Cognitive Demands and Course Pedagogical Design: Understanding Success in Online Learning Environments

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Abstract
The COVID-19 pandemic catalyzed a global shift to online learning, highlighting both the challenges and opportunities of this mode of education. Despite extensive research on student performance in online courses, there remains a lack of focus on the pedagogical characteristics that influence educational outcomes. This study investigates the relationship between the pedagogical design of online courses and academic performance in higher education, with particular emphasis on Universal Design for Learning (UDL) principles and cognitive complexity levels defined by Bloom's taxonomy. Data were collected from 661 students across 22 online courses, analyzing demographic variables, pedagogical features, and students' interaction patterns on course platforms. Multiple regression models revealed that both demographic and pedagogical characteristics significantly predict online course grades, while student interaction patterns did not. Additionally, tasks requiring higher-order thinking skills were associated with lower grades, emphasizing the need for carefully scaffolded support in online environments. The study also found that UDL attributes may function differently across achievement levels, being less beneficial—or differently aligned—for high-achieving students. These findings underscore the importance of tailoring online course design to diverse learner needs and suggest a balance between accessibility and cognitive complexity. This research provides actionable insights for improving online learning environments and advancing evidence-based educational practices.

Keywords: Online learning, universal design for learning, Bloom's taxonomy, cumulative GPA

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In recent years, education systems have invested major efforts in designing new learning environments, with emphasis on the integration of technological means (Collins & Halverson, 2018). The outbreak of the COVID-19 pandemic in the spring of 2020 spawned a revolution in education systems across the globe by necessitating a comprehensive shift to remote learning for all students (Dietrich, 2020; Fewella, 2023). Despite the complexity of comparing online learning that was planned in advance to online learning necessitated by an emergency, the ongoing pandemic underscored the inherent difficulties when learners interacted with learning materials, lecturers and their fellow students online, as well as the decrease in sense of belonging to the academic institution among students and lecturers alike (Baxter & Haycock, 2014; Seifert & Bar-Tal, 2023). The situation also highlighted the inequality among learners, for example with respect to the physical conditions in their homes (Gillis & Krull, 2020).

In conjunction with the difficulties, online learning also opened new horizons and educational opportunities in academia. From the perspective of organizing the learning, the online environment provides flexibility and accessibility in time and place (Xie et al., 2020). From the didactic perspective, the online learning environment offers diverse possibilities for visual or auditory presentations (e.g., Olsson et al., 2016). The technological basis of online learning provides the ability to organize and document discussions to facilitate collaboration in constructing knowledge (Simpson, 2016) and in monitoring students' progress (Saghafi et al., 2014). In addition, the use of information and communications technology can support a variety of constructivist teaching strategies to develop 21st century skills (Zhu, 2008) and can promote communication between students, lecturers, and colleagues through forums and social groups, thanks to its flexible scheduling capabilities (Cheng & Chau, 2014). Consequently, understanding the pedagogical design of such environments—particularly in terms of accessibility and cognitive complexity—has become a central question for online higher education.

At the same time, alongside new educational challenges, the general mobilization for remote learning that took place during the COVID-19 pandemic launched an age of creativity and abundance in the field of pedagogical design of online learning environments. In addition, the status of online learning shifted from an alternative that could be rejected to a given situation that is unavoidable under certain circumstances. Indeed, the pedagogical improvement offered by online learning is not a matter of choice but rather a present need. Consequently, systematic characterization of online learning environments and formulation of institutional policy for online teaching and learning are of utmost importance.

Although extensive research has examined factors influencing educational outcomes, only a limited number of studies have systematically analyzed the *pedagogical quality* of online learning environments. Recent works published in *Online Learning Journal* have contributed valuable insights—such as the quantitative analysis of higher-order thinking development (Page, 2022) and studies on UDL implementation and instructor-driven design (Altowairiki, 2023; Underhill & Turk, 2024). Nevertheless, there remains a need for large-scale, integrative modeling that jointly examines multiple pedagogical dimensions—such as Universal Design for Learning and cognitive complexity—across diverse courses and disciplines.

The impact of integrating technology into education varies in accordance with type of technology, type of pedagogy, learners' ages, and areas of study (Jeong et al., 2019).

Further research is needed to better understand the factors affecting the online learning experience in higher education (Nortvig et al., 2018; Rodrigues et al., 2019). Lai and Bower (2019) systematically reviewed 365 research papers examining the use of technology in education. They found that most studies examined learners' academic achievements, viewpoints, learning styles, and motivation, whereas only 11% focused on pedagogical characterization. Their findings underscore the importance of pedagogical research to examine online learning environments in academia.

Despite changes in the academic world since the outbreak of the COVID-19 pandemic, academic institutions have not yet formulated any distinct policy for designing online courses, and academic lecturers are clearly having difficulty implementing optimal pedagogical practices in online teaching (Reich et al., 2020). In response to this gap, this research offers an examination of online college learning environments with the goal of understanding the relationship between the pedagogical components of online courses and their educational outcomes. The findings can make an important contribution to promoting evidence-based education and to understanding best practices or what works in education (Borman et al., 2003; Reynolds et al., 2014). The results can also help in designing an explicit policy for online courses and in promoting the professional development of the academic staff. To inform such policy and practice, a deeper theoretical understanding of pedagogical design in online environments is required. Building on this growing reliance on online learning, there is a pressing need to examine not only whether students succeed in digital environments, but how the pedagogical design of those environments shapes their learning outcomes. Two well-established frameworks—Universal Design for Learning (UDL) and Bloom's taxonomy—offer complementary perspectives for analyzing the quality and cognitive demands of online courses. The current study therefore investigates how these pedagogical dimensions, together with student characteristics, predict success in online higher education.

Theoretical Background

Characterization and Assessment of Online Learning Environments

Over the years, numerous studies have examined the effectiveness of online learning environments using a variety of indicators, most often through survey-based tools (Pardino et al., 2018). Early evaluations typically compared student achievement in online versus face-to-face courses (e.g., Jayachithra, 2020), while later research increasingly emphasized learners' perspectives through measures such as satisfaction, engagement, and perceived learning (Caspi & Blau, 2008; Malkawi et al., 2020; Rovai et al., 2009). These studies have provided valuable insights into how students experience online education but have focused mainly on outcome and interaction indicators rather than on the pedagogical design itself. Withinthe broader socio-cognitive perspective, several models have characterized the quality of online learning through patterns of interaction among learners, instructors, and materials (Nortvig et al., 2018). The Community of Inquiry (CoI) framework (Garrison et al., 2000) has been particularly influential in describing the cognitive, social, and teaching presence that underlie meaningful online learning. However, while such models advance understanding of communication and engagement, they do not directly address the instructional and cognitive design features that shape learning processes.

