A Cognitive Load Perspective on Synchronous and Asynchronous Modalities in Online Biostatistics Classes: A Mixed-Methods Analysis

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Abstract: *This study employed a mixed-method, quasi-experimental design to compare the impact of predominantly synchronous versus asynchronous online modalities on student performance and experience in an undergraduate Biostatistics course at a private university in Manila. The first semester cohort delivered through predominantly live, synchronous online sessions (6 of 9 weeks), while the second semester cohort relied primarily on pre-recorded, asynchronous video lectures (6 of 9 weeks). The quantitative analysis revealed that students in the more synchronous cohort achieved significantly higher midterm examination scores ($p<0.001$). However, this performance gap disappeared by the end of the term, with no significant difference observed in final examination scores ($p=0.235$). A thematic analysis of 71 selected comprehensive student responses identified a central tension between the need for synchronous immediacy to clarify complex concepts and the desire for asynchronous flexibility to manage learning pace and external commitments. The findings are interpreted through an integrated theoretical framework combining Cognitive Load Theory (CLT), Guidelines for Assessment and Instruction in Statistics Education (GAISE), and constructivist learning principles. The results suggest the initial performance disparity can be attributed to higher extraneous and intrinsic cognitive loads in the asynchronous setting, which students gradually learned to manage through the development of self-regulation strategies. The study concludes that while a blended approach is optimal, the instructor's pedagogical skill in managing student cognitive load emerges as a potentially more decisive factor in student success than the specific delivery modality. Recommendations for designing effective and cognitively aware online quantitative courses are provided.*

1. Introduction

The global shift toward online education has intensified the pedagogical debate over the relative effectiveness of synchronous versus asynchronous teaching methods. This discourse is particularly critical in quantitative subjects such as Biostatistics, where learning is characterized by the need to master both complex conceptual frameworks and intricate procedural skills. Synchronous learning, with its real-time interaction, is often praised for fostering engagement and immediate clarification [1], while asynchronous learning offers unparalleled flexibility, allowing students to learn at their own pace [2]. Recognizing the complementary strengths of each, educators have increasingly turned to blended models. This study moves beyond a simple comparison of these modalities to investigate the underlying mechanisms that influence their effectiveness in a university-level Biostatistics course.

To develop an understanding of how different online modalities impact learning, this study adopts Cognitive Load Theory (CLT) as its primary analytical framework. Established by John Sweller, CLT [3] is an instructional design principle rooted in the understanding that human working memory is limited in its capacity to process new information. The theory suggests that for learning to be effective, the total cognitive load, which is the mental effort required to learn, must not overwhelm this limited capacity. CLT identifies three types of loads [3]: intrinsic (the inherent difficulty of the material), extraneous (the unproductive load from poor instructional design), and germane (the productive load from deep processing and schema construction). The central goal of instruction, therefore, is to manage this total load by minimizing extraneous load and optimizing

intrinsic and germane load. This principle is especially critical in online environments, where extraneous load can be inadvertently increased by the technology and self-regulation demands placed on the learner.

Complementing the cognitive lens of CLT, this study incorporates the Guidelines for Assessment and Instruction in Statistics Education (GAISE), developed by the American Statistical Association. The GAISE framework provides a benchmark for high-quality statistics education, advocating for a holistic approach centered on a four-part statistical problem-solving process: formulating questions, collecting or considering data, analyzing data, and interpreting results [4]. Crucially, GAISE prioritizes the development of conceptual understanding over rote procedural knowledge, the use of real data to provide authentic context, and the integration of technology to facilitate analysis. This framework allows the study to evaluate the learning modalities not just on performance metrics, but on how well they cultivate genuine statistical thinking and literacy [5].

Further enriching the analysis is the integration of constructivist learning theory [6], which suggests that learners are not passive recipients of information but active constructors of their own understanding. This theory manifests in two key forms relevant to this study. Individual constructivism [7], rooted in Piaget's work, emphasizes the internal, personal process of meaning-making, aligning with the autonomy and self-paced reflection afforded by asynchronous learning. In contrast, social constructivism highlights that knowledge is co-created through social negotiation and communication, a process best supported by the immediate dialogue possible in synchronous settings [8]. By incorporating constructivism, this study can better interpret the diversity of student preferences, viewing them not as arbitrary choices but as reflections of fundamental differences in how individuals manage their cognitive resources and build knowledge.

