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Neutrosophic Evidence Synthesis of Learning Management Factors and Academic Performance in University Virtual Classrooms: A Systematized Review

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Abstract. University virtual classrooms have shifted the discussion on digital education from technological availability toward the quality of learning management. This study synthesizes evidence published between 2020 and 2025 on the relationships among learning management systems, student engagement, self-regulated learning, teacher support, digital inclusion, and academic performance, while introducing a neutrosophic procedure to represent the consistency and indeterminacy of heterogeneous evidence. A systematized review guided by PRISMA 2020 principles assessed 37 records identified through directed academic searches and individual metadata verification in Crossref or official journal sources. Five records were excluded because their DOI or complete metadata could not be sufficiently verified, leaving 32 studies in the qualitative synthesis. Twenty-three studies directly related to six management factors were subsequently coded through a single-valued neutrosophic set using truth (T), indeterminacy (I), and falsity (F) degrees. The score function $S(a) = (2 + T - I - F)/3$ was used to prioritize the factors. Engagement and participation obtained the strongest evidential support ($S = 0.91$), followed by self-regulated learning ($S = 0.87$) and teacher support, feedback, and self-efficacy ($S = 0.80$). Digital inclusion in the Latin American context showed the highest indeterminacy ($I = 1.00$), reflecting limited regional evidence rather than lack of relevance. The findings show that neutrosophic evidence synthesis can make uncertainty explicit without converting heterogeneous educational studies into artificial effect-size estimates. The results support a management approach centered on pedagogical design, engagement monitoring, self-regulation support, teacher mediation, and context-sensitive digital inclusion.

Keywords: academic performance; learning management; neutrosophic evidence synthesis; self-regulated learning; single-valued neutrosophic set; student engagement.

1. Introduction

Virtual classrooms and learning management systems (LMS) have become routine components of higher education, particularly after the consolidation of remote and hybrid modalities. Their expansion has increased access to resources, asynchronous communication, assessment tools, and academic monitoring. Nevertheless, the presence of a digital platform does not by itself explain academic achievement. Recent evidence indicates that outcomes depend on the way technological resources are embedded in instructional design, feedback, participation, and students' capacity to regulate their own learning [2, 9, 25, 27]. Consequently, the analytical problem has moved from asking whether universities have digital infrastructure to examining how learning is managed within that infrastructure.

Student engagement is one of the most recurrent explanatory mechanisms in the literature. Cognitive and behavioral participation in discussion forums, collaborative activities, inquiry processes, and reflective tasks is more consistently associated with academic achievement than the simple frequency of platform access [12, 18, 30]. This distinction is relevant for university management because activity logs may record presence without demonstrating meaningful involvement. A management perspective therefore requires indicators that connect digital participation with the quality of learning experiences, the continuity of academic work, and the capacity of instructors to intervene when patterns of disengagement emerge.

Self-regulated learning provides a second explanatory layer. Planning, time management, monitoring, goal setting, and help-seeking are repeatedly associated with stronger performance in online and blended environments [10, 32, 33]. Readiness for online learning, academic self-efficacy, and teacher support also influence satisfaction and achievement [13, 34]. These findings imply that virtual learning should not be interpreted as a transfer of responsibility from the institution to the student. Instead, course design and academic support can either facilitate or intensify the regulatory demands that learners must manage.

The international evidence base is broad but unevenly distributed. A substantial proportion of studies comes from Asia, North America, and Europe, whereas Latin American research continues to document structural constraints related to connectivity, digital competence, and institutional support [23]. This imbalance creates a methodological difficulty for evidence synthesis. A factor may appear relevant in several settings while the degree of certainty about its transferability to other contexts remains limited. Conventional narrative synthesis can describe that uncertainty, but it does not always formalize the distinction between positive support, mixed evidence, and the absence of direct confirmation.

