targeted feedback for each response option. These pre-class assignments are deployed through Canvas to promote conceptual and problem-solving engagement and prepare students for interactive in-class learning. Furthermore, Dhungana leverages NotebookLM's integration with LaTeX to generate technical illustrations using the TikZ graphics library. These custom visualizations enrich instructional materials by providing precise and pedagogically grounded representations of physical phenomena and conceptual models. This workflow exemplifies how NotebookLM can be harnessed to enhance

Prompt given to ChatGPT 4: Draft a one-page statement of teaching philosophy paper with key components Learning environment, Assessment and feedback, Teacher-Student relationship and Ethical and Professional values.

Statement of Teaching Philosophy

As an educator, I believe that **learning is a complex and ongoing process**. ~~Teaching is not only just about transmitting knowledge but about creating conditions that inspire curiosity, foster critical thinking, and empower students to take ownership of their learning, which supports the lifelong retention of skillsets.~~ **Knowledge and abilities are achieved through effort and persistence. No one is born expert. Students often struggle due to barriers they face, not a lack of potential and with right guidance and support, every student can succeed. My teaching philosophy is guided by grounded-in-four-key components: learning-environment-student-centered learning, formative** assessment and feedback, teacher-student relationships, and ethical and professional values.

Learning Environment

I strive to create an inclusive and supportive learning environment where every student feels valued and respected. A positive classroom culture encourages risk-taking, collaboration, and open dialogue, allowing students to learn from both successes and mistakes. I use active learning strategies—such as group discussions, peer instruction, and hands-on demonstrations—to make abstract concepts tangible and to engage students with diverse learning styles.

Assessment and Feedback

Assessment is not simply a measure of performance but a tool for growth. I design assessments that align with learning objectives and provide opportunities for students to demonstrate understanding in multiple ways. Frequent, timely, and constructive feedback helps students identify their strengths and areas for improvement, while also guiding me in refining my teaching strategies. I encourage students to use feedback as a means of reflection and self-improvement rather than as a judgment.

Teacher-Student Relationship

I view teaching as a collaborative journey where both teacher and students contribute to the learning process. By maintaining approachability, empathy, and mutual respect, I seek to build strong relationships that motivate students to engage deeply with the material. I make a conscious effort to learn about students' goals, challenges, and perspectives, using this understanding to adapt instruction and support their academic and personal growth.

Ethical and Professional Values

As a teacher, I hold myself to the highest ethical and professional standards. I am committed to fairness, transparency, and integrity in all aspects of teaching, from grading to classroom interactions. I model professionalism by being prepared, punctual, and respectful, and I expect the same from my students. I also recognize the responsibility of educators to uphold equity and to provide all students with equal access to opportunities for success.

In summary, my teaching philosophy is guided by a commitment to cultivating an inclusive environment, using assessment as a tool for growth, nurturing meaningful relationships, and embodying ethical and professional values. Through these practices, I aim to help students develop not only as learners but also as critical thinkers and responsible members of society.

FIGURE 3: An SoTP sample assignment. In the first paragraph, black-colored text represents the content created by ChatGPT-4, maroon-colored strikethrough text represents the text removed, and red-colored text represents the new text added.

Did you use any Generative AI (GenAI) assistance to answer any of the questions? If so, please provide the prompt you used, and the response given by the GenAI on this page. You are allowed to use GenAI for learning purposes, but copying answers from GenAI tools for lab reports involves academic dishonesty.

Full Name and Initials:

FIGURE 4: A sample GenAI disclosure practice implemented for online and at-home lab course assignments.

resource integration, formative assessment design, and visual communication in a digitally mediated learning environment.

(b) Drafting Prompt for Question Generation with Built-In Feedback

Crafting a targeted prompt involves articulating the task with clear intent while ensuring that no essential detail is omitted. An effective prompt should explicitly communicate the desired scope, context, and expected response format, thereby guiding NotebookLM to produce focused and relevant output. By embedding key parameters such as cognitive targets, instructional framing, and content boundaries, a well-written prompt becomes a powerful tool for eliciting meaningful engagement and precise responses. For example, below is a prompt designed to generate a multiple-choice question with feedback for each response. However, it can be easily adapted to produce more than one question by modifying the phrasing accordingly.