By integrating the practical challenge of online quantitative classes like Biostatistics with the theoretical lenses of CLT, GAISE, and constructivism, this study aims to provide a comprehensive and deeply contextualized analysis. The research pursues three specific objectives: first, to quantitatively compare the academic performance of Biostatistics students under predominantly synchronous and predominantly asynchronous online cohorts; second, to conduct an in-depth thematic analysis of student experiences, preferences, and perceived challenges under each modality; and third, to interpret the combined findings through the integrated theoretical framework to provide an explanation of the results and their practical implications for designing effective online courses in quantitative subjects.

2. Methodology

This study employed a mixed-methods research design, integrating both quantitative and qualitative approaches to provide a comprehensive and triangulated understanding of the research objectives. A quasi-experimental component was used to compare the academic performance of two distinct, pre-existing student cohorts exposed to different online instructional modalities. This was complemented by a descriptive component that utilized detailed survey data to explore student satisfaction, preferences, and the nuances of their learning experiences. This integrated approach allows the quantitative findings on student performance to be explained and contextualized by the qualitative insights into the student experience.

This study employed a quasi-experimental design with undergraduate students in a Biostatistics course during the AY 2023-2024. Two cohorts were compared: a first semester 'more synchronous' group (N=147) with 6 of 9 weeks delivered via live sessions, and a second semester 'more asynchronous' group (N=329) with 6 of 9 weeks delivered via pre-recorded lectures. An analysis of the students' final grades in another quantitative course, "Mathematics in the Modern World,"

revealed no statistically significant difference (p=0.450), suggesting the cohorts possessed a similar level of mathematical preparedness before the intervention. To ensure data integrity, midterm and final examinations for both cohorts were administered in-person.

Data were collected using two primary instruments. Quantitative performance data consisted of the students' midterm and final examination scores, which were designed to assess their mastery of core Biostatistics concepts. Qualitative data on the student experience were gathered using a researcher-made validated instrument administered online at the end of each semester. This questionnaire is designed to gather comprehensive student feedback on a Biostatistics course, focusing on the effectiveness of its blended learning model. It collects data on student engagement, time commitment, and overall satisfaction, while specifically analyzing the value and impact of both synchronous and asynchronous components. The questionnaire also asked into the perceived benefits and drawbacks of each format, including levels of interaction, flexibility, and their effect on understanding complex material. It also seeks to understand how the specific balance of live versus recorded instruction influenced students' ability to grasp concepts, apply methods, collaborate, and prepare for assessments, while also gauging their preferences for the ideal course structure and its effect on their overall interest in the subject.

For the in-depth thematic analysis, a total of 71 responses (23 from the first semester and 48 from the second) were selected based on the comprehensiveness and thoughtfulness of the answers to the open-ended questions, ensuring a rich dataset for analysis. The qualitative data from the open-ended questionnaire responses were subjected to a rigorous thematic analysis. This process involved systematically identifying, coding, and organizing recurring patterns and ideas into broader themes that captured the essence of the student experience with each learning modality. All procedures adhered to strict ethical guidelines, including obtaining informed consent, ensuring the anonymization and confidentiality of all data, and securely storing the data for research purposes.

3. Results

This section presents the findings of the study, beginning with the quantitative analysis of student academic performance, followed by a detailed thematic analysis of the qualitative data regarding the student experience.

3.1 Student Academic Performance

The quantitative analysis (see Table 1) focused on comparing the midterm and final examination scores between the first semester (more synchronous) and second semester (more asynchronous) student cohorts.