More recently, researchers have proposed integrative frameworks for analyzing learning environments through multiple pedagogical dimensions—such as educational principles, higher-order thinking, and learning psychology (Miedijensky et al., 2021; Sasson, 2019; Sasson et al., 2022). These approaches emphasize systematic characterization of

instructional practices and their relation to student outcomes, offering a foundation for the current study's focus on pedagogical quality in online course design.

Universal Design for Learning – UDL

Universal Design for Learning (UDL) is a pedagogical framework aimed at creating flexible teaching and learning methods that cater to the diverse needs of students, including those with and without special needs, in various educational contexts (Black et al., 2014; Capp, 2017; CAST, 2017; Evmenova, 2018). The concept is rooted in principles from architecture, where environments are designed to ensure accessibility for all individuals, regardless of their physical abilities or unique needs (Rao & Tanners, 2011).

UDL is built upon three core principles: (1) providing multiple means of engagement, (2) offering multiple means of knowledge representation, and (3) enabling multiple means of expression for understanding (Capp, 2017; CAST, 2017; Evmenova, 2018). These principles align with key components of the cognitive learning process, involving affective networks responsible for motivation, recognition networks for processing and analyzing information, and strategic networks for planning and executing actions (Dell et al., 2015; Robinson & Wizer, 2016).

Technology plays a significant role in supporting UDL by providing tools for presenting knowledge in diverse ways and enabling students to demonstrate understanding through various modalities. Research has shown that UDL-based interventions—such as online and blended learning, multimedia resources, social media platforms, and interactive websites—are effective in fostering diverse learning abilities (Hall et al., 2015; Kennedy et al., 2014; King-Sears et al., 2015). Recent empirical and institutional evaluations have shown the potential benefits of UDL-informed design in higher education (e.g., Garrad & Nolan, 2022; Altowairiki, 2023).

A related concept is Universal Design for Instruction (UDI), which focuses on curriculum and instructional strategies that offer equal learning opportunities to all students. UDI emphasizes additional principles such as promoting varied methods of instructional use, tolerance for error, fostering a community of learners with active communication, and creating an inclusive instructional climate that maintains high expectations for all students (McGuire & Scott, 2006).

Bloom's Taxonomy:A Framework for Cognitive Complexity

First introduced by Benjamin Bloom in the 1950s, Bloom's Taxonomy provides a foundational framework for classifying cognitive processes in learning (Bloom, 1964). The taxonomy is organized into six hierarchical levels, each reflecting a progressively complex form of cognition: knowledge, comprehension, application, analysis, synthesis, and evaluation. The knowledge level emphasizes the recall of factual information or previously acquired concepts, while comprehension focuses on grasping the meaning of information and explaining ideas. Application involves utilizing acquired knowledge in novel contexts, and analysis requires breaking down complex ideas into their components to explore relationships. Synthesis entails combining elements to create new ideas, and evaluation requires critical judgment based on specific criteria or standards. This hierarchy enables educators to promote higher-order thinking skills (HOTS) and deepen student understanding beyond mere memorization (Anderson & Kathwohl, 2001).

Bloom's Taxonomy is widely recognized for its effectiveness in distinguishing between tasks requiring rote memorization and those involving advanced cognitive functions such as application, analysis, or evaluation (Boeren & Iniguez-Berrozpe, 2022; Drakpa et al.,

2021; Muhayimana et al., 2022). Nevertheless, the taxonomy has been subject to criticism, particularly regarding the challenges of categorizing tasks into discrete levels. Scholars have noted the difficulty in distinguishing adjacent levels, such as comprehension versus application (Athanassiou & McNett, 2003). Bloom himself acknowledged this ambiguity, recognizing the overlapping nature of cognitive tasks and the complexity of accurately assigning them to specific levels.

Building on the pedagogical frameworks of UDL and Bloom's taxonomy, this study examines how these principles manifest in the design of online courses in higher education. By focusing on the diversity of teaching methods, cognitive complexity levels, and engagement strategies, the study aims to explore their role in academic performance. Although previous research has addressed each of these frameworks separately, few studies have integrated UDL and Bloom's taxonomy within a unified, quantitative coding framework for evaluating course design. The present study therefore employs these two models as the conceptual foundation for the coding and analytical procedures described in the Methods section.

Research Questions

a) What are the predictors of success in an online course, as examined through three models: (1) student demographic characteristics, (2) pedagogical characteristics of the course, and (3) students' login patterns on the course platform?

b) How is cumulative GPA related to online course performance, and to what extent do pedagogical characteristics of the course and students' login patterns moderate this relationship?

Methods

The courses included in the study were selected based on a list of all online undergraduate courses offered during the academic year across three faculties at the institution. This list, comprising 72 courses, was obtained from the college's academic administration. All instructors teaching these courses were contacted and informed of the study's objectives and voluntary nature. Ultimately, 22 instructors provided informed consent, and their courses were included in the research.

All 22 courses were part of undergraduate programs across various disciplines, including education, social sciences, humanities, and science and technology. The courses varied in scope, including both introductory and content-specific courses, and were delivered in asynchronous or blended formats. The college does not have a formal policy or set of guidelines for online course design, nor does it enforce a standardized model for pedagogical practice in online learning. While no mandatory training was provided to instructors, those who sought pedagogical or technical support were able to receive assistance from the college's Center for Innovation in Teaching and Learning. Universal Design for Learning (UDL) is not formally promoted at the institutional level and is not embedded in institutional policy or training programs. As such, the inclusion of UDL-related features in the courses examined reflects individual instructors' pedagogical choices rather than institutional directives.