Neutrosophic logic offers a useful framework for addressing this problem because it represents truth, indeterminacy, and falsity as distinct dimensions rather than forcing evidence into a binary supported/unsupported judgment. In a single-valued Neutrosophic set (SVNS), an element can be characterized simultaneously by degrees T, I, and F within the unit interval [35]. This structure is suitable for heterogeneous educational literature in which findings may be positive, conditional, correlational, or context-dependent. The methodological contribution of the present study lies in using SVNS as an evidence-synthesis layer that preserves the narrative interpretation of the literature while making evidential consistency and uncertainty explicit.

Accordingly, this study had two objectives. First, it synthesized research published between 2020 and 2025 on the relationships among virtual classrooms, engagement, self-regulated learning, and academic performance in higher education, with attention to implications for university learning management. Second, it operationalized a neutrosophic evidence-synthesis procedure to prioritize six management factors according to the balance among evidential support, indeterminacy, and contrary evidence. The guiding question was: Which learning-management factors are most recurrently associated with academic performance in university virtual classrooms, and how can the degree of certainty surrounding those factors be represented through a Neutrosophic framework?

2. Neutrosophic Framework for Evidence Synthesis

Neutrosophy was developed to study propositions and phenomena in which affirmation, indeterminacy, and negation coexist. Within applied decision and assessment contexts, single-valued neutrosophic sets provide a practical representation because each evaluated element can be expressed as a triplet a = <T(a), I(a), F(a)>, where T, I, and F belong to [0, 1]. Unlike a conventional fuzzy membership value, the three components are not required to be complements of one another. This property is important when the available evidence is heterogeneous, because strong positive findings can coexist with contextual uncertainty or methodological limitations without being collapsed into a single binary conclusion [35].

For evidence synthesis, the meaning of the three components must be defined in relation to the review question rather than treated as abstract mathematical labels. In this study, T represents direct positive evidential support for an association between a management factor and academic performance, engagement, or persistence; I represents mixed, heterogeneous, context-dependent, or exclusively correlational evidence; and F represents evidence reporting no effect or effects in the opposite direction. This operational definition does not claim that T, I, and F are effect sizes. Instead, they summarize the consistency and epistemic status of findings reported across studies that differ in design, population, measurement, and educational context.

The prioritization stage used the score function $S(a) = (2 + T - I - F)/3$, which maps the neutrosophic triplet to a value between 0 and 1 and gives higher scores to factors with stronger positive support and lower indeterminacy or falsity [24]. When two factors share the same score, the accuracy function $H(a) = T - I$ can be used as a secondary criterion; if a tie persists, the volume of studies addressing the factor provides an additional descriptive criterion. This procedure enables an ordered interpretation while retaining the original T, I, and F values, which remain necessary for understanding why two factors with similar scores may reflect different evidential structures.

Applying this framework to higher education is methodologically appropriate when the objective is not to pool standardized effect sizes but to compare the evidential consistency of management factors across diverse studies. The included literature contains empirical designs, systematic reviews, and meta-analyses, and therefore does not support a single quantitative effect metric without imposing strong assumptions. The neutrosophic layer complements rather than replaces the qualitative synthesis. It provides a transparent coding structure through which evidential support, uncertainty, and contradiction can be displayed and discussed in a common analytical space.

3. Materials and Methods

3.1 Review design and search procedure

A systematized literature review with a descriptive and interpretive orientation was conducted following the transparency and traceability principles of PRISMA 2020 [19]. The term systematized review is used deliberately because the identification stage did not rely on a complete export from multiple bibliographic databases. Instead, candidate publications were located through directed academic searches and each record was individually verified against Crossref or the official journal source. This distinction avoids attributing a level of exhaustiveness to the review that the available procedure cannot demonstrate, while preserving explicit criteria for selection, verification, and synthesis.

The review targeted publications issued between 2020 and 2025. Ten search equations in English were constructed around the concepts virtual learning environment, learning management system, academic performance, student engagement, and self-regulated learning. Examples included “virtual learning environment academic performance higher education,” “LMS learning management system student performance systematic review,” and “self-regulated learning virtual environment higher education.” For each candidate reference, authorship, year, title, journal, volume, pagination or article number, and DOI were checked against Crossref or the journal's official webpage when a DOI was available.