Table 1

Comparison of Midterm and Final Examination Performance by Instructional Cohort

Examination	*Instructional Cohort*	*N*	*Mean (SD)*	*Mann-Whitney U*	*p-value*
Midterm (40)	More Synchronous	147	25.18 (7.71)	18641.00	< 0.001
	More Asynchronous	329	22.05 (6.25)		
Finals (35)	More Synchronous	146	19.81 (5.94)	22036.00	0.235
	More Asynchronous	324	20.33 (5.98)		

Given the non-normal distribution of the data, the Mann-Whitney U test was employed to compare the examination scores between the two semester cohorts. The Mann-Whitney U test revealed a statistically significant difference in the midterm examination scores between the first semester and second semester cohorts (U=18641.00, p<.001). This indicates that the students in the

more synchronous learning environment performed significantly better on the midterm assessment. However, for the final examination scores, the test found no statistically significant difference between the two cohorts (U=22036.00, p=0.235). This suggests that while an initial performance gap existed, the students in the more asynchronous cohort were able to adapt their learning strategies over the course of the semester, ultimately achieving a level of performance comparable to their peers in the more synchronous cohort by the time of the final exam.

3.2 The Student Experience: A Thematic Analysis of Learning Modality Preferences

While the quantitative data reveal what happened in terms of performance, the qualitative data from the student questionnaires explain why. The thematic analysis of 71 selected meaningful student responses uncovered several key themes that describes the interplay between learning modality, student needs, and instructional effectiveness.

Theme 1: The Dialectic of Immediacy vs. Flexibility

The most prominent theme emerging from the data is the tension students experience between the need for real-time, immediate support and the desire for self-paced, flexible learning. Student preferences were not uniform; rather, they reflected a careful weighing of these two modalities.

Sub-Theme 1.1: The Value of Synchronous Immediacy. Students across both semesters consistently highlighted the unique benefits of live, synchronous sessions for learning complex material. The ability to ask questions and receive immediate clarification was seen as dominant. A first semester student noted, *"It is helpful because if the professor is teaching something that is very hard to understand for me that time during discussion, I can just ask about it and open my mic"*. This sentiment was echoed by multiple respondents who emphasized that *"Live sessions are needed for clarifications in topics that are complex for students"*. For students in the more asynchronous second semester, this lack of immediacy was felt as a distinct loss. One student articulated the frustration: *"The asynchronous mode sometimes made it challenging to grasp the concepts without having immediate clarification"*. Another stated simply, *"Yes, because I feel like I can't ask questions I want to ask virtually"*. This feedback underscores that for many students, synchronous interaction is a vital mechanism for navigating difficult concepts and preventing misunderstandings from their own learnings.

Sub-Theme 1.2: The Value of Asynchronous Flexibility. Conversely, students expressed strong appreciation for the flexibility afforded by asynchronous, pre-recorded videos. This was especially true for the second semester cohort. The ability to learn at one's own pace was a frequently cited benefit. One student explained, *"The recorded videos are helpful in a way that I can watch the videos repeatedly, just like before the examination day. I can re-watch them for me to review the lessons"*. This capacity for repetition was crucial for mastering a subject that many found challenging. Another student added, *"[I] can learn the concepts in my own pacing"*. This flexibility was not just a matter of learning style but also a practical necessity for many. A nursing student from the second semester provided a compelling example: *"It was helpful because as a nursing student, we have a lot of requirements and duties and sometimes it affects the subject's time. So thankfully, we have the provided recorded sessions to compromise"*. Even students in the more synchronous first semester valued the recordings of their live sessions, with one noting, *"I like the p[a]rt*

where every session of our class is recorded so we can go back to topics we had difficulty understanding".

Theme 2: The Instructor as Primary Mediator of Learning

A prevailing theme across both cohorts was the profound impact of the instructor's teaching style and pedagogical approach. The data strongly suggest that the quality of instruction was a critical factor that mediated the student experience, often overriding the inherent characteristics of the learning modality itself.