Participants included 661 students in 22 online courses. The data provided by the Department of Student Administration at the college showed 338 of the students (51.1%) majored in education and teaching, 223 (33.7%) majored in social sciences and humanities,

and 98 (14.8%) majored in science and technology. Data from two students were not included in this file. With respect to gender, 463 (70%) were women and the rest were men (198, 30%). Moreover, 172 students (26%) were in their first year of academic studies, 182 (27.5%) were in the second year, 249 (37.7%) were in the third year, and 55 (3.8%) were in the fourth year. Data from three students were not included in this file. With respect to ethnicity, 494 (74.7%) of the students were Jewish and 164 (24.8%) were not Jewish. Data from three students were not included in this file. Finally, 98 students (15%) were diagnosed with learning disabilities.

The pedagogical characterization of online courses focused on two key aspects: universal design for learning (UDL) attributes and cognitive complexity levels based on Bloom's taxonomy. Coding of UDL attributes: The analysis of UDL implementation covered all course materials available on the online learning platforms and was based on the three core UDL principles—multiple means of engagement, representation, and expression (Evmenova, 2018). Each dimension was coded on a three-level ordinal scale, reflecting the extent to which pedagogical practices were evident:

(1) *Engagement* – coded as 1 when up to two active-learning practices were identified (e.g., forum discussions, peer review), 2 when three to five were observed, and 3 when more than five were present.

(2) *Representation* – coded according to the variety of ways in which information was presented to students (e.g., text, visual materials, audio/video lectures, infographics).

(3) *Expression* – coded according to the range of modalities students were invited to use to demonstrate learning outcomes (e.g., written papers, oral presentations, creative projects, multimedia submissions).

The overall UDL score for each course reflected the average implementation level across these three dimensions.

Coding of cognitive complexity: Bloom's taxonomy (Anderson & Krathwohl, 2001) was applied to analyze the learning tasks and assignments presented in each course. Each task was reviewed in full, and every question within it was classified according to the six hierarchical levels of cognitive demand—*remember, understand, apply, analyze, synthesize, and evaluate*—based on the highest level of thinking required for an optimal response. For example:

Application level task:A high school administration seeks to introduce a pedagogical change integrating AI tools in teaching and learning. Refer to the first stage in Lewin's organizational change model and describe it in this context: What problem would initiate the change process? What actions would you take to create motivation for change and reduce resistance?" This task was coded at the *application* level because it requires applying a theoretical model to a concrete case.

Evaluation level task: Students were asked to conduct a self-assessment of their academic writing using a detailed rubric and then reflect on the experience: What conclusions can you draw? What did you learn about self-assessment and about yourself as a learner? Did you identify discrepancies between your self-evaluation and the instructor's assessment, and if so, what might explain them?" This task was coded at the *evaluation* level, the highest cognitive complexity, as it involves critical

reflection, metacognitive reasoning, and evaluative judgment. Each course was assigned the highest cognitive complexity level identified among all its tasks, representing the maximal level of cognitive challenge embedded in the course design.

Together, these coding procedures operationalized pedagogical quality as reflected in both accessibility and inclusivity (UDL) and cognitive demand (Bloom's taxonomy), providing the basis for subsequent statistical analyses.

To ensure reliability, two research assistants were trained to code the pedagogical features of the courses. During the initial phase, they jointly analyzed three courses to establish consistency in their approach. Subsequently, they independently analyzed three additional courses to assess inter-rater reliability, achieving an 83% agreement rate. Following this, each research assistant was assigned responsibility for coding eight courses individually.

Appropriate codes were used to calculate each student's behavioral patterns on the online course's Moodle platform. The focus was on the number of times each student logged into the course site and the characteristics of their learning sequence as reflected in these logins, as assessed on a five-point scale: 0 when a student logged in only once; 1 when a student logged into the course site several times on a given day; 2 when a student logged into the course site several times on consecutive days; 3 when a student logged in without following any organized sequence; and 4 when a student's login sequence was mixed (several days in a row, a break of several days, followed by several days in a row). These patterns were calculated for 16 types of activities that students conducted on the online course website via Moodle: link to a padlet board; PowerPoint presentation; link to an external site; link to the syllabus; blog; forum; list of references; lesson summaries or focused lesson descriptions; submitting an assignment via Moodle; accessing articles or textual information; link to a survey; question sheet; Moodle quiz; questions to prepare for exam or exams from previous years; accessing pictures (non-textual information, maps, charts and the like); external software package that includes a number of videos or text together with an online quiz (Quizz).

Behavioral indicators of student activity were extracted from the learning management system (LMS), including login frequency and sequence, representing the temporal patterns of course participation. These measures were chosen because they provide objective, student-level data that can be directly linked to academic outcomes. Although such indicators do not fully reflect students' psychological engagement or motivational states, they capture meaningful differences in learning behaviors—for example, whether students engage continuously throughout the course or concentrate their learning efforts in short, intensive periods.

In order to link students' demographic characteristics, academic performance, and LMS usage patterns, matching was performed across institutional datasets. Cases with missing demographic, achievement, or LMS data were excluded from the analyses to ensure data integrity and consistency across variables. The final dataset therefore included only students with complete information on all relevant measures.

Coders were granted access to the online course shells with the instructors' explicit consent, solely for the purpose of pedagogical analysis. The review included course materials, assignments, and activity structures, but no identifiable student information (such

as names, discussion posts, or submissions) was recorded. All data were documented in aggregate form, focusing only on pedagogical characteristics relevant to the coding framework, in accordance with institutional ethical approval.

Because instructor participation was voluntary, the final sample of 22 courses reflects those whose lecturers consented to take part in the study. This self-selection may introduce some degree of bias, as participating instructors might differ in their pedagogical interest or openness to innovation. However, the sample includes courses from all three faculties and across diverse disciplinary domains, providing a heterogeneous and reasonably representative picture of online teaching practices within the institution. The goal of the study was not statistical generalization, but rather to identify trends and relationships in pedagogical design across a range of authentic course settings.

Ethical Considerations

The study received approval from the institutional ethics committee, which also granted a waiver of student consent, as the data were drawn from administrative academic records and fully anonymized prior to analysis. One authorized research staff member handled the identifiable dataset to merge academic and LMS information, replaced all student identifiers with non-traceable codes, and deleted the identifiable file after anonymization. Coders accessed the online course shells with instructors' explicit permission for the purpose of pedagogical analysis only and did not view or record any identifiable student submissions or posts. All analyses were conducted using anonymized data in accordance with institutional and national ethical standards for research involving human participants.

