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A systematic review of eye-tracking technology in higher education: implications for effective feedback practices

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This study investigated the use of eye-tracking technology in higher education, as well as its implications for teaching and feedback, through a systematic review guided by the PRISMA 2020 guidelines (databases and registers only). Using keywords relating to eye tracking, feedback and the educational context, 2,544 records were retrieved from Web of Science-indexed journals published by Elsevier, Springer, SAGE, Taylor and Francis, Wiley and Frontiers. Following screening, 2,490 records were excluded, leaving 54 full-text reports to be assessed for eligibility. A total of 27 empirical studies conducted in higher education contexts involving undergraduate and graduate students, adult learners and university instructors met the inclusion criteria and were synthesized. Analysis of the learning environment showed that most studies were conducted in controlled laboratory settings (88.8%, $n = 24$), with a smaller proportion conducted in university classrooms (11.2%, $n = 3$). Interactive digital materials and standard/static digital materials were equally represented, each accounting for 44.4% of the reviewed studies. The findings were organized into four outcome domains: (1) cognitive processing and learning performance, (2) attention allocation and engagement, (3) affective states and (4) instructional skills and teaching quality. Overall, this review provides evidence-based insights into how eye tracking can inform the design and evaluation of feedback in face-to-face, blended and online higher education environments.

KEYWORDS
eye tracking, feedback design, higher education, systematic review, technology-enhanced learning

1 Introduction

Eye tracking is a valuable educational tool that allows researchers to find out learners' visual attention (van Gog and Scheiter, 2010), the cognitive load, emotional states, engagement levels and information process. With the help of diverse measurement characteristics, eye tracking technology can provide invaluable insights on how learners interact with learning material and feedback during the learning tasks. Such kind of data particularly valuable in higher education contexts, where understanding moment-to-moment learner attention and comprehension processes can inform the design and delivery of effective feedback interventions. Although eye-tracking research has

expanded significantly in recent years, there is still a need for systematic reviews that summarize its implications for providing feedback in higher education, particularly in technology-enhanced and online learning environments. This study addresses this need by examining how eye-tracking technologies contribute to feedback practices in higher education. By analysing the existing literature, this review aims to understand how eye tracking technology can improve the effectiveness of instruction and feedback in higher education and thus make valuable contributions to research and practice in this area.

The utilization of eye tracking technologies in educational settings has become a strong field of research, supported by different theoretical frameworks. Cognitive Load Theory (CLT) put that the working memory can handle a limited size of information at once, which means the learners can be overloaded if the tasks' demands exceed this limit (Sweller, 1988). Similarly, Limited Capacity Model of Motivated Mediated Message Processing (LC4MP) (Lang, 2017), suggests that individuals have limited cognitive resources which are distributed across encoding, storage and retrieval. Learning materials exceeds that limit interrupts information processing and negatively affect the learning process. In this regard, eye tracking technology enables researchers to keep track of mental effort in real time with the help of the gaze metrics which changes depending on the level of cognitive load. When learners are given tasks that require more mental effort such as processing more information or connecting information from parts, they tend to stare at longer a specific point or make shorter eye movements between these points (Debue and Van De Leemput, 2014; Kruger and Doherty, 2016).

Studies have consistently shown that eye movement patterns reflect cognitive processing demands in educational settings. van Gog and Scheiter (2010) reported that both fixation duration and number increased due to the more encoding and organizing effort. Similarly, a recent empirical study showed that adding decorative picture to text increased the cognitive load indices as well as the learners' eye fixations, even though the test scores did not change (Scharinger, 2024). Moreover, some studies have also demonstrated that the dilation of pupils can be associated with cognitive load (Klingner et al., 2011) that enlarged pupil size reflect greater mental effort (Gavas et al., 2017) or task complexity (Mitra et al., 2017). Synthesizing the literature, a recent meta-analysis has shown that various levels of cognitive load can be consistently identified by pupil size and blink rate (Wang et al., 2024). These studies emphasize that eye-tracking research can be an effective tool for assessing cognitive load and mental effort by identifying potential cognitive bottlenecks and guiding adaptive learning, thereby providing vital insights to improve feedback practices.