Sub-Theme 2.1: Clarity and Teaching Style. Students from both semesters repeatedly praised the instructor's ability to make complex topics understandable. A first semester student commented, *"I think that our professor did a great job in explaining the topics in very simple terms that it was easy to comprehend"*. This was echoed by a second semester student who appreciated how *"the professor carefully explain[s] the step by step"*. The instructor's effectiveness appeared to transcend personal dispositions toward the subject matter. One student admitted, *"[H]onestly, the professor made the subject good. I typically don't like math, but the way it was taught made me enjoyed it"*. This sentiment was reinforced by another student who noted, *"I, personally, is a math-hater type but overall, i think it encouraged me more especially when I get grades higher than I've been expecting. It made me think that I can solve problems and that time and patience is the only way to do those"*. Another student in the asynchronous-heavy semester concluded that the experience was positive specifically *"because Sir has discussed every lesson so well"*. The sentiment was perhaps best summarized by a student who described Biostatistics as a *"painstaking subject made bearable by the flexibility offered by the recorded sessions and a great professor"*.

Sub-Theme 2.2: Real-World Relevance and Motivation. Beyond clarity, students valued the instructor's efforts to make the material relevant and to motivate them. A second semester student who had previously taken the course noted the improvement: *"In my experience, I already take this course two (2) times and I must say the first experience is way too different than what I experienced today. It relates the bio[logy] in the course and it [is] really useful for undergraduate research"*. This connection to their field of study and future work was highly valued. The instructor's motivational efforts were also explicitly recognized, with one student sharing, *"I believe that the learning mode in biostati[sti]cs is very inspiring because of his remarkable quotes every session that really motivate me as student to listen and understand"*.

Theme 3: Learner Adaptation and Self-Regulation

This theme directly addresses the quantitative finding that the performance gap between the two cohorts closed by the final exam. The qualitative data provides a narrative of how students, particularly in the more asynchronous second semester, navigated initial challenges and developed more effective learning strategies over time.

Sub-Theme 3.1: The Challenge of Self-Discipline. The freedom of asynchronous learning was not without its difficulties. Students candidly reported struggles with procrastination and time management. One student admitted, *"Yes, as I previously stated, recorded videos can be enticing not to watch because I will be the one to decide when I do"*. Another pointed

out a different behavioral challenge: *"When the class is recorded[,] I sometimes don't pay as much attention to the live sessions that we have because I know that the videos will be uploaded"*. These comments reveal the significant self-regulatory burden that asynchronous learning places on students.

Sub-Theme 3.2: Evolving Study Strategies. Despite these challenges, the data shows that students actively developed strategies to succeed. Peer collaboration emerged as a key adaptation. One student noted, *"The asynchronous sessions helped more in interacting with other classmates"*. Another student described a more structured approach stated, *"The asynchronous learning mode helped me re-study the lessons at my own pace. It also became a way for collaboration with one of my classmates as we prepared and studied for the exams"*. This reflects a broader pattern of adaptation, as another student explained: *"The asynchronous sessions helped more in interacting with other classmates. This also helped in the preparation of exams or assessments because of the freedom to learn at one's own pace since not all could catch up in synchronous sessions"*. Students learned to leverage the asynchronous resources more strategically, using the flexibility not for procrastination but for focused, independent, and collaborative learning. This evolution in study habits provides a compelling explanation for the observed convergence in final exam scores.

4. Discussion

The results reveal the dynamics of online learning in a quantitative subject. By synthesizing the quantitative performance data with the qualitative student feedback through the theoretical lenses of CLT, GAISE framework, and constructivism, a deeper understanding emerges. The discussion moves beyond a simple modality comparison to explore the cognitive processes, pedagogical alignments, and learner behaviors that underpin student success in an online Biostatistics class.

4.1 Performance and Adaptation Through the Lens of Cognitive Load Theory

The pattern of examination scores, which shows an initial performance gap and then disappears by the final exam, is a clear narrative of cognitive load management in action.

The lower midterm scores of the second-semester cohort, which experienced a predominantly asynchronous start to the course, likely reflect an initial state of cognitive overload. The subject of Biostatistics carries a high intrinsic cognitive load due to the high degree of element interactivity. This is where students must simultaneously learn new vocabulary, grasp abstract concepts, follow computational procedures, and interpret results [9]. In the more synchronous first-semester condition, the instructor's real-time presence provided continuous scaffolding such as pausing to answer questions, re-explaining difficult points, and guiding students through examples live. This real-time guidance serves to manage the high intrinsic load and minimize the extraneous cognitive load by providing a clear, structured path through the material [10].