Data Analysis

Statistical analyses were conducted using SPSS (version 28). Prior to computing the interaction terms, all continuous predictors were mean-centered to reduce multicollinearity. The assumptions of linearity, normality of residuals, and homoscedasticity were verified through residual plots, histograms, and normal probability (P-P) plots. All assumptions were met within acceptable ranges. Multicollinearity diagnostics indicated that all tolerance values exceeded .40 and VIF values were below 2.5, suggesting no collinearity concerns. The regression models were estimated using the Enter method in three hierarchical steps. Missing data were handled listwise. Effect sizes and change in explained variance (ΔR^2) were examined for each model to evaluate the incremental contribution of the pedagogical and behavioral predictors.

The dataset included students nested within 22 online courses. Because the number of students per course varied and the study's primary focus was on individual-level predictors, all analyses treated students as independent cases. However, it is acknowledged that some degree of non-independence may exist due to shared course contexts. Future research using a multilevel modeling approach could more precisely estimate course-level effects.

Results

To answer the first research question, a multiple regression analysis was conducted to examine the predictors of online course grades (dependent variable) across three models.

Model 1: Demographic Characteristics

The first model included demographic predictors: academic major, year of study, gender, ethnicity, whether student was diagnosed with learning disabilities, and cumulative GPA. This model was statistically significant, $F(6, 274)=3.791$,$p=.001$ and explained 7.7% of the variance in online course grades (Adjusted $R^2=.056$). Among the predictors, academic major ($\beta=-0.148$, $p=.014$) and cumulative GPA ($\beta=0.260$, $p<.001$) were significant contributors.

Model 2: Pedagogical Features of the Course

The second model included the predictors from Model 1 and added pedagogical characteristics: Bloom's taxonomy level, UDL-engagement, UDL-knowledge, UDL-information, number of features, and the synchronous/asynchronous course format. This model was also statistically significant, $F(12, 268)=3.684$, $p<.001$, explaining 14.2% of the variance in course grades (Adjusted $R^2=.103$). Significant predictors included: Bloom's taxonomy level ($\beta=-0.146$, $p=.036$); Cumulative GPA ($\beta=0.265$, $p<.001$); and UDL-engagement ($\beta=-0.188$, $p=.041$). The inclusion of pedagogical features significantly improved the model ($\Delta R^2=.065$, $p=.003$).

Model 3: Patterns of Student Interaction with the Online Platform

The third model added variables related to student interaction with the course platform: overall average number of student logins to activities on the course website, and average login sequence pattern. This model was not statistically significant, $F(14, 266)=3.144$, $p=.943$, and did not explain additional variance beyond Model 2 ($\Delta R^2=.000$, $p=.943$).

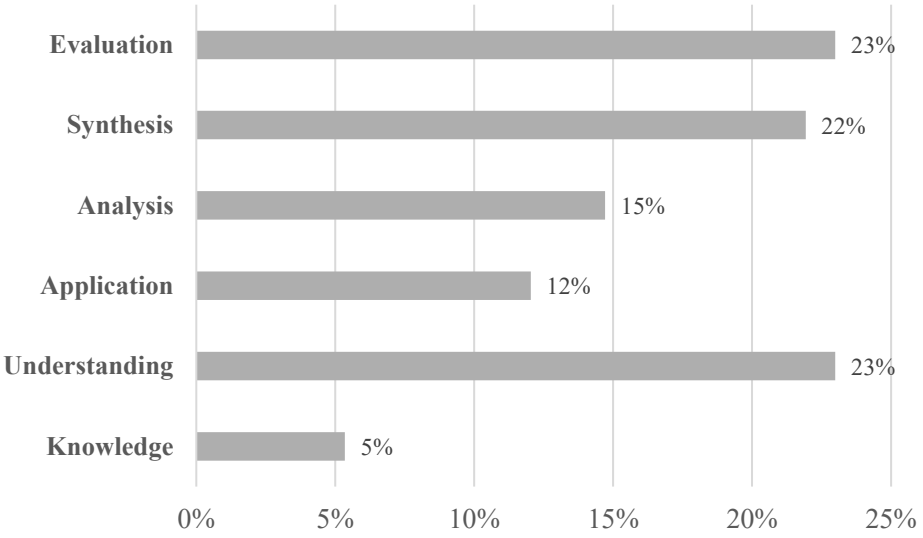
The results indicate that both demographic characteristics and pedagogical characteristics significantly predict online course grades. However, patterns of student interaction with the course platform did not contribute significantly to explaining variance in grades.

A one-way ANOVA was conducted to examine the differences in online course grades across Bloom's taxonomy levels. Levene's test for equality of variances indicated a violation of the assumption of homogeneity of variances, $F(5, 345)=5.650$, $p<.001$. Therefore, the Games-Howell post hoc test was used for pairwise comparisons.

The ANOVA was significant, $F(5, 345)=3.739$, $p=.003$, indicating differences in grades among Bloom's taxonomy levels. Pairwise comparisons using the Games-Howell test revealed significant differences: Students scored significantly lower on synthesis tasks ($M=76.84$, $S.D.=23.85$) compared to application tasks ($M=87.35$, $S.D.=8.55$), $p=.009$. Grades were also significantly lower on evaluation tasks ($M=79.22$, $S.D.=14.61$) compared to application tasks, $p=.002$. No significant differences were found between other Bloom's taxonomy levels. These results suggest that tasks requiring higher-order thinking skills, such as synthesis and evaluation, were associated with significantly lower grades compared to application tasks. Figure 1 presents the frequency of the courses according to the highest level in Bloom's taxonomy coded in the learning tasks on the course website.

