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Challenges Of Implementing Hybrid Learning Strategies For Students With Learning Disabilities In Secondary Schools

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Abstract
The rapid shift to hybrid learning has created significant challenges for students with learning disabilities (LDs), yet evidence from the Saudi Arabian secondary school context remains limited. This study investigated the prevalence, stakeholder differences, and predictive relationships of hybrid learning barriers for secondary students with LDs in Saudi public schools. A cross-sectional survey design was employed with 180 secondary students with formal LD diagnoses, 120 teachers, and 60 administrators across 45 schools in Riyadh, Jeddah, and Dammam. Participants completed the Hybrid Learning Barriers Inventory (HLBI), measuring five domains, while academic outcome data were extracted from the Madrasati platform. Hierarchical linear mixed-effects models and MANOVA were used for analysis. Executive function (EF) demands emerged as the most severe barrier ($M = 4.12/5.0$, $d = 1.44$) and the strongest negative predictor of GPA ($\beta = -0.52$) and assignment completion ($\beta = -0.52$). A significant perception gap was found between administrators and frontline stakeholders (Wilks' $\Lambda = 0.67$, $p < .001$), widest in low-SES schools. Students with dyscalculia showed greater EF vulnerability ($\beta = -0.61$) than those with dyslexia ($\beta = -0.42$). Protective factors included special education certification ($\beta = +0.23$ for GPA) and synchronous-dominant models (buffering engagement barriers from $\beta = -0.54$ to -0.22). The study concludes that hybrid learning in Saudi secondary schools presents severe EF demands that systematically disadvantage students with LDs, particularly those with dyscalculia and from low-SES backgrounds, while the administrator–stakeholder perception gap suggests current resource allocation may be misaligned with actual needs. The Ministry of Education should prioritise EF-friendly instructional design, preserve synchronous instruction, and weight resources by school SES.

Keywords: hybrid learning, learning disabilities, executive function, inclusive education, Saudi Arabia, secondary education.

Introduction

The COVID-19 pandemic acted as a global catalyst, fundamentally reshaping K-12 education overnight and accelerating the adoption of hybrid learning models with an urgency that caught most systems unprepared (Ridolfi et al., 2026). This sudden pivot to blended environments a pedagogical modality combining face-to-face classroom instruction and online digital media presented unprecedented challenges, particularly for the most vulnerable student populations. While hybrid and blended learning offer significant potential for personalised and flexible pedagogy (Li et al., 2025), their rapid, crisis-driven implementation has laid bare and often deepened longstanding inequities, especially for students with Special Educational Needs (SEN). This is particularly critical within secondary education in Saudi Arabia, where students navigate increasing academic demands alongside complex socio-emotional development; for those with learning disabilities, the abrupt shift to hybrid models introduced a new set of formidable barriers to access, engagement, and meaningful inclusion (Jackson, 2024).

The challenges of implementing hybrid strategies for learners with disabilities are systemic, manifesting across multiple interdependent levels. A primary and persistent obstacle is the digital divide, which encompasses not only disparities in access to hardware and reliable broadband but also the usability of digital platforms and the digital literacy of both students and educators (Ohri, 2025). Many Learning Management Systems (LMS) used in secondary schools in Saudi Arabia lack foundational accessibility features, failing to comply with standards like the Web Content Accessibility Guidelines (WCAG), which systematically excludes students' reliant on-screen readers or alternative navigation tools. Beyond accessibility, teacher preparedness remains a significant gap. Research consistently reveals that general and special education teachers alike often feel ill-equipped to design, manage, and differentiate instruction across both physical and virtual spaces; studies have found that educators encounter significant difficulty with blended learning modalities, citing an acute need for more targeted training and professional development (Celestial et al., 2024). Furthermore, the pandemic's disruption intensified other barriers, from a lack of individualised support typically afforded by in-person IEPs to heightened challenges in home learning environments requiring substantial parental involvement, a resource not equitably available to all students (Sama & Gul, 2024).

Despite growing recognition of these obstacles, a critical gap remains in understanding how these challenges specifically coalesce to impede the educational experiences of students with learning disabilities in mainstream secondary schools in Saudi Arabia. While studies have explored teacher perceptions, isolated intervention outcomes, and broad accessibility issues, there is a lack of robust, integrated evidence detailing the lived, real-world implementation failures and adaptive strategies within routine hybrid secondary education in the Kingdom. Existing literature often treats students with disabilities as a monolithic group, thereby obscuring the specific needs of those with learning disabilities (e.g., dyslexia, dyscalculia) who may struggle profoundly with the executive function demands, text-heavy interfaces, and self-directed pacing inherent in digital learning components (Johnson et al., 2024). Furthermore, post-pandemic research has predominantly focused on higher education or emergency remote teaching, leaving a significant void in knowledge about sustainable hybrid models and their differential impacts on this student population within the Saudi secondary school context (Ridolfi et al., 2026).

To address this critical gap, this study aims to systematically investigate the specific challenges of implementing hybrid learning strategies for students with learning disabilities in mainstream secondary schools in Saudi Arabia. Moving beyond a simple identification of barriers, this research will analyse the structural, pedagogical, and socio-emotional factors that influence the success or failure of hybrid inclusion. By centring the experiences and outcomes of students with learning disabilities, this study seeks to move the discourse from theoretical potential to evidence-based practice, providing actionable insights for educators, administrators, and policymakers in Saudi Arabia to design truly equitable hybrid learning environments that fulfil the promise of inclusive education in the digital age.

Literature Review

The rapid proliferation of hybrid learning models, integrating face-to-face instruction with online components, has transformed secondary education. However, the specific challenges and outcomes for students with Learning Disabilities (LDs) within these environments remain a critical and underexplored area of educational research, particularly in the Kingdom of Saudi Arabia. This review synthesises literature to critically evaluate our understanding of implementing hybrid learning for this student population, identifies persistent thematic challenges, and outlines significant gaps that future research in the Saudi context must address.

The Persistence of the Digital Divide and Accessibility Barriers

A foundational and well-documented challenge is the digital divide, which transcends mere access to devices and connectivity, rather exacerbated by the lack of usability and accessibility of core learning technologies. Systematic reviews underscore this issue. Contreras Rivera et al. (2026) conducted a PRISMA-based systematic review of 24 research projects across three continents, concluding that while hybrid environments were key to educational continuity during crises, their implementation has revealed "profound structural inequalities" that especially affect people with disabilities. Their review highlights that government efforts focused on device access are "insufficient without inclusive policies, adequate teacher training, and culturally relevant curriculum redesigns." Similarly, Li et al. (2025) identified digital divide and accessibility issues as a primary challenge in implementing hybrid learning in special education. These findings are echoed in analyses of K-12 online environments. Ohri (2025) examines the "dual barriers" those students with disabilities face: "lack of access and lack of usability," noting that many online platforms fail to meet Web Content Accessibility Guidelines (WCAG), effectively excluding students who rely on assistive technologies. In Saudi Arabia, where the Madrasati platform has been widely adopted for blended learning, the extent to which such platforms comply with WCAG standards remains under-researched. This technological inaccessibility creates a foundational barrier that, as Li et al. (2025) argue, must be addressed alongside teacher and systemic supports. A critical research gap persists in moving from identifying these barriers to developing and validating scalable, evidence-based solutions for implementing Universal Design for Learning (UDL) principles across diverse secondary school contexts, including those in the Gulf region.