Prompt: Using the provided source, develop one multiple-choice question appropriate for college-level physics students. Focus on the understanding level of Newton's laws of motion based on Bloom's taxonomy.

The question should:

- Incorporate all relevant topics and subtopics from the source
- Include a clear question stem and four answer choices (A–D)
- Provide feedback for each choice, starting with “**Correct**” or “**Incorrect**” (without revealing the correct answer in incorrect feedback)
- End with a final feedback note reinforcing the correct answer and briefly elaborating on the concept, beginning with an encouraging phrase like “Great job” or “Excellent”

The **output** for an image generated by NotebookLM is typed out below:

Multiple-Choice Question:

A 65 kg person stands on a weighing scale inside an elevator. Which of the following statements correctly describes the apparent weight experienced by the person?

A) The apparent weight is equal to the actual weight when the elevator moves downward at a constant velocity.

B) The apparent weight is greater than the actual weight when the elevator accelerates downward.

C) The person experiences zero apparent weight when the elevator moves upward at a constant velocity.

D) The apparent weight is always equal to the person's actual weight, regardless of the elevator's motion.

Feedback:

A) **Correct.** When an object moves at a constant velocity (including rest), it is in equilibrium. According to Newton's First Law, zero net force results in a constant velocity. Thus, the normal force (apparent weight) equals the gravitational force (actual weight).

B) **Incorrect.** When accelerating downward, the apparent weight is *less* than the actual weight, not greater. The net force is downward, so the normal force must be reduced.

C) **Incorrect.** Zero apparent weight occurs only during free fall, when the object accelerates downward at g . Constant velocity motion (even upward) implies equilibrium and a normal force equal to the weight.

D) **Incorrect.** Apparent weight varies with acceleration. It only equals the actual weight when the elevator is at rest or moves with constant velocity.

Final feedback:

Excellent job! This question tests your grasp of Newton's Laws in dynamic systems. Apparent weight reflects the normal force, which changes under acceleration. When velocity is constant (or the elevator is stationary), the net force is zero, and the apparent weight matches the actual weight. But acceleration alters this balance, leading to variations in what the scale reads.

The question and feedback can be copied and pasted into a Canvas multiple-choice quiz template.

(c) NotebookLM: A Virtual Instructor for Students at Home

Once students create a notebook using sources provided by the instructor or reputable materials found online, they can begin asking questions. It is a good idea to offer students a few example prompts that encourage learning rather than simply retrieving homework answers. For instance, helpful **prompts** might be: "Suppose you are my physics instructor. Teach me how to draw free-body diagrams and apply Newton's laws." and "Teach me

how to solve problems involving conservation of energy. Walk me through a sample problem step by step."

(d) Key Themes from Student Feedback

To gain insight into the impact of NotebookLM on student learning, informal end-of-semester conversations were conducted with students, following the Spring 2025 offering. Reflections were gathered from those who voluntarily shared their experiences. These responses represent preliminary impressions and should not be interpreted as a comprehensive or systematic evaluation of learning outcomes.

When invited to describe how NotebookLM most significantly influenced their experience in the course, students articulated a diverse range of use cases and perspectives. The core themes that emerged from these reflections included:

- **Enhanced Conceptual Understanding:** Students frequently used NotebookLM to clarify counterintuitive principles and engaged with it in a question-answer format similar to individual tutoring.
- **Efficient Content Retrieval:** NotebookLM enabled students to quickly locate information from course materials and videos, minimizing the need to manually skim through resources.
- **Memory Support and Review:** The tool helped students revisit and recall earlier topics from the semester by simply asking questions, reducing reliance on notes.
- **Improved Academic Performance:** A few students reported a significant improvement in exam results after using NotebookLM to study for the second exam, following a poor performance on the first.
- **Study Aid Features:** Respondents valued NotebookLM's ability to generate concept reviews, practice quizzes, and study sheets, as well as its integration of source-based citations aligned with instructor expectations.
- **Diverse Engagement Levels:** While many students actively used NotebookLM, others reported limited engagement or unfamiliarity, suggesting varied adoption across the cohort.