Figure 1

Frequency of Courses According to the Highest Level in Bloom's Taxonomy Coded in the Learning Tasks



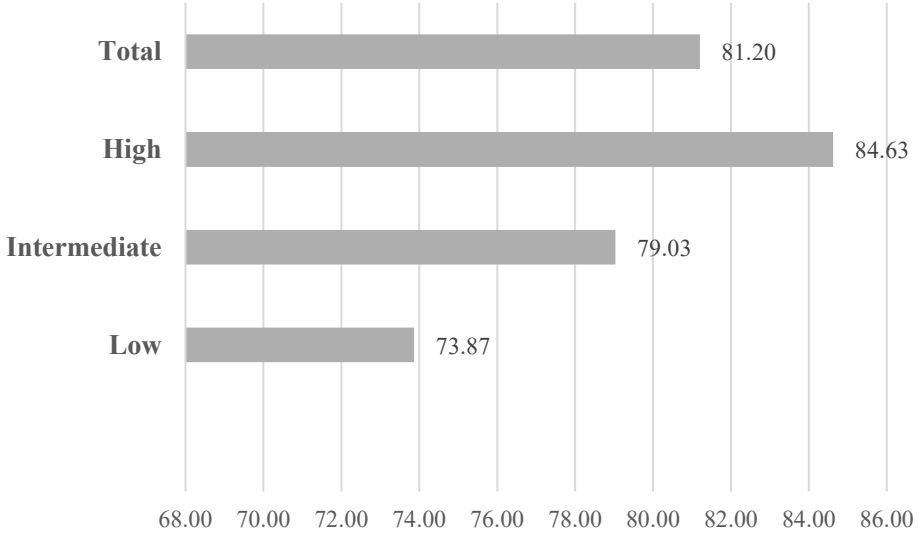
An independent-samples t-test was conducted to compare the grades of students in courses with only one active learning strategy versus those with multiple strategies (UDL-engagement). Levene's test indicated a violation of the assumption of equal variances ($p<.001$). Therefore, the results for equal variances not assumed were used. Results showed that students in courses with multiple strategies scored significantly lower ($M=78.37$, $S.D.=18.41$) compared to those in courses with only one strategy ($M=86.24$, $S.D.=11.99$), $t(347)=4.821$, $p<.001$. The effect size was calculated using Cohen's d, which indicated a medium effect ($d=0.492$).

A one-way ANOVA was conducted to examine the differences in online course grades across cumulative academic levels. Levene's test for equality of variances indicated a violation of the assumption of homogeneity of variances, $F(2, 484)=8.091$, $p<.001$. Therefore, the Games-Howell post hoc test was used for pairwise comparisons.

The ANOVA was significant, $F(2, 484)=9.050$, $p<.001$, indicating differences in grades among cumulative academic levels. Pairwise comparisons using the Games-Howell test revealed significant differences: Students in low academic level had significantly lower online course grades ($M=73.87$, $S.D.=27.29$) compared to students in high level ($M=84.63$, $S.D.=16.11$), $p=.020$. Grades were also significantly lower among students in intermediate level ($M=79.03$, $S.D.=19.63$) compared to students in high level, $p=.004$. No significant differences were found between students in low and intermediate levels. Figure 2 presents the means for each academic level.

Figure 2

Grade Means in Online Course for Each Academic Level



To answer the second research question, Pearson's correlation coefficient testing revealed a significant, low, and positive correlation between students' cumulative GPA and their grades in the online course ($r=0.162$, $p<0.001$). The PROCESS micro developed by Hayes (2013) and implemented in SPSS 28.0 was used to examine how the pedagogical characteristics of the online course and the student login patterns to course activities moderate this correlation. In the examination, cumulative GPA was the independent variable and grade in the online course was the dependent variable. The following moderation variables were examined: variety in how instructors present information (UDL-information), variety in how students present knowledge (UDL-knowledge), number of features, cognitive level of tasks according to Bloom's taxonomy, overall average number of student logins to activities on the course website, and average login sequence pattern. Among these variables, three were found to be significant moderators: variety in how instructors present information, variety in how students present knowledge, and number of features. These three variables are manifestations of the UDL principles.

Table 1 depicts the results with respect to the moderating variables found to be significant. As can be seen in Figures 3-5, the relationship between cumulative GPA and online course grade is weak when UDL manifestations are high (indicated by the low slopes of the dashed curves in the three figures), and this relationship strengthens significantly when UDL manifestations are low (indicated by the high slopes of the solid curves in the three figures). Additionally, the figures reveal differences among students at different academic levels in the effect of UDL attributes on their course grade. An increase in the number of features on the course website and an increase in the variety of ways the lecturer presents the information affects an increase in the course grade among students with a low academic level. An opposite trend was found among students at a high academic level. Similar but more moderate effects were found for the diversity in ways of presenting knowledge by the students. These findings highlight the differences in the impact of the pedagogical design of the online course on students at different academic levels.

These moderation findings suggest that the benefits of UDL-related features are not uniform across students. For students with lower cumulative GPA, a rich pedagogical design—featuring diverse materials, presentation formats, and engagement strategies—appears to enhance their course performance. In contrast, for students with higher cumulative GPA, the same features do not offer additional benefit and may even hinder performance, possibly due to redundancy or cognitive overload. The interaction plots (Figures 3–5) visually demonstrate this pattern: The solid line represents students in courses with low levels of UDL features. It shows a steep upward trend, indicating that higher cumulative GPA strongly predicts higher course grades in less pedagogically diverse courses. The dashed line, representing high levels of UDL features, is relatively flat suggesting that in courses with many UDL attributes, students' GPA is less predictive of their actual performance. This flattening of the slope implies that UDL features may serve as a form of scaffolding that levels the playing field for lower-achieving students, reducing the performance gap between students with lower and higher prior achievement. In other words, while high-GPA students tend to succeed regardless of the course design, low-GPA students benefit significantly from thoughtful and inclusive pedagogical strategies. This highlights the importance of aligning course design with learner diversity and offering differentiated support.

Table 1

Moderating Variables in the Relationship Between Cumulative GPA and Grade in the Online Course

Variable	*B*	Std.Err.	β
Variety in how instructors present information (UDL-information)	47.996	17.523	1.493*
Cumulative GPA	1.225	0.383	0.788*
UDL-information* Cumulative GPA	-0.562	0.209	-1.659*
Variety in how students present knowledge (UDL-knowledge)	40.769	15.449	1.308*
Cumulative GPA	1.107	0.317	0.712**
UDL-knowledge* Cumulative GPA	-0.518	0.183	-1.564*
Number of features	32.729	11.353	1.711*
Cumulative GPA	1.242	0.374	0.801*
Number of features* Cumulative GPA	-0.379	0.136	-1.834*

Note. ** p<.01, ** p<.001*

Figure 3

The Level of Diversity in how Instructors present information as a Moderating Variable of the Relationship Between the Student's Cumulative GPA and the Grade in the Online Course