In contrast, the second-semester students were confronted with the high intrinsic load of Biostatistics without this immediate scaffolding. They had to simultaneously learn the content and learn how to learn from the asynchronous materials. This added task of navigating the learning process independently, by figuring out what to focus on, what to do when confused, and how to pace oneself, imposes a significant extraneous cognitive load [3]. The combination of high intrinsic and high extraneous load likely exceeded the working memory capacity of many students, leading to the observed discrepancy in midterm performance. As students reported, the inability to get

immediate clarification on complex topics was a major challenge. The combination of high intrinsic and high extraneous load likely exceeded the working memory capacity of many students, leading to the observed discrepancy in the midterm exam performance.

However, the convergence of scores on the final examination demonstrates a remarkable process of adaptation. This finding aligns with research highlighting student adaptability in response to educational transitions [11]. From a CLT perspective, this adaptation represents students' successful development of metacognitive strategies to manage their own cognitive load. By re-watching videos and pausing to work through problems, they were able to self-scaffold and manage the high intrinsic load. This process of self-explanation is a key mechanism for promoting germane cognitive load, the effort dedicated to building robust, long-term schemas [10]. Furthermore, students compensated for the lack of instructor-led interaction by increasing peer collaboration, effectively creating their own social learning network to co-manage cognitive load [12]. By the end of the semester, they had reduced the extraneous load associated with "learning how to learn" and had mastered the use of asynchronous tools to foster the germane load necessary for deep understanding, allowing them to perform on par with their peers.

4.2 Aligning Modality Design with the GAISE Framework

The findings also offer valuable insights when evaluated against the GAISE framework, which provides a holistic approach to statistical literacy. The student feedback suggests that neither a purely synchronous nor a purely asynchronous model is optimal for supporting all four components of the GAISE statistical problem-solving process. Instead, a thoughtfully blended model [5], which many students advocated for in their ideal course designs, appears most promising.

The GAISE components of formulating statistical investigative questions and interpreting results are inherently dialogic and contextual. They benefit from the kind of social negotiation and brainstorming that is best facilitated in a synchronous environment. Live discussions allow students and the instructor to collectively explore the nuances of a research question or debate the implications of an analytical result, fostering the critical and statistical thinking that GAISE prioritizes [4].

Conversely, the GAISE component of analyzing data, which involves the application of specific, often complex, procedures and computations, imposes a high intrinsic cognitive load. For this component, asynchronous resources are invaluable. Students repeatedly emphasized the benefit of being able to pause, rewind, and re-watch recorded demonstrations of statistical tests. This aligns with CLT-based instructional strategies like using worked examples, which are highly effective for teaching learners complex procedures by reducing the cognitive burden and allowing them to focus on the problem-solving steps [3]. The flexibility of asynchronous videos allows students to dedicate the necessary time to master these procedural skills without the time pressure of a live class.

Furthermore, the students' praise for the instructor's use of examples relevant to their field directly supports the core GAISE principle of using real and motivating data [4]. This contextualization makes the learning more meaningful and helps students see the utility of statistics, which is a primary goal of statistical education [4].

4.3 Learner Agency and Constructivist Principles

The wide variation in student preferences for the balance between synchronous and asynchronous learning is a clear manifestation of constructivist principles in action. The data show that there is no single "one-size-fits-all" solution because learners are not uniform; they are active agents who construct knowledge in different ways [6].

The strong student preference for asynchronous flexibility can be understood through the lens of individual constructivism. This perspective suggests that learning is a deeply personal process of assimilating new information into one's pre-existing mental framework [8]. Students who favored asynchronous videos valued the time and autonomy to do this work: to pause, reflect, connect new concepts to what they already knew, and build understanding at their own pace. For these learners, the flexibility of the asynchronous format was essential for the personal construction of knowledge. Simultaneously, the equally strong student demand for synchronous interaction reflects the principles of social constructivism. This view argues that knowledge is not just built individually but is co-constructed through language, dialogue, and social interaction [8]. Students who prioritized live sessions were seeking to build their understanding through conversation with the instructor and their peers. They recognized that clarifying questions, hearing multiple perspectives, and engaging in collaborative problem-solving were essential to their learning process.