3.2 Eligibility criteria and study selection

Studies were eligible when they met three conditions: they were published in peer-reviewed journals between 2020 and 2025; they addressed virtual classrooms, LMS use, engagement, self-regulation, satisfaction, academic performance, or closely related educational processes in higher education; and their bibliographic metadata could be verified in a primary editorial source. Conference proceedings without clear evidence of formal peer review, working papers, preprints, and references whose metadata could not be sufficiently confirmed were excluded. Methodological sources used to support the review or the neutrosophic procedure were retained in the reference list but were not counted as part of the thematic corpus.

Thirty-seven records were evaluated in detail. No exact duplicates were identified. Five records were excluded because their DOI or complete metadata could not be sufficiently verified, leaving 32 studies in the final qualitative synthesis. Two additional references, Creswell and Plano Clark [7] and Page et al. [19], were used exclusively as methodological support and were not part of the thematic corpus. The selection process is summarized in Figure 1, which preserves the distinction between the records assessed, excluded, and included without overstating the review as an exhaustive database-level systematic search.

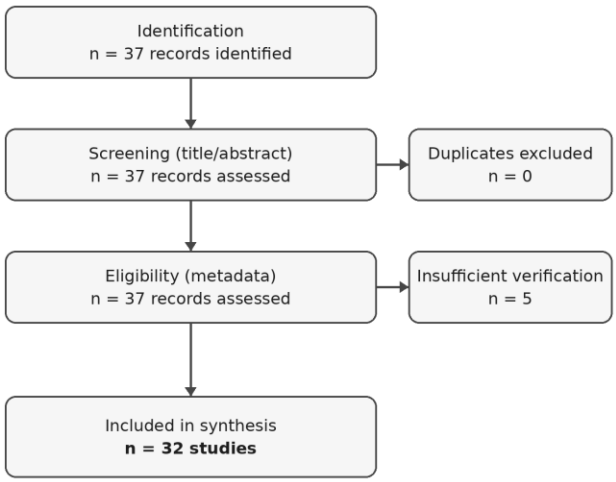


Figure 1. Flow of study selection for the systematized review. Note. Thirty-seven records were assessed, 32 were included in the synthesis, and 5 were excluded because DOI or complete metadata could not be sufficiently verified.

3.3 Thematic synthesis and management factors

The 32 studies were organized through thematic categorization. Each study was assigned to one principal category for counting purposes, even when it addressed more than one dimension. The categories were LMS and virtual environments; engagement and participation; self-regulated learning; satisfaction, self-efficacy, and modality; systematic reviews and meta-analyses; Latin American context; and other related findings concerning adaptive learning, gamification, virtual reality, and associated factors. The synthesis compared convergences, divergences, and implications for university management without recalculating effect sizes reported by the original studies.

Table 1. Thematic distribution of the 32 included studies

Thematic category	Studies included	n
LMS and virtual environments	Abuhassna et al. (2020); Cabero-Almenara et al. (2023); Shafiq et al. (2025); Singh et al. (2024)	4

Thematic category	Studies included	n
Engagement and participation	Hao et al. (2025); Nkomo et al. (2021); Sharif Nia et al. (2023); Wang et al. (2024)	4
Self-regulated learning	Faza & Lestari (2025); Jin et al. (2023); Xu et al. (2022); Xu et al. (2023); Yavuzalp & Bahcivan (2021)	5
Satisfaction, self-efficacy, and modality	Fabriz et al. (2021); Huang & Wang (2023); Kaspar et al. (2024); Sun & Kim (2022)	4
Systematic reviews and meta-analyses	Chung et al. (2022); Liu et al. (2022); Meng et al. (2024); Rahmani et al. (2024); Xiong et al. (2024)	5
Latin American context	Salas-Pilco et al. (2022)	1
Other related findings	Akpen et al. (2024); Cao (2023); du Plooy et al. (2024); Flores et al. (2025); Prabowo et al. (2022); Rishko et al. (2025); Sun et al. (2023); Yu (2021); Zeng et al. (2024)	9

Note. Each study was assigned to its principal thematic category for counting purposes. The two methodological references were not included in the total of 32 studies.