The initial implementation of NotebookLM yielded overall positive feedback, highlighting benefits such as enhanced conceptual understanding and efficient content retrieval.

3. AI IN ASSESSMENT

In a teaching and learning process, some learning goals are established in a unit or the whole course that students will achieve after its completion. We need some reliable and effective tools to assess whether those goals were achieved or not. These can be formative or summative assessment tools based on the objectives of the assessments [38]. Formative assessments monitor student learning while the course is running (e.g., poll questions, one-minute paper, discussions and questions, etc.) [39], whereas summative assessments evaluate student learning at the end of a learning unit or the course (e.g., exams, projects, presentations, portfolios, etc.) [40].

Among many assessment tools, a technology-based assessment tool that integrates AI to make grading more consistent, efficient, and effective is Gradescope [41, 42]. Kafle has been using Gradescope to grade exams in large introductory physics and astrophysics classes. He found that grading using Gradescope is more convenient, efficient, and effective than traditional grading techniques. The following features of Gradescope make it very useful as an assessment tool:

(1) A human grader can create rubrics and apply them on the fly while grading, and the rubrics can be easily updated and modified as needed. Fig. 5 shows an example of creation and implementation of rubrics in grading a multiple-choice question in an introductory physics exam. As shown in the figure, there were multiple rubrics created while grading this question, one of which was applied to this particular response. This can also be implemented in grading an open response problem as shown in Fig. 6. This example shows an open-response problem in an astrophysics exam, graded using Gradescope.

(2) It saves time for grading and shows a clear picture of students' performance in the assignments. As soon as the grading of an assignment is done, it produces a basic statistical distribution of the grades, including the minimum and the maximum grades, mean, median, and standard deviation of the distribution.

(3) It supports all kinds of problems like open-response problems, multiple-choice questions, etc.

(4) For some question types like multiple choice, Gradescope AI assists in forming groups of similar answers to a question submitted by multiple students. This makes grading quicker and easier. Although Gradescope utilizes AI to group similar responses together, the human grader has to review and decide the correctness of the AI-generated groupings, apply the rubrics properly, and make final decisions on grades.

(5) Gradescope is very easy and secure to provide students with feedback in their work. After the grading of an assignment is completed and the grades are released, students can immediately see their grades in that assignment, the rubrics used in grading, and the feedback provided by

the instructors. This will give an opportunity for the students to correct their mistakes on time, and improve their performance in future assignments. Research shows that use of Gradescope for assessment along with adaptation of instructional strategies has improved student learning of the materials, their course satisfaction, and hence their performance in the tests [43, 44].

(6) Gradescope helps in administering and grading online and in-class assignments.

(7) If a grader makes mistakes in grading an assignment, students can request for regrading of the assignment through Gradescope.

In summary, AI-integrated tools are useful for evaluating student work consistently, more efficiently, and effectively. Recent research shows that GenAI has a strong potential to assess student work in various subjects [45–47].

GENERATIVE AI AND THE FUTURE CLASSROOMS

In spite of restricting the use of GenAI, we should take advantage of it to educate the future generation by establishing suitable policies and guidelines. The traditional teaching and assessment methods need to be updated significantly. The future teaching can consider a variety of innovative approaches as follows [1, 48]:

Flipped Classrooms: Students can engage with basic course content at home before they come to class, utilizing GenAI tools with instructors' lecture notes, pre-recorded videos, or podcasts for preliminary learning. Classroom time is then dedicated to deeper exploration of essential course components, hands-on activities, group discussions, and fostering critical thinking skills [49].

Oral and In-Person Exams: To ensure genuine understanding of the course contents and minimizing potential misuse of GenAI, student learning assessments can be done with in-person and real-time assessment techniques such as oral exams, live presentations, or in-person tests [50, 51].