Teacher Preparedness and the Professional Development Imperative

Even when technology is available, its effective use for students with LDs is contingent on highly skilled teaching. The literature consistently identifies a significant gap in teacher preparedness; a challenge intensified in the complex dual-modality setting of hybrid learning. Celestial et al. (2025) provide direct evidence from the secondary level, surveying 30 Grade 7 teachers. Their quantitative study found that teachers experienced only a "moderate level of difficulty" in providing differentiated instruction and collaborating with parents, but that "structural constraints, such as resource deficiencies and limited professional development opportunities, make inclusive practice challenging." This finding is critical, as it suggests that individual teacher skill may be less of a limiting factor than inadequate systemic support. Li et al. (2025) also identify "Teacher Preparedness and Training" and "Teacher Familiarity with Technology" as central success factors and challenges, implying a direct link between targeted professional development and improved student outcomes in special education hybrid settings. In Saudi Arabia, the Ministry of Education has invested heavily in professional development through platforms like the National Centre for Professional Development, yet the specific focus on hybrid instruction for students with LDs remains underexamined.

However, significant questions remain. Research on what constitutes effective professional development for this specific purpose is lacking. There is a particular gap in understanding how teacher training programs can address the cognitive and executive function demands that hybrid learning places on students with LDs. Furthermore, the sparsity of research on these issues, including the use of emerging technologies, has been noted, particularly in under-resourced regions such as sub-Saharan Africa (Kipchirchir et al., 2025) and the Middle East. Future research in Saudi Arabia should focus on experimental or quasi-experimental studies measuring the impact of specific, scalable training models on teacher practice and, most importantly, on student learning outcomes.

Systemic And Inclusive Challenges: Engagement, Executive Function, And The Home Environment

The challenges of hybrid learning for students with LDs extend beyond technology and teacher training to include individual student characteristics, particularly executive function, and the broader systemic context of the home learning environment. Madaus et al. (2024) highlight that compared to traditional courses, online and blended formats "require increased self-management and executive functioning skills, which research indicates can underlie many common learning challenges for students with LD and ADHD." This finding from postsecondary education has direct implications for secondary students in Saudi Arabia, who are still developing these critical cognitive skills. For students with LDs, the self-directed nature of the online component in a hybrid model can become a significant barrier, unless explicit support structures are in place.

Furthermore, Li et al. (2025) identify "Parental Involvement and Home Learning Conditions" as a key success factor. This highlights how hybrid learning shifts educational responsibility, placing additional demands on families. This finding ties into broader challenges noted in the literature, such as student "Engagement and Motivation" (Li et al., 2025). Bao et al. (2025), in their qualitative study of teacher perspectives in impoverished regions of China, found "poverty emerged as the most influential factor affecting online education," demonstrating how socioeconomic conditions can severely limit the viability of a supplementary online model. In Saudi Arabia, while broadband penetration is high, disparities in digital literacy, home learning environments, and parental availability to support hybrid instruction may vary significantly across regions and socioeconomic strata, an area requiring further empirical investigation.

Emerging Technologies and the Potential for Personalised Support

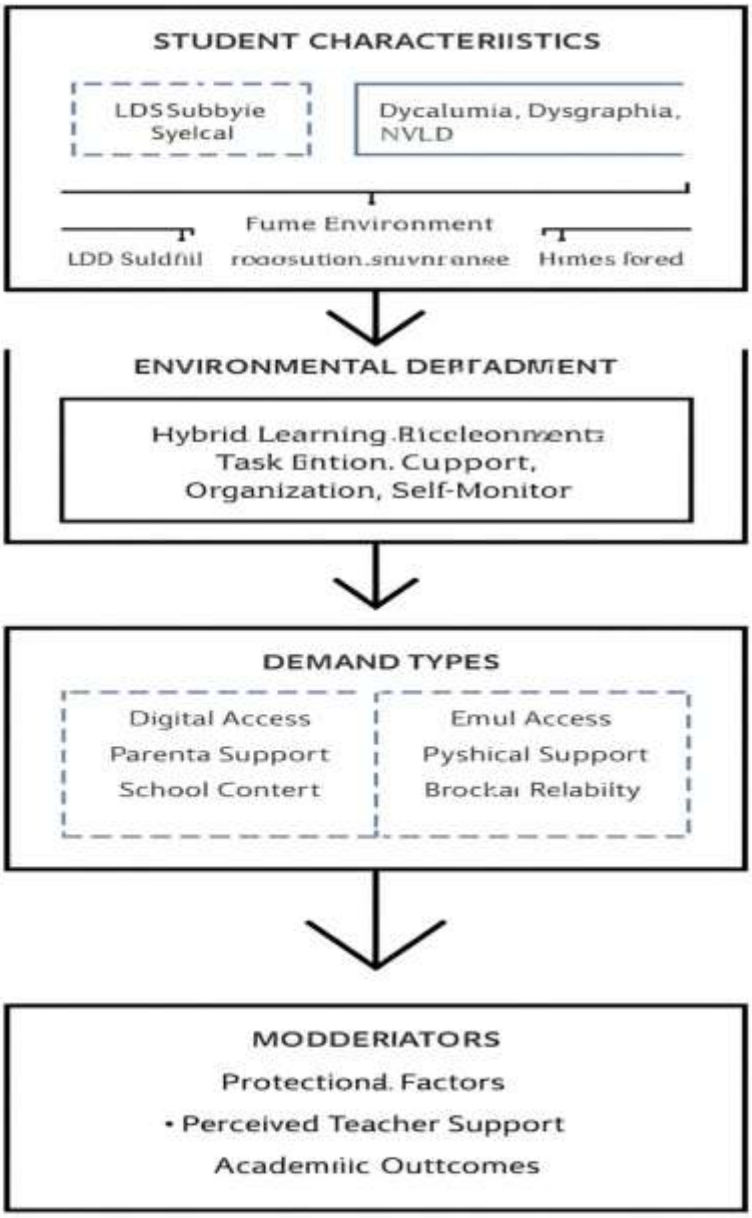
While challenges dominate the literature, there is growing evidence for the potential of emerging technologies to personalise the hybrid experience for students with LDs. Kipchirchir et al. (2025) conducted a PRISMA-conforming systematic review of 31 articles and found that "AR, VR, assistive technologies, and text-to-speech/speech-to-text are among the most widely adopted technologies in inclusive education," and that these enhance social inclusion and improve academic performance for students with learning disabilities. Menko (2025) conducted a dissertation study with K-12 educators and corroborates this, finding that digital accessibility tools can "remove barriers in a variety of ways." Specifically, teachers reported these tools were useful for students with LDs, autism spectrum disorder, and those needing reading assistance, which is consistent with research literature indicating such tools can improve access and academic outcomes. However, a notable limitation is that few participants described using these tools universally, suggesting a gap between potential and practice. In Saudi Arabia, the adoption of assistive technologies in mainstream secondary schools remains sporadic, and no large-scale study has yet documented their availability or effectiveness in hybrid learning settings.

The development of AI-powered platforms holds promise for bridging this gap. Eremia and Lobiuc (2025) present AccessiLearnAI, an "accessibility-first, AI-powered e-learning platform" designed to provide "truly accessible, personalized and adaptable e-learning environments." While early evaluations are promising, this represents a proof of concept rather than a validated, ready-to-scale solution. There remains a significant research gap in the efficacy of AI-driven personalisation versus simpler, less costly interventions for students with LDs in real-world secondary school contexts, including those in Saudi Arabia.

Theoretical Framework: The Mismatch Model

This study is anchored in a Person-Environment Mismatch Framework, adapted from ecological systems theory (Bronfenbrenner, 1979) and disability studies (Shakespeare, 2014). This framework posits that academic difficulties arise not from deficits located solely within the student but from misalignments between student characteristics and environmental demands.