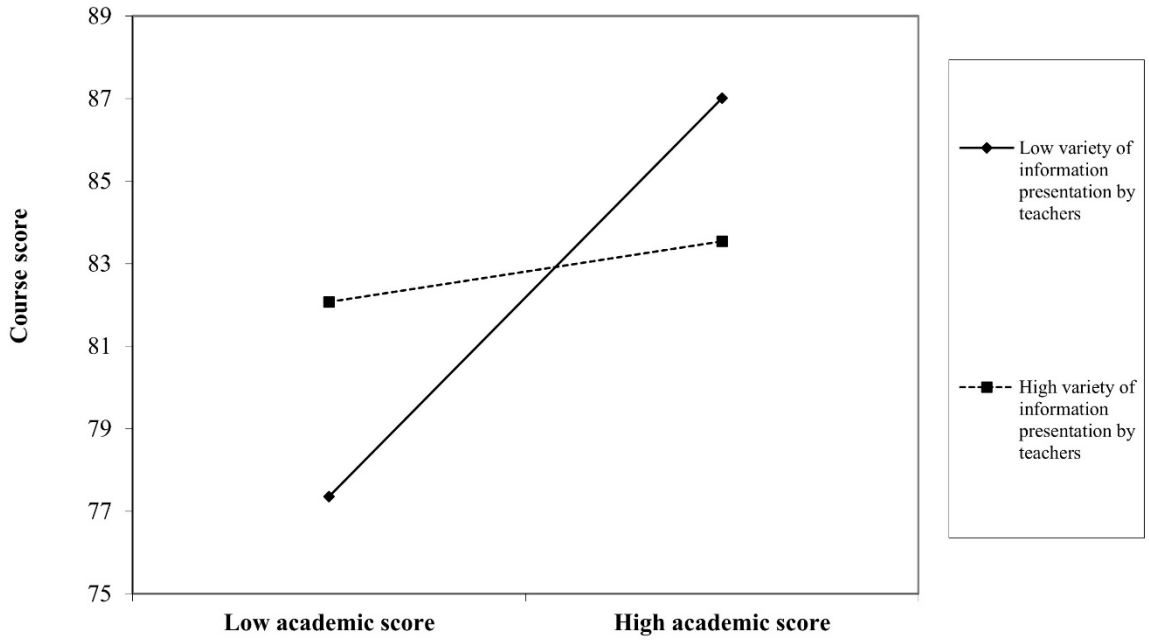


Figure 4

The Level of Diversity in How Students Present Knowledge as a Moderating Variable of the Relationship Between the Student's Cumulative GPA and the Grade in the Online Course?

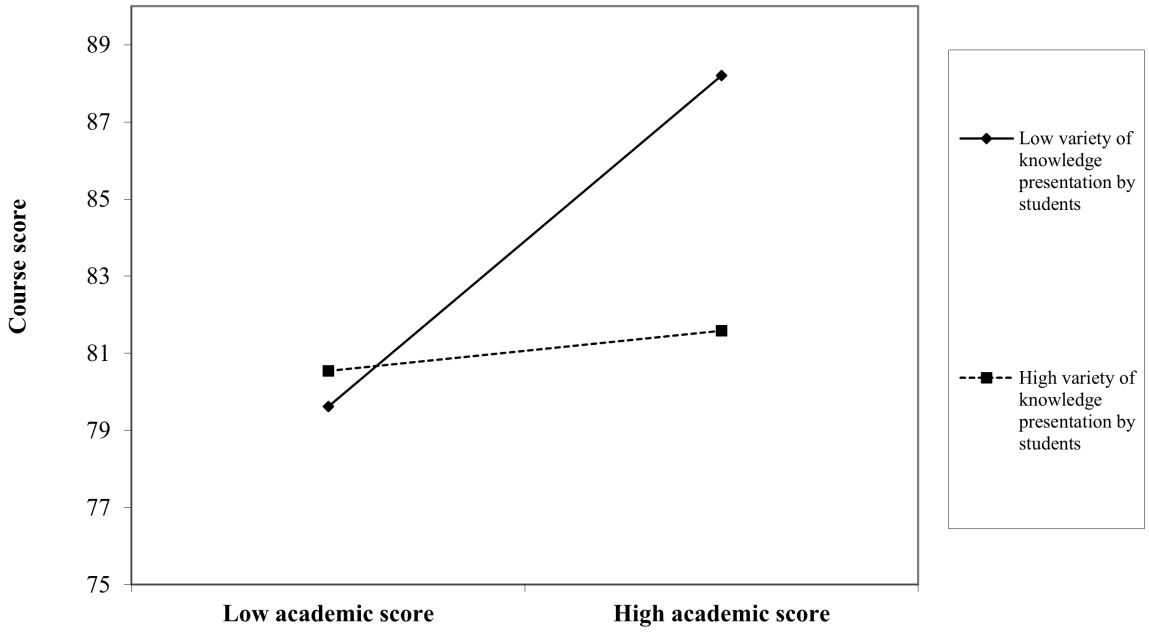
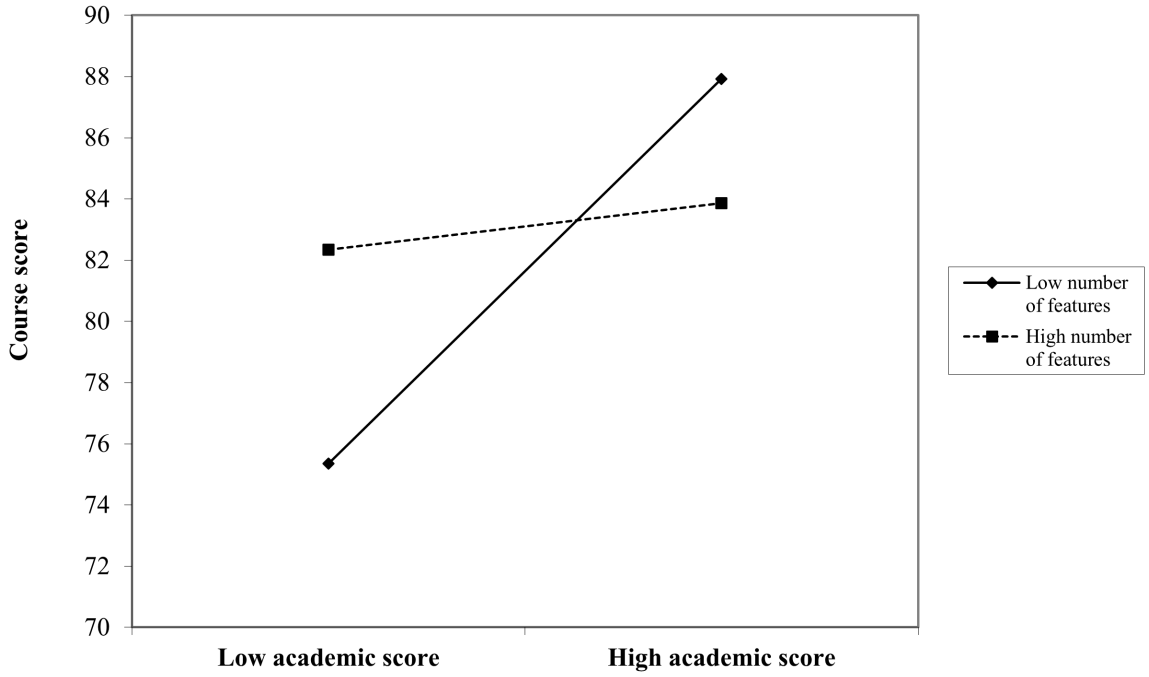