Project-Based Learning: By working on real-world, multidisciplinary projects, students can develop the ability to apply knowledge creatively and collaboratively. These tasks will emphasize critical thinking and problem-solving and discourage surface learning, just by relying on their work with GenAI [52, 53].

Problem-Based Learning: To make students champions on solving problems, they should be given complex and open-ended problems. This approach encourages students to analyze scenarios, conduct research, and propose well-founded solutions. These activities cultivate balanced use of GenAI and develop essential skill sets [54, 55].

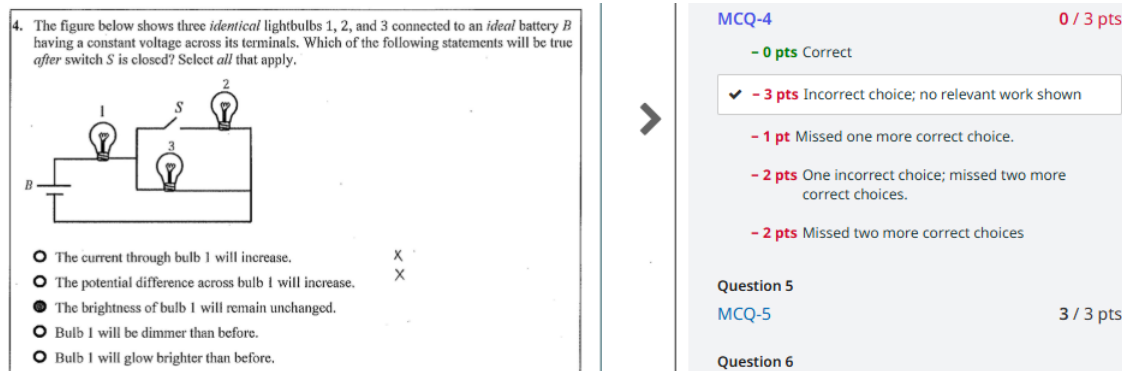


FIGURE 5: An example of rubric creation and application in Gradescope for grading a multiple-choice question, demonstrating the AI-assisted assessment process.

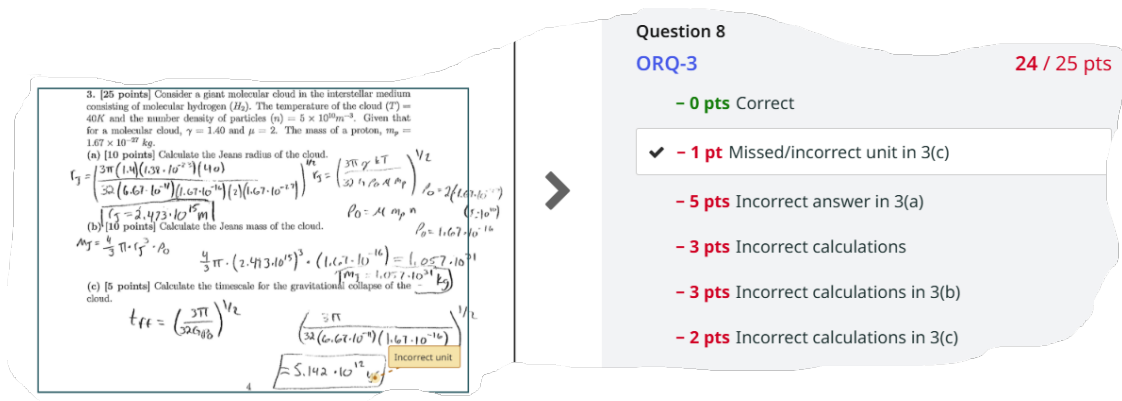


FIGURE 6: An example of rubric creation and application in Gradescope for grading an open response problem.

Collaborative Learning Environments: Learning is a social process. Encouraging teamwork and peer-to-peer interaction helps students build communication and interpersonal skills. In this process, students can consult the GenAI to create prompts for discussion and other learning materials [56, 57].