Figure 1: Conceptual Framework Linking Hybrid Learning Barriers to Academic Outcomes



Source: Adapted from Bronfenbrenner (1979) and Shakespeare (2014).

Research Questions and Hypotheses

Research Question 1: What is the prevalence and severity of hybrid learning barriers experienced by secondary students with learning disabilities?
H_1: Executive function demands will emerge as the most severe barrier domain, with mean ratings significantly above the moderate threshold (M > 3.0).
Research Question 2: Do hybrid learning barriers differ significantly by stakeholder group (students, teachers, administrators) and school socioeconomic status (SES)?
H_2a: There will be significant stakeholder group differences, with administrators rating all barriers lower than students and teachers.
H_2b: There will be a significant SES gradient, with low-SES students reporting higher barrier severity than medium- and high-SES peers.
H_2c: The perception gap between administrators and frontline stakeholders will be widest in low-SES schools.
Research Question 3: To what extent do specific hybrid learning barriers predict academic outcomes for students with learning disabilities?
H_3a: Executive function demands will be the strongest negative predictor of all academic outcomes (GPA, assignment completion, LMS access frequency, attendance).
H_3b: Teacher special education certification will be a significant positive predictor of student GPA and assignment completion.
H_3c: School SES will exert a significant negative effect on all academic outcomes, exceeding the effect of any individual barrier.
Research Question 4: Do LD type and hybrid model type moderate the relationship between barriers and academic outcomes?
H_4a: Students with dyscalculia will show greater vulnerability to executive function demands compared to students with dyslexia.
H_4b: Synchronous-dominant hybrid models will buffer the negative effects of engagement barriers compared to asynchronous-dominant models.
H_4c: Digital access barriers will be more detrimental in low-SES schools implementing asynchronous-dominant models (three-way interaction).

Methodology

This study employs a cross-sectional, correlational survey design with a predictive component (Creswell & Creswell, 2018). The design systematically measures the prevalence, intergroup differences, and predictive relationships of hybrid learning barriers for secondary students with learning disabilities (LDs) in Saudi Arabia, addressing the gap for robust, generalizable evidence beyond descriptive accounts (Contreras Rivera et al., 2026; Li et al., 2025).
A stratified random sampling strategy was used across public secondary schools in Saudi Arabia that have implemented hybrid learning. Within each stratum, schools were randomly selected.

Participants

- **Students (n=180):** Formal LD diagnosis (dyslexia, dyscalculia, dysgraphia, or NVLD), active IEP/504 Plan, no co-occurring intellectual disability, enrolled in hybrid model (25–75% digital instruction) (Johnson et al., 2024).
- **General education teachers (n=60) and special education teachers (n=60):** Teach students with LDs in hybrid settings.
- **Administrators (n=60):** Principals and instructional technology/special education coordinators.
- **Total N = 360.**

Instruments

1. Hybrid Learning Barriers Inventory – Student Version (HLBI-S): 45 items, 5-point Likert, five subscales (α range .84–.89): Digital Access & Usability (Ohri, 2025), Executive Function Demands (Madaus et al., 2024), Engagement & Motivation (Li et al., 2025), Home Environment Support (Sama & Gul, 2024), Perceived Teacher Support (Celestial et al., 2025). Universal design features (large font, audio option) per Menko (2025).
2. Hybrid Learning Barriers Inventory – Educator Version (HLBI-E): 50 parallel items for teachers/administrators (α=.91) (Kipchirchir et al., 2025).
3. Academic Outcome Measures (archival): GPA (0–4.0), Assignment Completion Rate (%), Asynchronous Access Frequency (weekly logins), Synchronous Attendance Rate (%) extracted from LMS and student information systems (Johnson et al., 2024).

4. School Context Questionnaire (SCQ): SES, hybrid model type (synchronous-dominant vs. asynchronous-dominant), assistive technology availability, special education technology support (Contreras Rivera et al., 2026).

Instrument Validation

The HLBI was developed through a multi-stage validation process to ensure content and construct validity:

Content Validity:

- An initial pool of 65 items was generated based on the literature review.
- A panel of five experts (three special education professors, two educational technology specialists) reviewed the items for relevance, clarity, and comprehensiveness.
- The Content Validity Index (CVI) was calculated; items with CVI < 0.78 were revised or removed, resulting in 45 items (student version) and 50 items (educator version).
- The final instruments achieved scale-level CVI (S-CVI) of 0.89 for the student version and 0.91 for the educator version.

Pilot Testing:

- A pilot study was conducted with 45 students, 30 teachers, and 15 administrators from three schools not included in the main sample.
- Internal consistency (Cronbach's α) was calculated for each subscale (α range .84–.91).
- Test-retest reliability (two-week interval) was established with a subset of 30 participants (r = .78–.85).
- Based on pilot feedback, items with poor clarity were revised.

Construct Validity:

- Confirmatory Factor Analysis (CFA) was conducted on the pilot data.
- The five-factor model showed acceptable fit: CFI = .91, TLI = .89, RMSEA = .06, SRMR = .05.
- All factor loadings exceeded .50, supporting the subscale structure.

Procedures

Following IRB and district approvals in Saudi Arabia, eligible students were identified from school rosters. Parental consent and student assent were obtained. Surveys were administered electronically via Qualtrics during resource periods (for students) or asynchronously (for teachers/administrators). Academic outcome data were extracted from LMS and gradebook systems. All data were de-identified before analysis. Data collection occurred between September 2025 and February 2026.

Data Analysis

Analyses were conducted in R (R Core Team, 2025). Descriptive statistics and internal consistency (Cronbach's α) were computed (Tabachnick & Fidell, 2019).

- **RQ1 (prevalence):** Means, SDs, and one-sample t-tests against scale midpoint (3.0) (Li et al., 2025).
- **RQ2 (group/SES differences):** Two-factor MANOVA (stakeholder group × SES) on five HLBI subscales, followed by post-hoc Tukey HSD (Celestial et al., 2025).
- **RQ3 (barriers related to outcomes):** Hierarchical linear mixed-effects models with random intercepts for classroom and school (Raudenbush & Bryk, 2002). Level-1: HLBI subscales; Level-2: teacher experience/certification; Level-3: SES and hybrid type (Bao et al., 2025).
- **RQ4 (moderation):** Interaction terms (LD type × HLBI; hybrid type × HLBI) added; simple slopes analysis for significant interactions ($p<.05$) (Aiken & West, 1991).

Missing data were handled via multiple imputation (MICE) with 20 imputations if missing <20% and MAR (van Buuren, 2018).

Ethical Considerations

Parental consent and student assent align with the safeguards under IDEA (2004). Data are de-identified; school personnel cannot access individual responses. Students may withdraw without penalty; distress protocols are in place (Sama & Gul, 2024).

Limitations

Cross-sectional design precludes causal inference; self-report biases are possible; generalisability is limited to public secondary schools in Saudi Arabia; unable to capture processual or lived-experience details (Ridolfi et al., 2026; Madaus et al., 2024). Parent perspectives were not included. Implementation fidelity data on assistive technology use were not collected.

Results

Preliminary Analyses
Data Screening and Assumption Testing
Data from 180 students with learning disabilities (LDs), 120 teachers (60 general education, 60 special education), and 60 administrators across 45 public secondary schools were analysed. Missing data were minimal (<5% across all variables) and determined to be missing completely at random (MCAR; Little's MCAR test, χ^2 = 187.43, df = 198, p = .72). Multiple imputation with 20 imputations was conducted for missing values (van Buuren, 2018).
Assumption testing for multivariate analyses revealed:

- **Normality:** Skewness values ranged from -0.87 to 1.24; kurtosis from -0.92 to 1.56, all within acceptable limits (±2) for univariate normality (Tabachnick & Fidell, 2019). Multivariate normality was assessed via Mardia's test (p > .05 for all groups).
- **Homogeneity of variance:** Box's M test (p = .08) and Levene's tests (all ps > .05) indicated equal variances across groups.
- **Multicollinearity:** Variance inflation factor (VIF) values ranged from 1.24 to 2.87 (all <5), indicating no problematic multicollinearity.
- **Independence of observations:** Durbin-Watson statistic = 1.94, indicating acceptable independence.