3.4 Neutrosophic coding and prioritization

Six learning-management factors were defined for the neutrosophic synthesis. Five factors were derived directly from the dimensions summarized in the qualitative review: C1, instructional design and academic use of the LMS; C2, engagement and participation; C3, self-regulated learning; C4, teacher support, feedback, and self-efficacy; and C5, digital inclusion and the Latin American context. A sixth factor, C6, monitoring of engagement and academic support for dropout prevention, was derived from reviews addressing correlates of performance and persistence in online higher education [6, 21].

Three coding rules were applied to the 23 studies that directly addressed at least one of the six factors. Rule R1 assigned a truth point when a study reported a positive or statistically significant association between the factor and academic performance, engagement, or persistence. Rule R2 assigned an indeterminacy point when findings were mixed, heterogeneous across contexts, moderated by external variables, or exclusively correlational. Rule R3 assigned a falsity point when a study reported no effect or an effect in the opposite direction. A study could contribute to more than one component when its findings were mixed. The nine studies grouped as "other related findings" in Table 1 were not coded because they did not correspond directly to the six management factors.

For each factor, the accumulated T, I, and F points were normalized by the number of studies addressing that factor, yielding the triplet <T, I, F>. Factors were then ordered using $S(a) = (2 + T - I - F)/3$. The score was interpreted only as a prioritization index of evidential support within this review. It was not treated as a pooled effect estimate, a probability of causation, or a measure of educational impact. This distinction is essential because the underlying studies vary in design and outcome measurement. The procedure therefore formalizes evidential consistency while preserving the interpretive limits of the original literature.

4. Results

4.1 Thematic findings

The first consistent finding is that the LMS does not operate as a sufficient predictor of academic performance. Technological availability becomes educationally meaningful when platform functions are connected with instructional structure, feedback, clear activity sequences, and opportunities for interaction. Abuhassna et al. [2] and Shafiq et al. [25] show that the academic value of learning platforms depends on how students use their functions and how instructors structure learning tasks. Singh et al. [27] reaches a similar conclusion in a broader review of e-learning in higher education. These findings support a management perspective in which platform quality is evaluated through pedagogical use rather than technical deployment alone.

Engagement emerged as one of the most consistent dimensions. Nkomo et al. [18] identified a recurrent relationship between digital participation and student engagement, while Hao et al. [12] and Wang et al. [30] showed that cognitive interaction, inquiry, discussion, and reflective learning are associated with stronger academic outcomes. The evidence therefore suggests that access counts and submission frequencies should be interpreted cautiously. From a management standpoint, the quality of participation and the continuity of interaction offer more meaningful information for identifying low involvement and designing timely academic support.

Self-regulated learning formed a second explanatory axis. Xu et al. [32, 33] reported positive relationships between self-regulatory strategies and achievement in online or blended environments. Faza and Lestari [10] broadened this pattern by identifying goal setting, time management, self-reflection, and help-seeking as relevant practices for performance, motivation, and engagement. Jin et al. [14] further showed that artificial intelligence applications can support self-regulated learning when they are integrated into a clear pedagogical purpose. Across these studies, self-regulation appears neither as a fixed personal trait nor as an exclusively individual responsibility, but as a capacity that can be supported through course design and institutional guidance.

Teacher support, academic self-efficacy, and the organization of synchronous and asynchronous learning also influenced the virtual experience. Huang and Wang [13] linked teacher support and self-efficacy with engagement and achievement, while Yavuzalp and Bahcivan [34] associated online learning readiness with self-regulation, satisfaction, and performance. Fabriz et al. [9] and Sun and Kim [28] showed that different combinations of synchronous and asynchronous activity alter the organizational demands placed on students. These findings position teacher mediation as a management factor because feedback quality, timing, task clarity, and academic presence shape the conditions under which students regulate their learning.