As well as the cognitive load, empirical studies have also showed that eye measurements can provide deeper understanding in cognitive and learning process. Research has revealed that medium fixation periods (300–500 ms) contribute positively to learning whereas very short (<150 ms) or very long (>1,000 ms) fixations can indicate distraction or confusion in educational videos (Negi and Mitra, 2020). Similarly, that long-term fixations can be associated with mindless reading (Reichle et al., 2010). Moreover, the duration of the fixation can be an indicator of depth of cognitive engagement. Fixation duration during reading is positively correlated with activation in brain regions associated with attention, oculomotor control, and language processing, suggesting that longer fixations reflect deeper cognitive engagement with text (Henderson et al., 2015). Additionally, research has demonstrated that the frequency of eye blinks is linked to disengagement or mind wandering during the learning process. A study demonstrated that blink rates during 5-second intervals were significantly higher during mind-wandering episodes compared to on-task periods (Smilek et al., 2010). High performers blinks less frequently than low performers (Renker et al., 2019), which suggest lower blink rates may indicate an increased cognitive engagement (Kaakinen and Simola, 2020). These findings provide educators with important information for evaluating and developing learning materials that are appropriate for learners' cognitive abilities.

Research has also shown that it is possible to infer different feelings of learners and engagement patterns with eye tracking technology. A study showed that specific patterns of visual attention associated with emotional experiences such as disappointment and regret (Bault et al., 2016). In educational settings, learners' confusion can be located by longer fixations and frequent regressions (Pachman et al., 2016). Moreover, low saccade speed, long fixations and out of interest gaze are the strong detectors of mind wandering (Hutt et al., 2016). Likewise, prolonged gaze and infrequent transitions, combined with EEG/GSR, classifies boredom with nearly 80% accuracy (Seo et al., 2019). Eye tracking cameras can now indicate the engagement level of learners by watching where they look and how they position their head with a high accuracy (Sharma et al., 2022). Measuring the wideness of pupils helps distinguish between learners who are interested or bored and not trying (Bradley et al., 2008). Taken together, eye tracking can facilitate developing learning systems that can spot emotional barriers and offer timely support to learners who are having difficulty.

Eye tracking studies provide valuable insights into teachers' behaviours, especially with respect to visual attention and interaction with students. The eye-tracking technology allowed researchers to find out how teachers distribute visual attention and its implications for teaching quality. Recent eye tracking studies have shown how instructors differ in their awareness of visual attention for instance, Kim et al. (2012) found that expert teachers showed significantly higher gaze rates on the student zone (around 56%–60%), while novice teachers' gaze was more frequently directed to non-teaching zones (around 40%–45%). Expert teachers' gaze patterns formed a 'T' shape, extending to the rear areas of the classroom, while novices' gaze remained narrowly focused in the middle areas forming an 'I' pattern. Similarly, Kosel et al. (2023) found that expert teachers had shorter fixation times than novices and more frequent fixations resulting in more efficient visual information processing and other studies investigated how eye tracking technologies can improve this awareness. Coskun and Cagiltay (2021) showed that novice university instructors increased their awareness of classroom management by distributing their attention more evenly. Likewise, Kaminskienė et al. (2023), found that university teachers who viewed recordings and heat maps of their own gaze patterns during lectures became more aware of their visual attention distribution and reflected on more balanced attention. Moreover, the study of Soares et al. (2024)

suggests that eye tracking technology may help teachers identify when students are distracted or confused, allowing them to provide immediate intervention and potentially maintain student attention and engagement during lessons. Collectively these findings suggest that eye tracking is not only a simple diagnostic tool but also a facilitator of reflective practice in todays' contemporary classrooms.

Eye tracking technologies further allows researchers to understand how students engage with feedback, or how feedback affected students eye movement during the interaction of learning material. The use of eye tracking in feedback studies can deepen our understanding on how students react different kinds of feedback and how feedback type or its presentation would affect students' visual attentions, gaze durations, saccades, mind wanderings etc. during the tasks. Existing eye tracking technologies enabled researcher to find out the effect of content and timing of feedback on students' fixation behaviors (Taxipulati and Lu, 2021), how and when student engage with feedback more effectively (Ritzhaupt et al., 2018; Tärning et al., 2020), and the types of feedback that students tend to prefer (Zhai et al., 2018), and the optimal feedback design that gets learners attention to the problem (Wiebe et al., 2009). For instance, Ritzhaupt et al. (2018) showed that adding pictures to written feedback collects more attention and increases satisfaction with feedback. Cutumisu et al. (2019) revealed that student spent more time looking at critical feedback than praise, suggesting that learners think more deeply about negative feedback. These studies collectively demonstrate how eye tracking helps revealing exactly how students process feedback and identify the best ways designing effective feedback practices.