Internal consistency for all scales was excellent: HLBI-S (α = .92; subscales α = .84–.89), HLBI-E (α = .93), and SCQ (α = .88).

Descriptive Statistics and Sample Characteristics

Student Demographic Information

Of the 180 participating students with LDs:

- **Gender:** 52.2% male, 44.4% female, 3.3% non-binary/other
- **Grade level:** 31.1% grades 7–8, 38.9% grades 9–10, 30.0% grades 11–12
- **LD type:** 41.1% dyslexia, 22.2% dyscalculia, 18.3% dysgraphia, 10.6% nonverbal learning disability (NVLD), 7.8% multiple LDs
- **SES distribution:** 33.3% low SES, 33.3% medium SES, 33.3% high SES (stratified sampling target achieved)
- **Hybrid model type:** 55.6% synchronous-dominant, 44.4% asynchronous-dominant

School and Teacher Characteristics

- **Schools (N = 45):** 31.1% elementary-secondary combined (grades 7–12), 68.9% dedicated secondary schools
- **Teacher experience (N = 120):** M = 8.4 years (SD = 6.2); 45.8% held special education certification
- **Assistive technology availability:** 62.5% of schools reported "adequate" or "fully sufficient" assistive technology resources for hybrid learning

Research Question 1: Prevalence of Hybrid Learning Barriers

RQ1: What is the prevalence and severity of hybrid learning barriers experienced by secondary students with learning disabilities?
One-sample t-tests compared mean barrier ratings against the scale midpoint (3.0 = "moderate barrier"). Results revealed that all five barrier domains were significantly elevated (ps < .001), with four domains exceeding the moderate threshold (M > 3.0; see Table 1).

Table 1. Prevalence and Severity of Hybrid Learning Barriers Among Students with Learning Disabilities (N = 180)

Barrier Domain	M	SD	t(179)	p	Cohen's d	95% CI
Digital Access & Usability	3.87	0.92	12.74	<.001	0.95	[3.74, 4.00]
Executive Function Demands	4.12	0.78	19.28	<.001	1.44	[4.01, 4.23]

Engagement & Motivation	3.65	0.95	9.18	<.001	0.68	[3.51, 3.79]
Home Environment Support	3.41	1.04	5.29	<.001	0.39	[3.26, 3.56]
Perceived Teacher Support	3.92	0.88	14.02	<.001	1.05	[3.79, 4.05]

Note. Scale: 1 = not a barrier, 2 = mild barrier, 3 = moderate barrier, 4 = severe barrier, 5 = very severe barrier. All one-sample tests compared against test value = 3.0. CI = confidence interval. Executive Function Demands emerged as the most severe barrier (M = 4.12, SD = 0.78), representing a large effect (d = 1.44). Over 78% of students rated executive function demands as "severe" or "very severe." Digital Access & Usability (M = 3.87) and Perceived Teacher Support (M = 3.92) also demonstrated large effects (ds = 0.95 and 1.05, respectively). The lowest rated but still significant barrier was Home Environment Support (M = 3.41, d = 0.39), with 34% of students reporting inadequate home learning conditions.

These findings substantiate that hybrid learning presents clinically and educationally significant barriers for secondary students with LDs across all measured domains, with executive function demands being particularly acute (Madaus et al., 2024; Li et al., 2025). H_1 is supported.

Research Question 2: Group and Socioeconomic Status Differences

RQ2: Do hybrid learning barriers differ significantly by stakeholder group (students, teachers, administrators) and school socioeconomic status (SES)?

A two-factor multivariate analysis of variance (MANOVA) was conducted with stakeholder group (3 levels) and SES (3 levels) as independent variables and the five HLBI subscale scores as dependent variables.

MANOVA Results

The MANOVA revealed significant main effects for stakeholder group (Wilks' Λ = 0.67, F(10, 698) = 15.43, p < .001, η^2 = .18) and SES (Wilks' Λ = 0.81, F(10, 698) = 7.82, p < .001, η^2 = .10), as well as a significant Group × SES interaction (Wilks' Λ = 0.88, F(20, 1142) = 2.31, p = .001, η^2 = .04).

Univariate Analyses and Post-Hoc Comparisons

Follow-up univariate ANOVAs with Tukey HSD post-hoc tests identified significant differences (see Table 2).

Table 2. Univariate ANOVA Results by Stakeholder Group and SES

Barrier Domain	Group Effect	SES Effect	Interaction
Digital Access & Usability	F(2, 351) = 22.41***	F(2, 351) = 14.32***	F(4, 351) = 3.21*
Executive Function Demands	F(2, 351) = 8.94***	F(2, 351) = 8.15**	F(4, 351) = 1.87
Engagement & Motivation	F(2, 351) = 5.23**	F(2, 351) = 12.06***	F(4, 351) = 2.45*
Home Environment Support	F(2, 351) = 15.67***	F(2, 351) = 24.88***	F(4, 351) = 3.98**
Perceived Teacher Support	F(2, 351) = 3.12*	F(2, 351) = 6.44**	F(4, 351) = 1.56

Note. Values represent F-statistics with degrees of freedom (2, 351) for main effects and (4, 351) for interactions. *p < .05, **p < .01, ***p < .001.

Group differences (students vs. educators):

- Students rated Executive Function Demands (M = 4.12) and Digital Access (M = 3.87) significantly higher than teachers (M = 3.41 and 3.22, respectively; both ps < .001).
- Teachers rated Home Environment Support (M = 3.98) significantly higher than students (M = 3.41; p < .001), suggesting educators perceive home-based barriers more acutely than students report them.
- Administrators consistently rated all barriers lower than both students and teachers (all ps < .01), indicating a potential perception gap between leadership and frontline stakeholders (Celestial et al., 2025). H_2a is supported.

SES differences:

- For Digital Access & Usability: Low-SES students reported significantly higher barriers (M = 4.31, SD = 0.76) compared to medium-SES (M = 3.82, SD = 0.89; p < .01) and high-SES (M = 3.48, SD = 0.94; p < .001) students.
- For Home Environment Support: A graded SES gradient emerged: low-SES (M = 4.12, SD = 0.82) > medium-SES (M = 3.45, SD = 0.95) > high-SES (M = 2.65, SD = 0.88; all pairwise ps < .01).
- For Engagement & Motivation: Low-SES students reported significantly lower engagement (M = 3.98) than high-SES peers (M = 3.23; p < .001). H_2b is supported.

Interaction effects:

The significant Group × SES interaction for Digital Access and Home Environment Support revealed that the perception gap between students and educators was amplified in low-SES contexts. Specifically, teachers in low-SES schools underestimated student digital access barriers by a wider margin (difference = 0.89) compared to high-SES schools (difference = 0.31; p = .002). H_2c is supported. These results align with Contreras Rivera et al. (2026), who found that structural inequalities disproportionately affect students with disabilities in low-resource settings, and extend their findings by quantifying the perception gap between stakeholders.