Formative and Reflective Assessments: Assessments are important components in a learning process. Instant real-time feedback, continuous feedback, and self-reflection opportunities with GenAI allow both students and instructors to monitor students' progress, identify gaps in understanding, and develop meta-cognitive skills. This transformational capability of GenAI can foster a deeper and more personalized learning experience for students and can reduce the grading work for instructors [51, 58].

By integrating these methods in our classrooms, we can better prepare students to thrive in a GenAI-augmented world, promoting not only knowledge acquisition but also creativity, critical analysis, and lifelong learning.

RECOMMENDED GUIDELINES

Research shows that most instructors and students have already interacted with GenAI in some form and reported that their efficiency in teaching and learning significantly increased. For those who have not used it, the primary barrier is found to be a lack of knowledge about GenAI or its training [59, 60]. One example is that the number of publications and citations about the *use of AI in Higher Education* topics has dramatically increased after the release of ChatGPT [32]. Furthermore, research shows that students have a positive opinion on the use and integration of GenAI in the teaching and learning process, and the use of GenAI, such as ChatGPT, is not seen as a threat eroding the essential goal of education [32, 61, 62]. The recent release of ChatGPT-5, which reports 700 million weekly users [63], underscores its rapidly growing role in education and beyond. With this trend, institutions must invest in awareness programs, technological infrastructure, and ongoing support for the teaching and learning process, and the community.

This study utilized *Google Scholar*, recognizing its

comprehensive coverage of peer-reviewed publications, books, and articles. Using the search prompts “*GenAI Teaching and Learning: Its Opportunities and Challenges*” and “*Generative AI Transforming Teaching and Learning*,” we identified about 100 relevant articles. The main themes emerging from these works can be summarized into four key areas: *irreplaceable human component of teaching and learning*, leveraging GenAI to promote student-centered teaching and learning, pressing need of developing clear policies for the ethical use of GenAI, and establishing robust institutional frameworks. These themes are briefly explained below:

(1) Irreplaceable Human Component of Teaching:

While GenAI can significantly augment the teaching and learning process, it can never replace the human element at the heart of education [5]. Authentic and deep learning relies on more than the delivery of information. It requires motivation, empathy, social connection, and emotional intelligence, which are the qualities associated uniquely with humans. Teachers not only guide academic growth but also inspire curiosity, foster resilience, and nurture students’ personal, ethical, and emotional development. They create meaningful connections between learners, peers, and the wider community, enabling education to serve as a bridge to societal engagement and cultural understanding [1, 64, 65]. Silwal had an opportunity to present a part of the work in a colloquium talk at UNCC. In the discussion after the talk, students expressed that they can learn content knowledge on their own, and pursuing graduate studies is not primarily about knowledge acquisition, but about something deeper. This perspective strongly resonates with the theme of the irreplaceable human component in teaching.

GenAI can be most effective as a secondary collaborator, particularly in multidisciplinary contexts, where it can facilitate research, teamwork, and problem-solving. In collaborative projects, GenAI can serve as a peer reviewer, a tutor for improving comprehension and retention, and a catalyst for an active engagement [66]. GenAI can support these efforts by handling repetitive tasks, generating resources, and providing personalized scaffolding, allowing educators to devote more time to high-value interactions, such as mentoring, facilitating discussions, and encouraging critical reflection. However, the human capacity for compassion, moral judgment, and cultural sensitivity remains inevitable for shaping well-rounded learners to thrive in an interconnected world [6].

(2) Use of GenAI for Student-Centered Teaching and Learning: GenAI should be integrated into courses only after clearly defining learning objectives and desired proficiency levels, ensuring alignment with established educational goals [1, 66–68]. When thoughtfully embedded as a *study tool*, GenAI can foster not only content knowledge but also essential skills such as creativity, critical thinking, social and emotional intelligence, and

overall holistic competence, preparing students for life-long learning and the future workforce [65, 69, 70]. In a GenAI-enabled learning environment, students should be encouraged to actively reflect on their learning processes, regulate their thinking, and maintain control over their own learning. This meta-cognitive awareness helps ensure that GenAI serves as a tool for empowerment rather than fostering AI dependency [1, 65, 69, 71, 72].