Existing eye tracking literature provides invaluable insights into how instruction or feedback mechanisms could be designed more effectively. However, the diversity of existing studies and the increasing number of studies examining the effects of teaching and feedback mechanisms on eye movements necessitate a systematic review in this field. Research on eye tracking and feedback has generally been conducted using different methodologies and feedback types, and a holistic perspective is needed for the consistency and general validity of the results. By synthesising the existing literature, this review aims to clarify how eye-tracking technology is used in feedback studies, which feedback types affect learners' cognitive processes, and how these findings can inform educational practice. It also seeks to address contradictions in the research and to guide future investigations.

Many review studies have been conducted to synthesize the effects of eye-tracking technologies in educational research. These studies have examined the diverse applications of eye-tracking technology across disciplines, learner groups, and instructional contexts. They have highlighted the technology's potential to foster learning outcomes as well as its methodological limitations.

Lai et al. (2013) conducted a content analysis of 113 eye-tracking studies in SSCI index from 2000 to 2012. As a result of the content analysis, the studies were categorized into seven themes as: information processing patterns, instructional design effects, reexamination of existing theories, learning strategy effects, conceptual development, individual differences, and patterns of decision making, and Alemdag and Cagiltay (2018) reviewed 58 studies on the use of eye-tracking in multi-media learning and concluded that multimedia content, multimedia learning principles, learner characteristics, emotions and metacognition were the factors affecting eye movement measurements. Strohmaier et al. (2020) synthesized 161 mathematics education studies and reported that eye movements were strongly linked to cognitive effort and strategy use. Extending this research to younger learners, Paskovske and Kliziene (2024) reviewed 17 elementary school studies and concluded that eye tracking can effectively detect problem-solving strategies and shortcuts.

Dostálová et al. (2022) analyzed 11 studies focusing on self-regulation in higher education context from 2012 to 2021 and concluded that most of the studies focus on judgments of learning, metacognitive monitoring, meta-comprehension, and learning strategies in self-regulation processes. Mikhailenko et al. (2022) synthesized 90 publications and emphasized that eye tracking can enhance personalization, detect inattention, and measure cognitive load. Suprapto et al. (2024) conducted a bibliometric analysis of 774 studies and revealed a disciplinary imbalance, with the majority of studies concentrated in computer science (40%), followed by the social sciences and medical training. They also urged future research to better connect eye-movement data with actual learning outcomes. Dostálová and Plch (2023) analyzed 16 studies and found that, although webcam-based trackers increase accessibility, the majority of research (70%) remains limited to attention, engagement, and mind-wandering. Only a small proportion (12%) investigates deeper cognitive processes, such as reading strategies.

Taken together, these review and synthesis studies have provided valuable insights into how eye-tracking technologies can be integrated into educational research. Most of the prior reviews have concentrated on specific domains (e.g., mathematics), particular topics (e.g., multimedia learning, self-regulation), or general methodological considerations. However, no systematic reviews have addressed how eye-tracking technology can inform feedback practices in higher education. This represents a significant gap in the literature, as feedback is a critical component of effective instruction, and understanding how learners visually process and respond to different feedback types could inform evidence-based pedagogical design.

The present study addresses this gap by conducting a systematic review that synthesizes eye-tracking research on feedback across diverse higher education settings. By identifying patterns in how feedback influences learners' visual attention, cognitive processing, and affective responses, this review aims to provide actionable design guidelines for educators, instructional designers, and educational technology developers seeking to optimize feedback effectiveness in higher education.

This research aimed to investigate how eye tracking technology can be used in higher education context to inform feedback mechanisms through a systematic review. Focusing on the peer-reviewed articles from higher education published from 2000 to 2024, a thematic meta-synthesis was conducted to integrate findings across studies. This study contributes to the literature by synthesizing findings on students interact with different types of feedback across diverse learning environments, which can provide a deeper understanding of optimal feedback

practices in the learning process. In line with these aims, the following questions were addressed:

RQ1) How are eye-tracking studies on feedback in higher education distributed across years, countries, disciplines, participant groups, research designs, learning environments and materials, and intervention methods?

RQ2) What types of feedback are investigated in eye-tracking studies in higher education, and what are their reported effects on learners' cognitive, affective, and behavioral outcomes?