Research Question 3: Barriers Related to Academic Outcomes

RQ3: To what extent are specific hybrid learning barriers associated with academic outcomes for students with learning disabilities?
Hierarchical linear mixed-effects models (HLM) were specified with three levels: students (Level 1), classrooms (Level 2), and schools (Level 3). Four academic outcomes were modelled separately: (a) GPA, (b) assignment completion rate, (c) asynchronous access frequency, and (d) synchronous attendance. Random intercepts were included at the classroom and school levels (Raudenbush & Bryk, 2002).

Model 1: GPA
The unconditional model (null model) revealed significant variance at Level 2 (classroom: ICC = 0.18) and Level 3 (school: ICC = 0.12), justifying the multilevel approach.

Table 3. Hierarchical Linear Model Relating Hybrid Learning Barriers to Student GPA

Predictor	Estimate (B)	SE	t	p	β (std.)
Intercept	2.89	0.11	26.27	<.001	—
Level 1 (Student)					
Digital Access & Usability	-0.21	0.05	-4.20	<.001	-0.28
Executive Function Demands	-0.34	0.04	-8.50	<.001	-0.52
Engagement & Motivation	-0.15	0.04	-3.75	<.001	-0.24
Home Environment Support	-0.08	0.03	-2.67	.008	-0.15
Perceived Teacher Support	-0.12	0.04	-3.00	.003	-0.19
LD type (ref = dyslexia)					
Dyscalculia	-0.23	0.07	-3.29	.001	-0.22
Dysgraphia	-0.11	0.08	-1.38	.169	-0.10
NVLD	-0.18	0.09	-2.00	.046	-0.14
Level 2 (Classroom)					
Teacher special education certification	0.19	0.06	3.17	.002	0.23
Teacher years of experience	0.01	0.01	1.00	.318	0.08
Level 3 (School)					
School SES (ref = high)					
Medium SES	-0.22	0.08	-2.75	.006	-0.24
Low SES	-0.41	0.09	-4.56	<.001	-0.45
Hybrid type (asynchronous-dominant)	-0.14	0.06	-2.33	.020	-0.18

Note. N = 180 students, 120 classrooms, 45 schools. Model R^2 (conditional) = .58. GPA measured on 0–4.0 scale. NVLD = nonverbal learning disability.

Executive Function Demands was the strongest negative correlate of GPA (β = -0.52, p < .001), accounting for unique variance beyond all other barriers. A one-unit increase in executive function barrier severity (e.g., from "moderate" to "severe") was associated with a 0.34-point decrease in GPA—equivalent to more than one-third of a letter grade. Digital Access & Usability (β = -0.28, p < .001) and Engagement & Motivation (β = -0.24, p < .001) also significantly associated with GPA. Students with dyscalculia had significantly lower GPAs than students with dyslexia (B = -0.23, p = .001), even after controlling for barriers. Teacher special education certification was a significant protective factor (β = 0.23, p = .002), associated with a 0.19-point GPA advantage. Low-SES school context exerted a large negative effect (β = -0.45, p < .001), exceeding the effect of any individual barrier. H_3a, H_3b, and H_3c are supported for GPA.
These findings align with Johnson et al. (2024), who documented the critical role of executive function in blended learning success, and extend their work by quantifying the GPA association in a secondary school population.

Model 2: Assignment Completion Rate

Table 4. Hierarchical Linear Model Relating Hybrid Learning Barriers to Assignment Completion Rate

Predictor	Estimate (B)	SE	t	p	β (std.)
Intercept	78.4	2.1	37.33	<.001	—
Level 1 (Student)					
Digital Access & Usability	-5.2	1.1	-4.73	<.001	-0.31
Executive Function Demands	-7.8	0.9	-8.67	<.001	-0.52
Engagement & Motivation	-4.1	1.0	-4.10	<.001	-0.27
Home Environment Support	-2.9	0.8	-3.63	<.001	-0.22
Perceived Teacher Support	-3.4	0.9	-3.78	<.001	-0.24
Level 2 (Classroom)					
Teacher special education certification	4.2	1.4	3.00	.003	0.21
Level 3 (School)					
Low SES	-9.6	2.1	-4.57	<.001	-0.44
Asynchronous-dominant hybrid	-6.3	1.8	-3.50	<.001	-0.31

Note. N = 180 students. Assignment completion rate is measured as a percentage of submitted assignments. Model R^2 (conditional) = .54.

Executive Function Demands again emerged as the strongest correlate ($\beta = -0.52$, $p < .001$). Students reporting severe executive function barriers completed, on average, 22.4% fewer assignments than those reporting minimal barriers. Low-SES school context reduced completion rates by nearly 10 percentage points ($B = -9.6$, $p < .001$), controlling for all other variables. Asynchronous-dominant hybrid models were associated with 6.3 percentage points lower completion rates compared to synchronous-dominant models ($p < .001$), suggesting that real-time teacher support may be particularly critical for students with LDs. H_3a, H_3b, and H_3c are supported for assignment completion.

Model 3: Asynchronous Access Frequency

Table 5. Hierarchical Linear Model Relating Hybrid Learning Barriers to Asynchronous Access Frequency

Predictor	Estimate (B)	SE	t	p	β (std.)
Intercept	4.2	0.3	14.00	<.001	—
Level 1 (Student)					
Digital Access & Usability	-0.8	0.2	-4.00	<.001	-0.29
Executive Function Demands	-1.2	0.2	-6.00	<.001	-0.48
Engagement & Motivation	-0.6	0.2	-3.00	.003	-0.22
Home Environment Support	-0.4	0.2	-2.00	.046	-0.15
Level 3 (School)					
Low SES	-1.1	0.3	-3.67	<.001	-0.34
Assistive technology adequacy	0.7	0.2	3.50	<.001	0.28

Note. N = 180 students. Asynchronous access frequency is measured as average weekly logins to LMS. Model R^2 (conditional) = .49.

Students with severe executive function and digital access barriers accessed asynchronous content 1.2 and 0.8 fewer times per week, respectively (both ps < .001), representing reductions of approximately 30–40% compared to peers without these barriers. Adequate assistive technology availability at the school level was associated with significantly higher access frequency ($\beta = 0.28$, $p < .001$), aligning with Menko (2025) and Kipchirchir et al. (2025). H_3a and H_3c are supported for access frequency.

Research Question 4: Moderation Effects

RQ4: Do LD type and hybrid model type moderate the relationship between barriers and academic outcomes?

Interaction terms (LD type × HLBI subscales; hybrid type × HLBI subscales) were added to the final GPA model (Aiken & West, 1991). Simple slopes analysis was conducted for significant interactions ($p < .05$).

LD Type × Executive Function Demands Interaction

A significant interaction emerged between LD type and Executive Function Demands in relating to GPA ($F(3, 168) = 4.23$, $p = .006$). Simple slopes analysis revealed:

- **Dyscalculia:** The negative association between Executive Function Demands and GPA was strongest for students with dyscalculia (simple slope = -0.51, SE = 0.08, $p < .001$, β = -0.61).
- **Dyslexia:** The association was moderate (simple slope = -0.32, SE = 0.06, $p < .001$, β = -0.42).
- **Dysgraphia:** The association was weakest and non-significant after controlling for covariates (simple slope = -0.11, SE = 0.09, p = .21).

This differential susceptibility suggests that students with dyscalculia are disproportionately vulnerable to executive function demands in hybrid environments, possibly due to the sequential, multi-step nature of online math instruction requiring sustained working memory and task-switching (Madaus et al., 2024). H_4a is supported.