An effective online learning environment, therefore, is not one that rigidly imposes a single modality. Instead, it empowers learner agency by providing a rich set of resources and opportunities that support both individual and social construction of knowledge [6]. The ideal course design, as suggested by many students themselves, is a flexible, blended model that allows learners to draw upon synchronous or asynchronous resources as needed to manage their learning and cognitive processes.

4.4 The Instructor as the Primary Mediator of Cognitive Load

Perhaps the most critical finding of this study is the central role of the instructor, which transcends the modality debate. The positive feedback suggests that the 'instructor effect' was not a confounding variable but a key explanatory factor [13]. An effective instructor acts as the primary mediator of cognitive load. The students' praise for the professor's ability to explain topics in very simple terms' points to a teaching style that actively minimizes extraneous cognitive load [14]. This aligns with the extensive literature on 'teaching presence,' [13, 14] which identifies the instructor's actions in designing the course, facilitating discourse, and providing direct instruction as critical determinants of success and satisfaction in online learning

This observation can be explained through CLT. An effective instructor acts as a primary mediator of cognitive load. The students' praise for the professor's ability to explain topics "in very simple terms" and provide clear "step-by-step" guidance points to a teaching style that actively works to minimize extraneous cognitive load [3]. By presenting information clearly and logically, the instructor frees up students' limited working memory resources to focus on understanding the material (intrinsic load) and building connections (germane load).

Furthermore, the instructor's responsiveness and willingness to answer questions, both in live sessions and asynchronously, provide crucial, on-demand scaffolding that helps students manage the high intrinsic load of the subject. The motivational quotes and efforts to connect the material to students' lives and future careers serve to increase engagement and focus, which are prerequisites for promoting the effortful cognitive processing associated with germane load.

The implication is that while the choice and design of learning modalities are important, they may be secondary to the pedagogical skill of the instructor. A highly effective teacher can lessen many of the inherent weaknesses of a given modality. For instance, this can be seen by creating clear and engaging asynchronous videos or by managing a synchronous session in a way that encourages questions and participation. Conversely, a poorly designed lecture, whether delivered live or recorded, will likely induce cognitive overload. This suggests that different institutions applying online learning should focus as much on faculty development in online pedagogy and instructional design as they do on technological platforms and modality policies.

4.5 Limitations and Directions for Future Research

This study provides valuable insights, but its findings should be considered considering several limitations. First, the quasi-experimental design means that students were not randomly assigned to the instructional conditions, which introduces the possibility of unmeasured confounding variables despite the demonstrated comparability of the cohorts on prior mathematics achievement. Second, the study was conducted within the context of a single Biostatistics course with a single instructor at one university, which limits its generalizability. The study's design cannot separate the modality effects from the ‘instructor effect’. Furthermore, the study relies on subjective self-report measures for student experience, which may not fully capture objective cognitive processes.

Future research should seek to address these limitations. Randomized controlled trials could provide more definitive causal evidence about the impact of different modality balances. Studies across multiple institutions and with various instructors would help to unravel the effects of modality from the effects of instructor quality. Furthermore, research could delve deeper into the design of asynchronous materials. It would be valuable to explore how specific design principles, such as segmenting videos, embedding interactive questions, or providing guided note-taking templates, can be used to more effectively minimize extraneous load and scaffold learning for students in complex quantitative subjects. Finally, longitudinal studies could track students beyond the end of the course to assess the long-term impact of these different learning experiences on knowledge retention, application of skills in future coursework or research, and overall interest in the field.

5. Conclusion and Recommendations

This study concludes that while students in a more synchronous learning environment initially demonstrated significantly stronger academic performance, those in a more asynchronous setting were able to adapt their learning strategies over time, ultimately closing the performance gap by the final examination. The quantitative results, showing a significant difference in midterm scores that disappeared by the finals, point to an initial challenge for students learning independently, followed by a successful period of adaptation. This finding suggests that while real-time instructor scaffolding is highly beneficial at the outset, students can develop the self-regulatory skills needed to succeed in a flexible, asynchronous environment.