The reviewed systematic reviews and meta-analyses generally reported positive effects of online learning, but those effects were not uniform across disciplines, modalities, and implementation conditions [16, 17, 31]. Rahmani et al. [21] further identified the absence of support as a factor associated with dropout in online higher education. The Latin American literature introduced an additional contextual constraint: connectivity gaps and uneven teacher digital competence can alter participation and the feasibility of transferring findings from better-resourced systems [23]. These variations justify an analytical model that separates evidential support from indeterminacy.

4.2 Neutrosophic prioritization of learning-management factors

The application of rules R1-R3 produced the neutrosophic triplets shown in Table 2. Engagement and participation (C2) achieved the highest score, S = 0.91, with T = 0.86 and I = 0.14. Self-regulated learning (C3) followed with S = 0.87, while teacher support, feedback, and self-efficacy (C4) reached S = 0.80. Instructional design and academic use of the LMS (C1) obtained S = 0.75, indicating substantial support but also greater contextual indeterminacy. Monitoring and academic support (C6) reached S = 0.67 because its evidence was more indirect and derived from a smaller set of review-level studies.

Digital inclusion and the Latin American context (C5) obtained the lowest score, S = 0.33, because the only regional study in the coded set did not report a direct positive association with performance, engagement, or persistence under rule R1. Instead, it documented connectivity gaps, unequal digital preparation, and institutional support needs, resulting in the triplet <0.00, 1.00, 0.00>. The value should not be interpreted as evidence that digital inclusion is unimportant. It indicates that the available regional literature is insufficient to establish direct positive support under the predefined coding criteria, making indeterminacy itself the substantive result.

Table 2. Neutrosophic coding and prioritization of learning-management factors

Factor	Studies coded	T	I	F	S(a)	Rank
C2. Engagement and participation	Hao et al., 2025; Liu et al., 2022; Meng et al., 2024; Nkomo et al., 2021; Sharif Nia et al., 2023; Wang et al., 2024; Xiong et al., 2024	0.86	0.14	0.00	0.91	1
C3. Self-regulated learning	Faza & Lestari, 2025; Jin et al., 2023; Xu et al., 2022; Xu et al., 2023; Yavuzalp & Bahcivan, 2021	0.80	0.20	0.00	0.87	2
C4. Teacher support, feedback, and self-efficacy	Fabriz et al., 2021; Huang & Wang, 2023; Kaspar et al., 2024; Sharif Nia et al., 2023; Sun & Kim, 2022	0.80	0.40	0.00	0.80	3
C1. Instructional design and academic LMS use	Abuhassna et al., 2020; Cabero-Almenara et al., 2023; Shafiq et al., 2025; Singh et al., 2024	0.75	0.50	0.00	0.75	4
C6. Engagement monitoring and academic support	Chung et al., 2022; Rahmani et al., 2024	0.50	0.50	0.00	0.67	5
C5. Digital inclusion and Latin American context	Salas-Pilco et al., 2022	0.00	1.00	0.00	0.33	6

Note. T, I, and F were obtained by normalizing the points assigned under rules R1-R3 by the number of studies addressing each factor. S(a) = (2 + T - I - F)/3. No factor received falsity points in the coded corpus.

5. Discussion

The qualitative and neutrosophic syntheses converge on the interpretation of virtual classrooms as socio-pedagogical systems rather than neutral technological infrastructures. The strongest scores were obtained by engagement and self-regulated learning, both of which depend on sustained interaction between learner behavior, instructional structure, and academic support. This pattern is consistent with Chung et al. (2022), who identified engagement and self-regulation among the recurrent correlates of performance in online higher education. The contribution of the neutrosophic model is to show not only that these factors recur, but also that their supporting evidence contains relatively low levels of indeterminacy compared with other management dimensions.