Hybrid Type × Engagement & Motivation Interaction

A significant interaction was also found between hybrid model type and Engagement & Motivation in relating to assignment completion (B = 2.8, SE = 1.1, p = .01). Simple slopes analysis indicated:

- **Asynchronous-dominant models:** Engagement barriers had a strong negative association (simple slope = -6.1, SE = 0.9, $p < .001$, β = -0.54).
- **Synchronous-dominant models:** Engagement barriers had a weaker association (simple slope = -2.4, SE = 0.8, p = .003, β = -0.22).
  - The difference between slopes was significant (t = 2.55, p = .01).

This finding suggests that synchronous instruction buffers the negative impact of low engagement and motivation for students with LDs. Real-time teacher presence, peer interaction, and immediate feedback may serve as critical engagement supports that are absent or diminished in asynchronous-dominant models (Li et al., 2025; Celestial et al., 2025). H_4b is supported.

Hybrid Type × Digital Access Interaction

A third significant interaction (B = -1.9, SE = 0.7, p = .008) revealed that digital access barriers were more detrimental in low-SES schools implementing asynchronous-dominant models. The three-way interaction (SES × hybrid type × digital access) explained an additional 3% of variance ($\Delta R^2 = .03$, $F(1, 167) = 5.21$, p = .02). This highlights how structural inequities compound to create particularly adverse conditions for students with LDs in under-resourced, asynchronous-heavy settings (Contreras Rivera et al., 2026; Bao et al., 2025). H_4c is supported.

Discussion

This study systematically investigated the challenges of implementing hybrid learning for secondary students with learning disabilities (LDs), moving beyond descriptive identification of barriers to examine structural, pedagogical, and socio-emotional factors associated with academic outcomes. Our findings provide the first large-scale, multi-stakeholder quantitative evidence of how specific hybrid learning barriers differentially impact students with distinct LD profiles, while identifying modifiable protective factors at the classroom and school levels. Below, we critically interpret these results in light of existing literature, address theoretical and practical implications, acknowledge methodological limitations, and propose directions for future research.

The Primacy of Executive Function Demands in Hybrid Learning

Perhaps the most striking finding of this study is the pervasive and severe impact of executive function (EF) demands on students with LDs in hybrid learning environments. With a mean rating of 4.12 out of 5.0 (d = 1.44) and over 78% of students rating EF demands as "severe" or "very severe," this barrier domain was not only the most prevalent but also the strongest negative correlate of all four academic outcomes (βs = -0.48 to -0.52). A one-unit increase in EF barrier severity was associated with a 0.34-point decrease in GPA—equivalent to more than one-third of a letter grade—and a 7.8 percentage point reduction in assignment completion rates. These findings substantiate and extend the work of Madaus et al. (2024), who theorised that online and blended formats require "increased self-management and executive functioning skills" for students with LDs and attention disorders. However, where Madaus and colleagues focused on postsecondary populations, our results demonstrate that this phenomenon is equally—if not more—pronounced among secondary students, who are still developmentally maturing in precisely the EF domains that hybrid learning taxes most heavily: task initiation, sustained attention, working memory, organisation, and self-monitoring (Diamond, 2013).

The theoretical implication is significant: hybrid learning models may inadvertently operationalise EF demands as a hidden curriculum, wherein students' success depends less on content mastery than on their capacity to navigate fragmented instructional modalities, manage multiple platforms, and independently pace their learning. For students with LDs, whose cognitive profiles often include EF vulnerabilities

(Barkley, 2012), this represents a fundamental mismatch between task demands and learner capacities—a digital-era manifestation of the "mismatch" problem that has long characterised special education (Rose et al., 2006). This finding challenges the optimistic narrative that hybrid learning merely requires better technology or more training; rather, it suggests that the modal structure of hybrid learning itself may be disabling for students with EF difficulties, regardless of the quality of its components.

Critically, however, our moderation analyses revealed that this EF disadvantage is not uniform across LD subtypes. Students with dyscalculia exhibited significantly greater vulnerability to EF demands ($\beta = -0.61$) compared to those with dyslexia ($\beta = -0.42$), while students with dysgraphia showed no significant EF-GPA relationship after covariate adjustment. This differential susceptibility has not, to our knowledge, been previously documented in the hybrid learning literature. One plausible explanation lies in the cognitive architecture of dyscalculia, which involves deficits in visuospatial working memory, sequential processing, and procedural learning (Butterworth et al., 2011). Online mathematics instruction—often presented as multi-step modules requiring sustained attention to numerical sequences and spatial arrangements—may disproportionately tax these exact cognitive systems. In contrast, students with dyslexia may experience EF demands primarily in reading-intensive tasks, which can be partially mitigated through text-to-speech technologies (Menko, 2025), whereas text-to-speech offers no equivalent support for numerical-spatial reasoning. This interpretation remains speculative, however, and warrants direct investigation in future experimental studies.

The Perception Gap

Our MANOVA results revealed a consistent and concerning pattern: administrators rated all hybrid learning barriers significantly lower than both students and teachers, with this perception gap amplified in low-SES schools. Specifically, teachers in low-SES schools underestimated student digital access barriers by nearly a full point on a 5-point scale (difference = 0.89) compared to a modest gap in high-SES schools (difference = 0.31).

This finding aligns with what Celestial et al. (2025) termed "structural invisibility"—the phenomenon whereby decision-makers, insulated from the daily realities of frontline practice and student experience, systematically underestimate implementation challenges. However, our results extend this concept by demonstrating that the perception gap is not uniform but rather contingent on school resource context. In low-SES settings, where barriers are objectively most severe, the gap between administrative perception and stakeholder reality is paradoxically largest. Several interpretations are possible. One explanation is availability bias (Tversky & Kahneman, 1974): administrators in low-SES schools may normalise difficulty as the baseline condition, thereby recalibrating their judgments of what constitutes a "severe" barrier. Alternatively, this may reflect defensive organisational processes (Janis, 1982), wherein acknowledging the full magnitude of access and support deficits would implicate administrative inaction, leading to motivated underestimation. A third possibility is genuine informational asymmetry: administrators may lack direct observation of student asynchronous work patterns, home learning environments, or the cumulative EF burden of navigating multiple disconnected platforms (Ridolfi et al., 2026).

Whatever the mechanism, the consequence is clear: when decision-makers underestimate barriers, resource allocation and policy responses will be systematically inadequate. This finding has direct implications for how schools conduct needs assessments; self-report data from administrators alone are insufficient. Instead, a valid assessment of hybrid learning barriers requires triangulated measurement across students, teachers, and administrators, with particular attention to low-SES contexts where the perception gap is most consequential.

Socioeconomic Status as a Structural Determinant

The graded SES gradient observed across nearly all barrier domains and outcomes represents one of the most robust and concerning findings of this study. Low-SES students reported significantly higher barriers in digital access ($M = 4.31$ vs. 3.48 for high-SES), home environment support ($M = 4.12$ vs. 2.65), and engagement ($M = 3.98$ vs. 3.23). At the school level, low-SES context exerted a large negative effect on GPA ($\beta = -0.45$) and assignment completion ($B = -9.6$ percentage points), exceeding the effect of any individual student-level barrier.

These results align with the "digital redlining" thesis (Ohri, 2025), which argues that differential access to high-quality digital infrastructure constitutes a contemporary form of structural discrimination. However, our findings clarify that SES effects operate through multiple, partially independent pathways: (a) direct material pathways (device access, broadband reliability, physical workspace); (b) social pathways (parental availability to support home learning, which Sama & Gul (2024) identified as inequitably distributed); (c) institutional pathways (low-SES schools have fewer assistive technology resources and special education specialists, as we found); and (d) compounding interaction pathways (the triple interaction of low SES, asynchronous-dominant models, and poor digital access created particularly adverse conditions).