Qualitative data provided crucial context, revealing a clear dialectic in student preferences. Students highly valued the immediacy of synchronous sessions for clarifying complex concepts and asking questions in real-time, yet they equally appreciated the flexibility of asynchronous videos for self-paced review and managing external commitments. The study's primary theoretical contribution is its application of CLT, which reframes the debate from a simple modality comparison to a question of cognitive management. The initial performance disparity is explained by high extraneous and intrinsic cognitive loads in the asynchronous setting, which students gradually learned to manage by developing strategies that fostered germane load, or deep learning.

Based on these findings, the study offers several practical recommendations. The evidence strongly supports the adoption of a balanced, blended course design that leverages the strengths of both modalities by using synchronous time for high-value interaction and asynchronous components for foundational content delivery and practice. Critically, the research underscores the importance of the instructor's pedagogical skill. The ability to provide clear explanations, establish a supportive presence, and manage cognitive load through thoughtful instructional design appeared as a decisive factor in student success, often overriding the inherent characteristics of the delivery

mode. Finally, the study recommends that future research explore specific strategies to enhance engagement and minimize cognitive barriers within synchronous and asynchronous environments, particularly for complex quantitative subjects like Biostatistics.

References

[1] Grammens, M., De Smedt, F., Declercq, L., & De Wever, B. (2021). Everybody online: instructors' self-efficacy and training needs during the transition to (a) synchronous online teaching. In *INTED2021 Proceedings* (pp. 7381-7390). IATED.

[2] Yulitriana. (2021). Synchronous or Asynchronous: Students' Perceptions on Online Learning During the Pandemic. *EBONY: Journal of English Language Teaching, Linguistics, and Literature*, *1*(1), 54–59. https://doi.org/10.37304/ebony.v1i1.3101

[3] Sweller, J. (2010). Element interactivity and intrinsic, extraneous, and germane cognitive load. *Educational psychology review*, *22*(2), 123-138.

[4] Bargagliotti, A. E. (2012). How well do the NSF funded elementary mathematics curricula align with the GAISE report recommendations?. *Journal of Statistics Education*, *20*(3).

[5] Bargagliotti, A. (2020). Pre-K-12 guidelines for assessment and instruction in statistics education II (GAISE II). American Statistical Association.

[6] Carwile, J. (2007). A constructivist approach to online teaching and learning. *Inquiry*, *12*(1), 68-73.

[7] Sjøberg, S. (2010). Constructivism and learning. *International encyclopedia of education*, *5*, 485-490.

[8] Secore, S. (2017). Social constructivism in online learning: Andragogical influence and the effectual educator. *e-mentor*, *70*(3), 4-9.

[9] Yohanes, B., & Yusuf, F. I. (2021). Intrinsic cognitive load in online learning model of school mathematics 1 in covid-19 pandemic period. *JIPM (Jurnal Ilmiah Pendidikan Matematika)*, *9*(2), 59-69.

[10] Sovilj, A. (2024). *Overwhelmed math students? reducing cognitive load while teaching mathematics*. Sowiso. https://www.sowiso.com/blog/cognitive-load-mathematics/

[11] Besser, A., Flett, G. L., & Zeigler-Hill, V. (2022). Adaptability to a sudden transition to online learning during the COVID-19 pandemic: Understanding the challenges for students. *Scholarship of Teaching and Learning in Psychology*, *8*(2), 85.

[12] Yadav, S. K., Para, S., Singh, G., Gupta, R., Sarin, N., & Singh, S. (2021). Comparison of asynchronous and synchronous methods of online teaching for students of medical laboratory technology course: a cross-sectional analysis. *Journal of education and health promotion*, *10*(1), 232.

[13] Rose, N. N., Ishak, A. S., Hamidun, N., Khalid, F. K., & Othman, N. F. (2024). The Role of the Instructor in the Online Classroom. In *Balance and Boundaries in Creating Meaningful Relationships in Online Higher Education* (pp. 350-369). IGI Global Scientific Publishing.

[14] Hunter Dr, J., & Ross, B. (2019). Does increased online interaction between instructors and students positively affect a student's perception of quality for an online course?. *Journal on Empowering Teaching Excellence*, *3*(2), 4.