2 Methods

This study employs a systematic review approach, which is a structured, protocol-driven method for rigorously analysing and evaluating research relevant to specific questions (Kitchenham, 2004) to examine eye-tracking research on feedback in higher education. The most crucial component of systematic review studies, the review procedure, was conducted in accordance with the PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only (Page et al., 2021). In this study, the review process comprised the following steps: (a) identifying relevant databases, (b) selecting appropriate databases for the research scope, (c) defining explicit inclusion and exclusion criteria, (d) screening titles and abstracts, (e) retrieving and assessing full-text reports for eligibility, and (f) interpreting and synthesizing the findings. The methodological framework, presented in Figure 1, illustrates the systematic review process as structured by the PRISMA 2020 guidelines.

The systematic review procedure, which is central to the integrity and replicability of the study, comprises the following key steps:

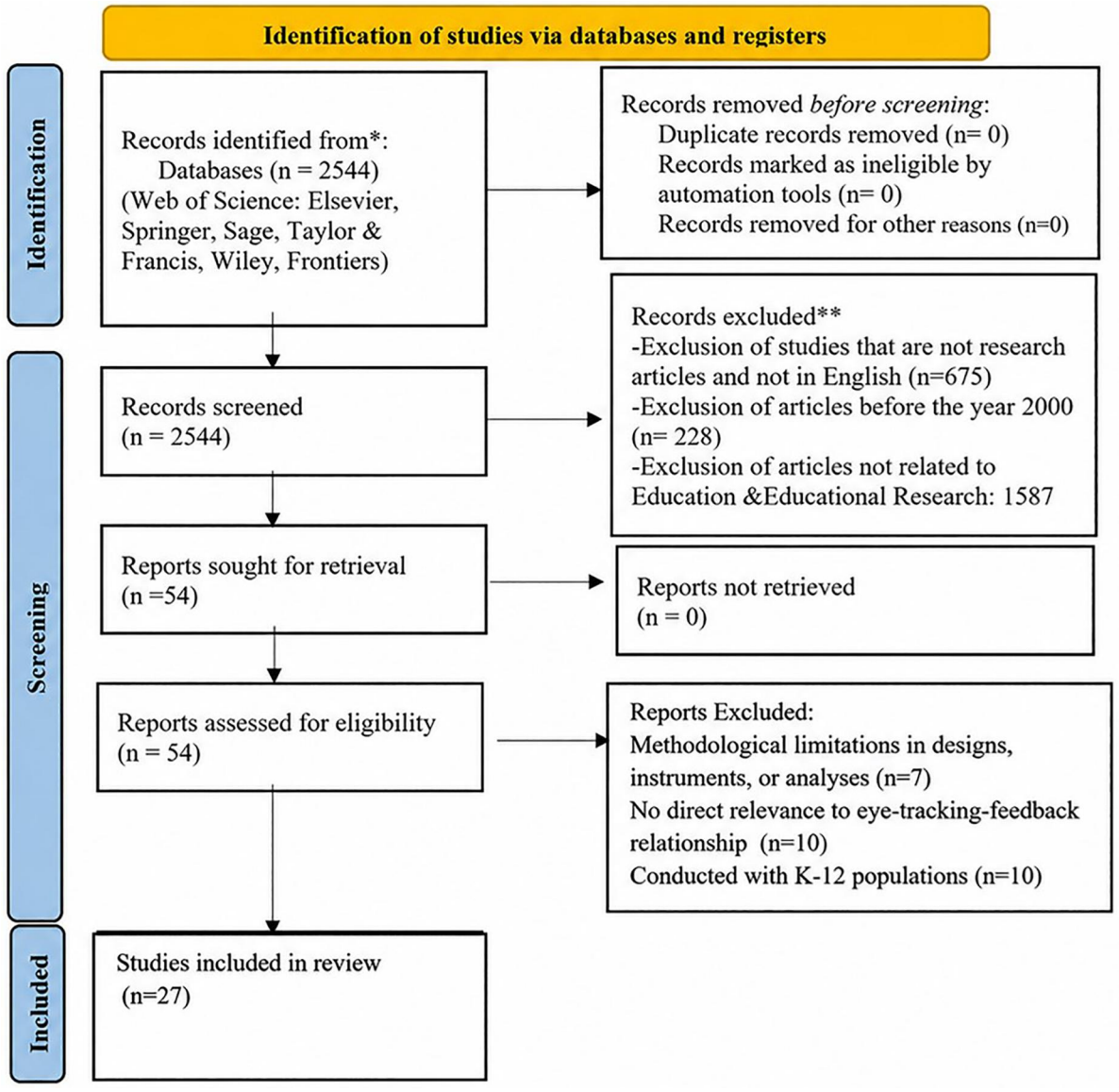


FIGURE 1
PRISMA flow diagram for systematic review process.