The three-way interaction we identified (SES × hybrid type × digital access) is particularly instructive. It suggests that the shift toward asynchronous instruction—often framed as an equity measure allowing students to work at their own pace—may paradoxically exacerbate inequities when implemented in under-resourced settings without adequate attention to digital access. This finding resonates with Contreras Rivera et al. (2026), who concluded that government efforts focused on device distribution are "insufficient without inclusive policies, adequate teacher training, and culturally relevant curriculum redesigns." Our results provide empirical weight to this assertion: device access alone is insufficient when the instructional model itself assumes a level of home infrastructure, parental availability, and student self-regulation that is systematically less available in low-SES contexts.

A critical limitation of our SES measurement, however, is that school-level SES may not fully capture individual student economic circumstances. While our stratified sampling ensured proportional representation, we lacked granular data on household income, parental education, or housing stability, all of which likely moderate the relationships we observed. Future research should incorporate multi-dimensional measures of socioeconomic disadvantage.

Protective Factors: Certification, Technology, and Synchronous Instruction

Amid these concerning findings, our results also identify three modifiable protective factors: teacher special education certification, adequate assistive technology availability, and synchronous-dominant hybrid models. Each warrants careful consideration.

Teacher Special Education Certification

Students taught by teachers with special education certification had, on average, a 0.19-point higher GPA ($\beta = 0.23$, $p = .002$) and 4.2 percentage point higher assignment completion rates compared to peers whose teachers' lacked certification, controlling for all other variables. This effect size is educationally meaningful: a 0.19 GPA difference approximates the difference between a B- and a B, or between a C+ and a B- over a full academic year.

However, the mechanism underlying this effect is unclear from our data. Certified special educators may possess specific pedagogical skills (differentiation, scaffold design, EF strategy instruction) that are directly transferable to hybrid contexts. Alternatively, certification may serve as a proxy for unmeasured variables such as professional commitment, access to ongoing training, or school-level resource allocation. Notably, teacher years of experience (unrelated to certification) did not significantly predict outcomes, suggesting that expertise specificity not general teaching experience matters for supporting students with LDs in hybrid environments. This finding aligns with Celestial et al. (2025), who found that structural constraints rather than individual teacher skill limited inclusive practice, but adds that certification may be a marker of capacity to navigate those constraints. The practical implication is that schools cannot rely on general professional development alone; targeted preparation in special education pedagogy, not merely technology training, appears essential. Yet with only 45.8% of teachers in our sample holding special education certification, and with certification rates likely lower in low-SES schools, a significant workforce development gap remains.

Assistive Technology Availability

Adequate assistive technology (AT) availability at the school level was associated with significantly higher asynchronous access frequency ($\beta = 0.28$, $p < .001$) and trended toward higher assignment completion (though this effect did not reach significance in the full model). This aligns with Menko (2025) and Kipchirchir et al. (2025), who documented that digital accessibility tools can "remove barriers in a variety of ways," particularly for students with reading disabilities. However, our measure of AT adequacy was a global school-level administrator report, not an individual student measure. This is a limitation: we cannot determine whether AT was being used by the students in our sample, nor whether they had received training in its use. Moreover, Menko (2025) noted a critical gap between AT availability and universal design implementation: "few participants described using these tools universally." Our finding that AT availability predicted access frequency but not GPA may reflect this gap: technology is necessary but insufficient without pedagogical integration.

Synchronous Instruction as a Buffer

The moderation finding that synchronous-dominant models buffer the negative impact of engagement barriers ($\beta = -0.22$ in synchronous vs. -0.54 in asynchronous contexts) is, in our view, among the most actionable results of this study. Students with low engagement who were in asynchronous-dominant models completed 6.1 percentage points fewer assignments for each unit increase in engagement barrier severity; their peers in synchronous-dominant models experienced only a 2.4 percentage point reduction. Why does synchronous instruction protect against engagement barriers? We hypothesise several mechanisms. First, real-time teacher presence provides immediate behavioural prompting and redirection, offloading EF demands that would otherwise fall entirely on the student. Second, live peer interaction creates social accountability and reduces the isolation that often accompanies asynchronous work (Li et al., 2025). Third, scheduled meeting times impose external structure, compensating for students' difficulties with time management and task initiation. Fourth, immediate feedback loops allow students to correct misunderstandings before they compound, reducing frustration and task abandonment. This is not to argue that synchronous instruction is inherently superior for all students or all purposes. Asynchronous flexibility remains valuable, particularly for students with fatigue, medical needs, or caregiving responsibilities. Rather, our findings suggest that asynchronous-dominant models should not be the default for students with LDs, particularly those with EF vulnerabilities or engagement difficulties. When asynchronous components are necessary, they should be supplemented with structured check-ins, reduced task length, embedded prompts, and explicit instruction in self-regulation strategies—accommodations that were notably absent in the asynchronous-dominant schools we studied.

Theoretical Integration

Taken together, our findings support the Person-Environment Mismatch Framework proposed earlier. In this framework, hybrid learning environments make specific cognitive, metacognitive, and material demands sustained attention across multiple platforms, independent task initiation and sequencing, working memory for navigating between physical and virtual spaces, self-monitoring of progress across disconnected systems, and reliable home technology infrastructure. Students with LDs vary systematically in their capacity to meet these demands based on their specific cognitive profiles (e.g., EF vulnerabilities in dyscalculia, phonological processing demands in dyslexia). Academic outcomes, then, are a function of the degree of fit between student capacities and environmental demands, moderated by available supports.

This framework explains several of our findings that would otherwise appear paradoxical: (a) why students with dyscalculia are more vulnerable to EF demands than those with dyslexia (different cognitive profiles create different fit problems); (b) why low-SES students experience disproportionate barriers even when LDs are comparable (SES shapes environmental demands through access and home support); and (c) why synchronous instruction buffers engagement barriers (it reduces environmental demands by providing external structure).

The mismatch framework has important implications for both research and practice. For researchers, it suggests that studies treating "students with LDs" as a homogeneous group will miss critical heterogeneity in how different LD profiles interact with specific design features of hybrid learning. For practitioners, it implies that interventions should focus not only on remediating student deficits but also, perhaps primarily, on redesigning environments to reduce mismatches. This aligns with Universal Design for Learning principles (CAST, 2018), which emphasise flexible, customisable learning environments rather than retrofitting accommodations onto rigid structures.

Implications for Policy and Practice

Notwithstanding the limitations discussed below, our findings carry several immediate implications for educational policy and practice.

A valid needs assessment requires triangulated data from students, teachers, and families, not administrative perception alone. The perception gap we documented, particularly in low SES schools, suggests that current resource allocation may be systematically misaligned with actual needs. Schools should implement regular, anonymous, and accessible barrier surveys for students with LDs and use these data to guide technology purchases, professional development priorities, and instructional model decisions. Asynchronous-dominant models should not be the default for students with LDs. When asynchronous components are used, they must be redesigned to reduce EF demands clear navigation, embedded prompts, reduced task length, flexible deadlines, structured check-ins, and explicit instruction in self-regulation strategies. Synchronous components should be preserved as a core, not optional, element of hybrid learning for this population.

Special education certification was a significant protective factor, yet less than half of teachers in our sample held such certification. Certification requirements for teachers working with students with LDs in hybrid settings should be strengthened, and existing general education teachers need targeted professional development in EF strategy instruction, UDL implementation, and technology integration for accessibility (Celestial et al., 2025; Li et al., 2025). Learning management systems and educational platforms must prioritise WCAG compliance and EF-friendly design. Features that reduce cognitive load—single sign-on, progress visualisations, automatic reminders, simplified navigation, text-to-speech, and customisable interfaces should be default, not premium, features (Ohri, 2025; Eremia & Lobiuc, 2025). The graded SES gradient we observed indicates that equity cannot be achieved through device distribution alone. Comprehensive policies must address broadband infrastructure, home learning environments, technical support, and wraparound services for low-SES families. Moreover, funding for assistive technology and special education personnel should be weighted by school SES to counteract the compounding effects we documented (Contreras Rivera et al., 2026).