The result for engagement has practical and methodological implications. High participation does not necessarily imply deep learning, yet the reviewed literature repeatedly associates cognitive and behavioral engagement with stronger outcomes. The neutrosophic triplet for C2 captures this predominance of positive evidence while preserving the small proportion of context-dependent findings through I = 0.14. Accordingly, universities should avoid reducing engagement analytics to access counts or task completion. More informative indicators include the quality of discussion, continuity of participation, interaction with learning resources, and reflective activity, especially when these indicators are used formatively rather than punitively.

The prioritization of self-regulated learning reinforces the shared responsibility between students and institutions. Planning, time management, self-monitoring, and help-seeking are individual strategies, but course architecture can make them easier or more difficult to enact. Ambiguous instructions, overloaded calendars, fragmented assessment, or delayed feedback increase the regulatory burden placed on students. In contrast, predictable sequences, explicit deadlines, timely feedback, and structured opportunities for help can reduce avoidable barriers. The relatively high T value for C3 therefore supports institutional interventions that teach and scaffold self-regulation rather than assuming that students already possess these capacities when they enter virtual or blended courses.

Teacher support and instructional design occupy an intermediate position in the ranking because the evidence is positive but more dependent on implementation conditions. C4 and C1 both show substantial T values alongside higher indeterminacy than engagement or self-regulation. This pattern is conceptually coherent: the same LMS function, feedback practice, or instructional arrangement can produce different outcomes depending on disciplinary expectations, course organization, students' prior digital experience, and the timing of academic support. Neutrosophic representation is useful here because it prevents heterogeneous evidence from being interpreted as contradiction when it may instead reflect legitimate contextual variation.

The Latin American result requires particularly cautious interpretation. C5 has the highest indeterminacy not because regional digital inclusion is unimportant, but because the coded corpus contains only one study directly representing the region under the defined criteria. Salas-Pilco et al. [23] documented connectivity limitations, unequal teacher digital competence, and institutional support needs, but these findings did not establish a direct positive association with the selected outcomes. The neutrosophic model therefore makes a research gap visible: the evidential problem is insufficient regional confirmation. This distinction is preferable to assigning a low substantive priority to digital inclusion on the basis of sparse evidence.

The absence of falsity points across all six factors should also be interpreted conservatively. It indicates that the coded studies did not report direct evidence against the factors under rule R3; it does not establish universal validity or causal certainty. The review includes heterogeneous designs and outcome measures, and several associations are correlational. For that reason, the score function serves as an ordering mechanism rather than a causal estimator. Keeping the T, I, and F components visible alongside S(a) prevents the ranking from obscuring the structure of the evidence from which it was derived.

6. Implications for University Learning Management

The synthesis supports a shift from platform administration toward learning management. Universities should evaluate virtual classrooms according to the pedagogical relationships among objectives, learning activities, feedback, assessment, and opportunities for interaction. A technically stable LMS remains necessary, but its educational value depends on how course architecture channels student effort and supports meaningful participation. Institutional quality assurance can therefore include periodic review of course design, response times, assessment coherence, and the extent to which digital activities require active learning rather than passive access to content.

Engagement monitoring can be incorporated into academic support systems when it is used to identify patterns that warrant pedagogical intervention. Participation data, interaction with activities, timely submission, and continuity of access can function as early signals of reduced academic connection. However, the evidence summarized here does not justify deterministic risk labeling based on platform traces. The higher-priority neutrosophic factors suggest that monitoring should be linked to human interpretation, tutorial support, and course redesign so that analytics become a resource for learning rather than a mechanism of surveillance or sanction.

Self-regulated learning should likewise be treated as a teachable institutional competence. Orientation programs, tutoring, and course-level guidance can explicitly address planning, time management, goal setting, progress monitoring, and help-seeking. Artificial intelligence applications may support these processes by providing adaptive prompts or timely feedback, as suggested by Jin et al. [14], but such tools should remain

subordinate to pedagogical purposes and human oversight. The management challenge is therefore not simply to add automation, but to align technological support with transparent learning goals and instructor responsibility.