- Identifying Databases: In line with the PRISMA 2020 flow diagram for new systematic reviews which included searches of databases and registers only (Page et al., 2021), the identification stage of the review focused on journals indexed in the Web of Science database (SSCI, ESCI, SCI-E) within the fields of education and educational research. Among these, only journals published by major academic publishers such as Elsevier, Springer, Sage, Taylor and Francis, Wiley, and Frontiers were considered. This strategy was employed to ensure that the studies included in the review were sourced from reputable publications with consistent indexing standards and rigorous peer review processes.
- Selecting Appropriate Databases: These databases have been specifically selected for their reputation and comprehensive coverage of educational technology and eye-tracking. Their institutional and organizational structure is widely recognized, with many countries considering publication in these databases as a key criterion for academic promotion. The journals within these databases are highly selective, attracting submissions from researchers around the world seeking to publish their high-quality studies. As a result, the articles indexed in these databases are considered to represent a diverse and robust collection of qualified research.
- Establishment of inclusion and exclusion criteria: A detailed set of inclusion and exclusion criteria was carefully defined to ensure the selection of studies that were relevant, methodologically sound, and aligned with the research objectives. Inclusion criteria required studies to be published from 2000 onwards and to be research articles. All searches were conducted in the Web of Science Core Collection using the Topic field (TS), which covers title, abstract, author keywords, and Keywords. To capture eye-tracking research on feedback within higher-education and broader educational contexts, the search strategy was structured around core eye-tracking terms paired with feedback and combined with education-related context terms. The exact Web of Science query strings were: Query set (Eye-tracking×Feedback×Educational context): TS = [("eye tracking" OR "eye tracker" OR "eye movement") AND feedback AND (education OR learning OR teaching OR "distance learning")]. Alternative phrasing variants (tested within the same scope): TS = ["eye tracking" AND feedback AND (education OR learning OR teaching OR "distance learning")]; TS = ["eye movement" AND feedback AND (education OR learning OR teaching OR "distance learning")]; TS = ["eye tracker" AND feedback AND (education OR learning OR teaching OR "distance learning")]
    - Inclusion criteria: To ensure that the final corpus aligned with the research aims, studies were included when the following conditions were met. First, only peer-reviewed journal articles published from 2000 onwards and written in English were retained. Second, a higher education context was required, and only studies conducted with undergraduate or graduate students, adult learners, or university instructors were included. Third, only empirical studies (quantitative, qualitative, or mixed-methods) were retained, and eye-tracking (or eye-movement tracking) was required to be used as a core methodological component. Finally, feedback was required to be treated as a central construct (e.g., feedback design, delivery, processing, or effects) and to be examined in relation to eye-tracking measures, as operationalized through the Web of Science search queries reported above (e.g., "eye tracking/eye movement/eye tracker" combined with "feedback" and education-related terms).
    - Exclusion criteria: Records were excluded when they did not meet the scope of the review. Specifically, non-English publications were excluded, and dissertations/theses, conference abstracts/proceedings, and review articles (including systematic reviews and meta-analyses) were removed. In addition, studies conducted with K–12 populations (i.e., elementary, middle, or high school students) were excluded to maintain a clear focus on higher education contexts, ensuring that the synthesis remained directly applicable to undergraduate and graduate students, adult learners, and university instructors.
- Interpreting Research: The selected studies were thoroughly analyzed and interpreted to derive meaningful results relevant to the research question. This analysis was based on the studies' theoretical underpinnings, objectives, methods, results, and discussions.

A network analysis was carried out using Gephi (0.10.1) to visualise the thematic and methodological framework of higher-education studies that explored feedback through eye-tracking technology. Relationships among nodes were modelled using weighted edges, representing more recurrent or prominent connections in the dataset with greater emphasis. Community detection was performed using the Modularity algorithm with randomization enabled and edge weights incorporated to identify clusters of closely related topics and methods. The resolution parameter was set to 1.0 and community classes were indexed starting at 0. To capture influence beyond simple frequency counts, eigenvector centrality was computed under the directed setting with a maximum of 100 iterations. To achieve clearer visual separation and facilitate inspection of the network structure, layouts were generated using ForceAtlas2 and Fruchterman–Reingold. However, interpretation was primarily guided by the computed network metrics rather than spatial positioning in the layouts. The resulting network maps illustrate the organisation of eye-tracking–based feedback research in higher education, with edge thickness and label size indicating the relative prominence of elements across studies. This approach facilitated the systematic identification of dominant research themes, recurring methodological choices and coherent clusters within the field.