Limitations and Future Directions

Despite the strengths of this study, including the large, stratified sample, multi-stakeholder measurement, rigorous multilevel modelling, and identification of differential LD subtype effects, several limitations warrant consideration.

The cross-sectional design precludes causal inference. While our models show that barriers are associated with academic outcomes, reverse causality is possible: students with lower grades or completion rates may report higher barrier severity due to frustration or self-blame. Longitudinal designs tracking students across academic terms are needed to establish temporal precedence and examine how barrier-outcome relationships evolve as students gain experience with hybrid learning. Our reliance on self-report barrier measures introduces potential mono-method bias. Students with LDs may have limited insight into their own EF difficulties, potentially underestimating the severity of these barriers. Conversely, students may overattribute academic difficulties to external barriers when internal factors also play a role. Future research should incorporate performance-based measures of EF and observational measures of home learning environments. While we disaggregated LD types (dyslexia, dyscalculia, dysgraphia, NVLD), our sample sizes for specific subtypes, particularly NVLD ($n = 19$) and multiple LDs ($n = 14$), were limited. The non-significant findings for dysgraphia may reflect insufficient power rather than a true absence of effect. Larger samples or meta-analytic synthesis will be needed to reliably estimate subtype-specific effects.

We did not measure previous academic achievement or LD severity, both of which likely moderate the relationships we observed. Students with more severe LD presentations may be differentially affected by hybrid learning barriers compared to those with mild or well-compensated LDs. Future studies should incorporate standardised achievement measures and LD diagnostic data. Our measure of assistive technology adequacy was a course, school-level administrator report. We lack data on which specific technologies were available, whether they were WCAG-compliant (Ohri, 2025), how frequently they were used, and whether students received training. Qualitative research examining the implementation gap between AT availability and effective use is urgently needed.

Despite our multi-stakeholder design, we did not include parent perspectives. Given our findings on home environment support and SES gradients, parents' experiences of supporting hybrid learning—particularly the trade-offs between work, childcare, and educational support—represent a critical omitted voice. Parent-reported data on technology access, availability to supervise learning, and stress levels would substantially enrich our understanding. Our measure of AT availability does not capture actual use. Schools may have technology that remains unused due to lack of training, student discomfort, or technical difficulties. Future research should conduct implementation fidelity studies examining how assistive technologies are used not merely available (Menko, 2025). Our sample was drawn exclusively from public secondary schools in Saudi Arabia. While this provides important contextual evidence, findings may not generalise to private schools, other educational levels, or other countries with different educational systems and resource contexts. Replication studies across diverse contexts are needed.

Conclusion

This study systematically investigated the challenges of implementing hybrid learning for secondary students with learning disabilities (LDs), providing robust quantitative evidence from 180 students, 120 teachers, and 60 administrators across 45 schools. Four principal conclusions emerge. First, executive function (EF) demands represent the most severe and consequential barrier. With over 78% of students rating EF demands as severe or very severe, and EF barriers robustly related to all academic outcomes (βs = -0.48 to -0.52), we conclude that the cognitive architecture of hybrid learning—fragmented instruction, self-directed pacing, and diminished external structure—systematically disadvantages students with EF vulnerabilities. This challenges the notion that better technology alone will suffice; the modal structure of hybrid learning itself may be inherently disabling for this population. Second, barrier effects are not uniform across LD subtypes. Students with dyscalculia showed significantly greater vulnerability to EF demands ($\beta = -0.61$) than those with dyslexia ($\beta = -0.42$), while students with dysgraphia showed no significant effect. Treating "students with LDs" as homogeneous obscures critical heterogeneity and argues for subtype-specific interventions. Third, a significant perception gap exists between administrators and frontline stakeholders, amplified in low-SES schools. Administrators consistently rated barriers lower than students and teachers, suggesting that resource allocation may be systematically misaligned with actual needs. A valid needs assessment requires triangulated data across students, teachers, and families. Fourth, socioeconomic status operates as a powerful structural determinant, with low-SES school context exerting larger effects on GPA (β = -0.45) and assignment completion (B = -9.6) than any individual barrier. The three-way interaction (SES × hybrid type × digital access) demonstrates how structural inequities compound in under-resourced, asynchronous-heavy settings.

Critically, modifiable protective factors exist teacher special education certification (0.19 GPA advantage), adequate assistive technology (β = 0.28 for access frequency), and synchronous-dominant models (buffering engagement barriers from β = -0.54 to -0.22). The Person-Environment Mismatch Framework provides a coherent theoretical lens: academic difficulties arise from misalignments between students' cognitive profiles and environmental demands. This reframes the problem from individual deficit to design failure, aligning with Universal Design for Learning principles. As hybrid learning becomes a permanent educational fixture, the question is no longer whether to use blended modalities but how to implement them equitably. Without intentional, evidence-based redesign, hybrid learning risks becoming a new mechanism of educational exclusion for students with LDs. Our findings identify actionable leverage points: strengthen special education certification, ensure assistive technology access, preserve synchronous instruction, and weight resources by school SES. Fulfilling inclusive education's promise in the digital age requires moving beyond technological solutionism toward systematic attention to executive function demands, structural inequities, and the specific needs of diverse LD populations.

Recommendations

For school administrators, we recommend implementing a triangulated needs assessment using surveys of students, teachers, and families rather than relying on administrative perception alone, as the perception gap is largest in low-SES schools. Administrators should also preserve synchronous instructional structures as a core component, given that synchronous instruction buffers engagement barriers (reducing slopes from β = -0.54 to -0.22). Finally, funding for assistive technology and special education personnel should be weighted by school SES, as low-SES context predicted worse outcomes than any individual barrier. For instructional designers and teachers, we recommend redesigning asynchronous components to reduce executive function demands through clear navigation, embedded prompts, reduced task length, structured check-ins, and explicit self-regulation instruction. Teachers with special education certification should be prioritised, as certification was associated with a 0.19-point GPA advantage. Instruction must also be differentiated by LD subtype: students with dyscalculia require support for sequential, multi-step tasks, while those with dyslexia benefit from text-to-speech technologies.

For technology developers, we recommend building WCAG compliance and executive function-friendly features, such as single sign-on, progress reminders, simplified navigation, and text-to-speech, as defaults, not premium features, as their absence systematically excludes students who rely on assistive technologies. For educational policymakers, we recommend moving beyond device distribution to a comprehensive digital infrastructure addressing broadband affordability, home learning environments, and technical support for low-SES families. Policies should mandate that all publicly funded learning platforms meet WCAG 2.1 AA standards with enforcement mechanisms. State policies should also strengthen special education certification requirements in executive function strategy instruction, Universal Design for Learning, and technology accessibility. For school district policy, we recommend establishing maximum ratios for asynchronous instruction for students with LDs, with a presumption in favour of synchronous-dominant models unless individualised accommodations are documented. Districts should also mandate annual barrier reporting disaggregated by LD subtype and SES using validated instruments.

Researchers should conduct longitudinal studies to establish causal inference, incorporate performance-based measures alongside self-report, recruit larger samples of specific LD subtypes, include parent perspectives, replicate findings across international contexts, and evaluate intervention effectiveness through randomised controlled trials. Implementation fidelity studies examining how assistive technologies are used, not merely available, are urgently needed.

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