Finally, digital inclusion should be treated as a quality condition rather than an auxiliary access issue. Connectivity, device availability, technical support, and teacher digital competence influence whether students can participate in the practices that the higher-ranked factors require. In Latin American institutions, the high neutrosophic indeterminacy of C5 is a signal for research and institutional monitoring. Decisions on infrastructure, faculty development, and student support should be accompanied by context-specific evidence capable of determining how digital inclusion interacts with performance, engagement, and persistence under local conditions.

Table 3. Synthesis of evidence and management implications

Dimension	Evidence synthesis	Management implication
LMS and instructional design	The platform alone does not explain academic performance.	Evaluate pedagogical quality, alignment among activities, feedback, and assessment.
Engagement	Cognitive and behavioral participation is recurrently associated with performance.	Use formative engagement monitoring and early academic support.
Self-regulated learning	Planning, time management, monitoring, and help-seeking support performance.	Embed explicit self-regulation support in courses, tutoring, and induction.
Teacher support and self-efficacy	Perceived support and academic confidence shape the virtual learning experience.	Strengthen teacher mediation, timely feedback, and academic accompaniment.
Latin American context	Connectivity and digital competence gaps remain structurally relevant, but direct outcome evidence is limited.	Integrate infrastructure, support, faculty development, and context-specific evidence gathering.

7. Limitations

The principal limitation concerns study identification. The initial search was conducted through directed academic queries and individual reference verification rather than complete database exports from Scopus, Web of Science, ERIC, SciELO, DOAJ, and Dialnet. The study should therefore be interpreted as a systematized review and not as an exhaustive systematic review of all available databases. In addition, no new meta-analysis was performed and no formal risk-of-bias instrument was applied to each study. Future updates should replicate the search through direct database strategies and incorporate design-specific quality appraisal tools.

The neutrosophic synthesis also has interpretive limitations. The coding rules were defined by the authors and applied to the included studies, which ensures procedural transparency but does not transform T, I, and F into objective effect parameters. The values represent an analytical formalization of evidential support, indeterminacy, and contradiction within this corpus. Future studies could test inter-rater agreement for neutrosophic coding, compare alternative score functions, or contrast the present ordering with expert judgments using neutrosophic AHP, TOPSIS, or related multicriteria procedures. Such extensions would strengthen methodological robustness without replacing the need for substantive educational interpretation.

8. Conclusions

The systematized review of 32 studies published between 2020 and 2025 shows that academic performance in university virtual classrooms cannot be explained by technological availability alone. Engagement, self-regulated learning, instructional design, teacher feedback, self-efficacy, and academic support interact to shape how students use digital environments. The neutrosophic synthesis adds an explicit representation of evidential certainty to this interpretation. Among the 23 studies coded for six management factors, engagement and participation received the strongest support, followed by self-regulated learning and teacher support with feedback, while the Latin American digital-inclusion factor was characterized primarily by indeterminacy.

For university management, the findings support decisions that connect digital transformation with pedagogy. Institutions can strengthen course design, monitor engagement for formative purposes, scaffold self-regulation, improve teacher feedback, and integrate digital inclusion into academic quality policies. The high indeterminacy observed for the Latin American context should motivate additional regional studies rather than

justify lower institutional attention. More broadly, the study illustrates how single-valued neutrosophic sets can complement qualitative evidence synthesis when heterogeneous educational findings need to be prioritized without being reduced to unsupported pooled effects.

Declarations

Originality. The authors declare that this manuscript is original, has not been published previously, and is not under simultaneous consideration by another journal or publication outlet.

Conflict of interest. The authors declare no conflicts of interest that could have influenced the interpretation of the evidence or the conclusions.

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Data availability. No primary dataset was generated. The synthesis was based on published studies and bibliographic metadata verified in Crossref or official editorial sources.

Generative artificial intelligence statement. During manuscript preparation, generative artificial intelligence tools were used as support for language revision, redundancy detection, formal organization, bibliographic cross-checking, internal consistency review, and adaptation to editorial requirements. The study corpus, coding criteria, assignment and review of T, I, and F values, neutrosophic calculations, interpretation of evidence, and scientific conclusions were reviewed and validated by the authors, who assume full responsibility for the final content.

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