Figure 5

Number of Features as a Moderating Variable of the Relationship Between the Student's Cumulative GPA and the Grade in the Online Course



Discussion

The present study aimed to explore the factors influencing academic performance in online courses, focusing on pedagogical characteristics, demographic variables, and student engagement patterns. Data were collected from 661 students enrolled in 22 online courses across diverse academic disciplines. The analysis incorporated multiple tools, including a detailed coding framework for pedagogical features based on UDL principles and Bloom's taxonomy, as well as metrics for assessing student interaction on the course platform.

The following sections discuss the findings in relation to the study's three main dimensions: pedagogical quality (HOTS), Universal Design for Learning (UDL), and behavioral engagement patterns.

Predictors of Student Success in Online Courses

The results reveal that both demographic and pedagogical characteristics are significant predictors of online course grades, while patterns of student interaction with the course platform did not substantially explain variance. This suggests that the quality of course design and individual student factors play a larger role in academic success than platform activity.

Although the regression models were statistically significant, they explained a modest portion of the variance in students' grades. This suggests that additional factors—such as instructional feedback quality, social interaction, or students' self-regulation—may

further account for differences in performance. Therefore, the findings should be interpreted as indicative rather than definitive, highlighting trends that warrant deeper investigation.

The findings are consistent with previous research indicating that student cumulative GPA is a high indicator of student success in online courses (Cavanaugh & Jacquemin, 2015; Daymont & Blau, 2008; Jost et al., 2012; Vella et al, 2016).

Pedagogical Quality and Higher-Order Thinking (HOTS) Tasks

The study revealed that tasks requiring higher-order thinking skills (HOTS) were associated with lower grades in online courses. This finding aligns with the well-established notion that cognitively demanding tasks pose greater challenges for students, as they require critical analysis, synthesis, and evaluation rather than rote memorization or straightforward application. Although literature often highlights the positive relationship between HOTS and academic success, as shown in Tanujaya et al. (2017), where HOTS significantly predicted higher GPAs among mathematics students, this pattern may not hold uniformly across all disciplines or instructional contexts.

In the current study, the online learning environment may have amplified the challenges of HOTS tasks. Limited real-time support, fewer opportunities for collaborative problem-solving, and potential difficulties in accessing resources could hinder students' ability to perform well on complex tasks. Furthermore, the asynchronous nature of many online courses might reduce the immediacy of feedback that is critical for mastering high-order cognitive skills. This finding suggests that while HOTS tasks are essential for developing critical and creative thinking, their implementation in online courses must be carefully designed with scaffolding and support mechanisms to ensure that all students can engage effectively.

Our results showed that students in online courses with multiple strategies scored significantly lower. The finding that courses with more active learning strategies resulted in lower grades contrasts with prior research emphasizing the benefits of active engagement (Furrer & Skinner, 2003; Gunuc, 2023; Hanaysha et al., 2023; Tay et al., 2021). Several possible explanations can arise in this context. Courses with multiple active strategies might demand higher cognitive and emotional effort, particularly for students in online learning that unaccustomed to such approaches. This could lead to decreased performance. Students might prefer more traditional, structured teaching methods. Courses with multiple strategies could appear chaotic or less coherent. Active learning strategies may not have been implemented effectively. For instance, tasks might not align well with course objectives. Students may perceive the tasks as busywork rather than meaningful engagement.

Universal Design for Learning (UDL) and Student Achievement

The moderating model underscores the differential impact of pedagogical design on students at varying academic levels. For lower-performing students, features such as UDL attributes—diverse presentation methods, multiple expression options, and active engagement practices—were beneficial, likely by reducing barriers to learning and enhancing accessibility. Conversely, for higher-performing students, these features appeared less impactful. Students with higher academic averages may perceive these features as unnecessary or redundant, potentially leading to lower perceived value and engagement. This points to the need for tailored pedagogical strategies that balance accessibility with intellectual challenge to meet the diverse needs of learners in online settings.

These moderation effects highlight an important pedagogical insight: UDL features may serve a compensatory function in online learning environments. Specifically, when the level of UDL implementation is high—meaning the course includes varied ways of

presenting information, diverse modes of student expression, and multiple engagement strategies—the correlation between students' cumulative GPA and their final course grade becomes weaker. This suggests that UDL-rich environments help lower-performing students improve their outcomes, thereby narrowing the performance gap. In contrast, when UDL features are limited or absent, the correlation between GPA and course grade strengthens, indicating that student success is more tightly tied to prior academic achievement.

The differences in the impact of UDL features on students with varying academic levels have not been previously studied. These differences may stem from distinct needs and the ways in which students at different levels respond to diverse pedagogical approaches. Lower-achieving students may benefit, as prior research suggests, from the broad response to their learning needs (Craig et al., 2024; Izzo, 2012; Yuzlu & Arslan, 2017) and from increased motivation and sense of self-efficacy through tailored learning experiences and a greater sense of control over their learning (Dempsey et al., 2023; Mayes, 2020; Palmer, 2015). In contrast, higher-achieving students may perceive some UDL features as unnecessary or repetitive, potentially leading to frustration or disinterest. These students may prefer more traditional learning methods that allow them to progress rapidly and maximize their potential.