GenAI can support various student-centered learning activities where students critically evaluate the content produced by it, complementing traditional teaching methods while promoting learners’ autonomy and preserving self-efficacy. For example, GenAI can generate quizzes, prompts, and feedback that enhance creativity and skill development. Importantly, students should be taught to recognize that GenAI has limitations, such as biased pre-trained data, a lack of human reasoning, and outdated information, making it essential to differentiate between accurate and flawed outputs [1, 69, 73, 74].

(3) Pressing Need of Clear Policy Development: The acceptable use of GenAI in teaching and learning should be explicitly outlined in course syllabi [75]. Course policies should be dynamic and adaptable with the advancements in GenAI technology to address new opportunities, risks, and ethical concerns. Collaboration across institutions, both locally and globally, is crucial for establishing consistent guidelines and best practices. So, shared policy frameworks promote fairness, reduce ambiguity for students and faculty, and ensure a unified approach to integrating GenAI in teaching and learning [1, 65, 68]. A bottom-up approach involving students’ participation while developing policy will be more effective. Furthermore, privacy and security are also critical components, especially when GenAI is used for personalized feedback, adaptive learning, or tutoring. Institutions must implement robust safeguards to protect students’ information, comply with relevant regulations, and ensure that GenAI tools operate within ethical and legal boundaries [1, 6, 76].

(4) Training and Infrastructure: Ethical and responsible use of GenAI requires comprehensive AI literacy and training programs for students, teaching assistants, and faculty [1, 77, 78]. Individual courses should include dedicated modules on GenAI, along with AI awareness programs, workshops, and training sessions. Furthermore, institutions can offer standalone courses focused on effectively harnessing GenAI for teaching and learning [1, 65, 66]. These initiatives will help reduce technostress among faculty while preparing students to use GenAI tools effectively, ethically, and responsibly. We should also invest in building particular database platforms with unbiased information, especially on social science topics [79]. Furthermore, learners using different versions of GenAI may have different experiences, it is crucial that tools like ChatGPT and NotebookLM remain

freely accessible, with OpenAI's original mission developing 'friendly AI' with *Artificial General Intelligence (AGI)* which is capable of doing any intellectual task that humans can see, and an overall democratization of AI access [80].

CONCLUSIONS AND DISCUSSIONS

GenAI can generate information, but cannot understand or "feel" content the way that humans do. Critically evaluating the content generated by GenAI is our responsibility. While GenAI offers powerful tools to enhance affordable and sustainable learning, the human element in teaching and learning is irreplaceable. Educators are no longer merely "sages on the stage," but increasingly "guides on the side" [81]. The role of the mentors is to support student growth by fostering critical thinking and to ensure meaningful learning in partnership with GenAI. Furthermore, Students' perceptions strongly influence their learning; therefore, policymakers should establish clear, well-informed, dynamic, and globally accepted guidelines for integrating GenAI in teaching and learning. The learners must be ethically aware, emotionally intelligent, and intrinsically motivated in addition to their technical skill sets. With thoughtful integration, GenAI can play an important role in making education more inclusive, effective, and transformative.

ACKNOWLEDGMENTS

We would like to acknowledge the ANPA Physics Education Research Division, including all presenters and active participants over the past two years, as well as those who attended our talk at the ANPA Conference 2025, whose engagement and feedback motivated this article. We also thank the Physics Education Research Lab and Learning Center, and the TA training program at UNC Charlotte for their support. Finally, we extend our sincere appreciation to the editors and anonymous reviewers for their valuable comments and suggestions that greatly enhanced the quality of the paper. The authors utilized ChatGPT and NotebookLM to assist with language refinement and clarity during manuscript preparation, with all content thoroughly reviewed and verified by the authors.

EDITORS' NOTE

This manuscript was submitted to the Association of Nepali Physicists in America (ANPA) Conference 2025

for publication in the special issue of the Journal of Nepal Physical Society.

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