While UDL features are designed to enhance accessibility and flexibility for diverse learners, the findings of this study suggest that they may have unintended consequences for high-performing students. One possible explanation is that such students often prefer efficiency, challenge, and autonomy in their learning. Courses rich in scaffolding, choice, and multimodal content might be perceived by these students as redundant, overly structured, or even distracting. This could result in lower engagement or motivation, especially when the instructional design does not sufficiently differentiate for learners who are already academically self-regulated and cognitively prepared.

From a theoretical perspective, the differential impact of UDL features can be explained through both cognitive and motivational lenses. According to Cognitive Load Theory (Sweller, 1988) and the Expertise Reversal Effect (Kalyuga et al., 2003; Kalyuga, 2007), extensive scaffolding and multimodal guidance that benefit novice learners may become redundant or even distracting for more experienced students, creating extraneous cognitive load. At the same time, self-determination theory (Deci & Ryan, 1985; Ryan & Deci, 2000) suggests that while structured and supportive environments enhance competence and autonomy for lower-achieving students, highly directive designs may restrict autonomy for advanced learners, reducing their intrinsic motivation. Taken together, these perspectives reinforce the need for adaptive course design that differentiates between learner profiles—providing scaffolds and varied representations for struggling students, while offering autonomy and enrichment opportunities for high achievers. For instance, instructors could integrate tiered assignments, optional challenges, or independent inquiry tasks that extend learning without over-structuring it.

Behavioral Indicators of Online Engagement (Login Patterns)

The overall average number of student logins to activities on the course website and average login sequence patterns were not found to predict students' grades in the online course, nor did they moderate the relationship between students' cumulative GPA and their online course grades. This finding stands in contrast to the results of Bravo-Agapito et al. (2021), who identified Moodle activity frequency, including logins, forum participation, and interaction with educational materials, as significant predictors of higher academic performance in online learning. Their study suggested that students who engaged more intensively with Moodle achieved higher grades. The discrepancy between these findings

may stem from differences in the types of student interactions measured and the contexts in which the studies were conducted. While Bravo-Agapito et al. (2021) examined a broad range of meaningful interactions, such as active participation in forums and engagement with quizzes, the current study focused primarily on login frequency and sequence patterns, which may not fully capture the depth or quality of student engagement. Additionally, the nature of the course content and the specific design of the online platform could influence how login behaviors translate into academic success. This suggests that the quantity of interaction alone may not be a sufficient indicator of performance; the quality and intent behind those interactions likely play a critical role.

Limitations and Future Directions

This study has several limitations that should be considered when interpreting the findings. First, the research focused on a single institution and a limited number of online courses, which may affect the generalizability of the results to other academic contexts or disciplines. Additionally, the reliance on quantitative measures for coding course characteristics, such as the number of UDL attributes or the cognitive complexity of tasks, might have oversimplified the pedagogical intricacies of the courses. It is important to consider additional pedagogical characterizations that can contribute to the understanding of the researched topic. In addition, it is advisable to conduct interviews or surveys to understand how students at different academic levels perceive the characteristics of the UDL in an online course. Future research should also consider longitudinal designs to examine how pedagogical features and engagement patterns evolve over time and their long-term impact on academic success.

A further limitation is that students were drawn from 22 different online courses, which may introduce some dependency among observations within the same course. Although the current analyses focused on individual-level predictors, future studies employing multilevel models could better account for course-level variance related to subject area, course design, or instructor characteristics.

It should be noted that LMS-based indicators such as login frequency and sequence represent behavioral traces rather than psychological engagement. While they provide valuable insights into students' study patterns and self-regulation strategies, they cannot fully capture motivation, affective involvement, or cognitive investment in learning. Future studies should therefore integrate both behavioral and perceptual data to obtain a more comprehensive understanding of engagement in online learning environments.

Despite these limitations, this study offers several significant strengths and contributions to the field of online education research. First, it integrates two well-established theoretical frameworks—Universal Design for Learning (UDL) and Bloom's taxonomy—to systematically analyze pedagogical features of online courses. This comprehensive approach provides a nuanced understanding of how course design influences student performance and engagement. Second, the study contributes to the growing body of research on online learning by examining the interplay between demographic factors, pedagogical characteristics, and student engagement patterns. By incorporating a moderating model, it highlights the differential impact of UDL attributes on students with varying academic levels, shedding light on the importance of tailoring online learning environments to diverse learner needs. It is important to think about improving the differential support and adjusting the UDL features to fit the needs of students at higher academic levels, for example, through more complex tasks or advanced learning options. Third, the study uses a robust methodological approach, combining detailed coding of pedagogical features with student interaction data from the course platform. This mixed-method approach enhances the reliability of the

findings and provides actionable insights for instructors and course designers. Finally, the study's findings challenge existing assumptions about the universal benefits of higher-order thinking tasks and intensive platform use, offering a fresh perspective on how these factors influence academic outcomes in online learning. These insights can inform the design of more equitable and effective online courses that address both accessibility and intellectual rigor.

Conclusion

This study examined the predictors of academic success in online courses, focusing on pedagogical design, demographic characteristics, and patterns of student engagement. The findings underscore the importance of course design, as both Universal Design for Learning (UDL) features and Bloom's taxonomy levels significantly influenced student performance, while login patterns did not. Notably, tasks requiring higher-order thinking skills were associated with lower grades, suggesting the need for carefully scaffolded support in online environments.

A central contribution of this study lies in identifying the differential effects of UDL features across academic performance levels. While UDL attributes improved outcomes for lower-performing students by reducing barriers to learning, they were less beneficial for high-performing students. This phenomenon may be explained by cognitive load theory and the Expertise Reversal Effect (Kalyuga et al., 2003; Sweller, 1988), as well as self-determination theory (Deci & Ryan, 1985; Ryan & Deci, 2000), which emphasize the importance of autonomy and instructional fit.

These findings highlight the need for adaptive online course design that balances accessibility with intellectual challenge. Instructors should consider offering differentiated pathways that support novice learners while engaging advanced students through enrichment and autonomy. By doing so, online learning environments can promote both equity and academic rigor.

Declarations

Ethical Approval Statement: Data were collected in accordance with ethical standards for the treatment of human subjects. Research ethics approval was obtained by the Institutional Review Board (#3-10/2022).

Conflict of Interest Statement: The authors declare that there are no conflicts of interest regarding the research, authorship, or publication of this article.

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