2.1 Review strategies

Following PRISMA 2020 guidelines (Page et al., 2021), relevant records were identified using the following keywords: "eye tracking and feedback," "eye movement and feedback," "eye tracker and feedback," and "distance learning." A total of 2,544 records were retrieved from Web of Science–indexed journals published by Elsevier, Springer, Sage, Taylor and Francis, Wiley, and Frontiers. After checking for duplicates and automation-based exclusions ($n = 0$), all records proceeded to the screening stage. During title and abstract screening, 2,490 records were excluded, including non-research articles and non-English publications ($n = 675$), articles published before the year 2000 ($n = 228$), and studies not related to education or educational research ($n = 1,587$).

This process resulted in 54 reports sought for retrieval, all of which were successfully accessed ($n = 0$ reports not retrieved). Subsequently, 54 full-text articles were assessed for eligibility. Of these, 7 reports were excluded due to insufficient clarity and accuracy in methods, data collection instruments, or statistical analyses, and 10 studies were excluded due to no direct relevance to the eye-tracking–feedback relationship, and 10 studies were excluded as they were conducted with K-12 populations. Ultimately, 27 studies met all inclusion criteria and were included in the final synthesis of this systematic review.

The selected studies were systematically evaluated based on several factors, including year of publication, country of origin, academic discipline, theoretical context, aims, research questions, study design, participant characteristics, learning environments and materials, software used, interventions employed and their findings. Both qualitative and quantitative analyses were employed to provide a comprehensive understanding of the field. Data from the selected studies were extracted using a predesigned data extraction form that included fields for study characteristics (e.g., author, year, country), research design, sample size, intervention details, outcomes, and key findings. The extracted data were then analyzed to identify patterns, trends, and gaps in the literature.

In this study, limiting the search process to journals indexed in the Web of Science Core Collection was adopted as a deliberate methodological decision. Journals indexed in Web of Science are widely recognized in international academic publishing and are considered important criteria in academic promotion and evaluation processes in many countries. They also offer a relatively institutionalized publication structure in terms of impact factors, indexing requirements, publication standards, and peer-review procedures. For this reason, Web of Science-indexed journals published by major international publishers such as Elsevier, Springer, SAGE, Taylor & Francis, Wiley, and Frontiers were considered to provide a more transparent, traceable, and quality-controlled corpus for the review.

This methodological delimitation is also supported by recent bibliometric evidence indicating that eye-tracking research in educational contexts is increasingly visible in internationally indexed and peer-reviewed journals. For example, Muna and Bahit (2023), in their bibliometric study of eye-tracking research in chemistry learning, reported that a considerable number of studies were published by major academic publishers, including Elsevier and Frontiers Media. They also found that most of the eye-tracking studies in their corpus were published in Scopus-indexed journals ranked between Q1 and Q3, with Q1 journals representing the largest proportion. Although their study focused specifically on chemistry learning and used a different database strategy, these findings suggest that eye-tracking research in education is frequently disseminated through internationally recognized publication channels. This provides additional contextual support for delimiting the present review to a quality-controlled corpus of internationally indexed peer-reviewed journal articles.

Nevertheless, this methodological choice also meant that some relevant studies in the field were excluded from the review. Eye-tracking research is published not only in educational sciences but also in related fields such as computer science, human–computer interaction, psychology, cognitive science, and learning analytics. Therefore, studies published in databases outside Web of Science, conference proceedings, book chapters, dissertations, theses, and regional indexes were not included in the scope of this review. Similarly, because a substantial proportion of the selected journals publish in English, and because the research team was able to access and evaluate English-language academic literature more effectively, the review was limited to publications written in English.

3 Results

3.1 RQ1) How are eye-tracking studies on feedback in higher education distributed across years, countries, disciplines, participant groups, research designs, learning environments and materials, and intervention methods?

An analysis of the selected articles reveals a consistent, linear increase in the use of eye-tracking technology in research over the years. This trend underscores the growing recognition of eye-tracking as a valuable investigative tool across disciplines (Figure 2).

This review revealed that the majority of eye-tracking studies have been conducted in the American and European continents, as well as in China and Taiwan. Within the European context, investigations are often conducted as part of collaborative projects involving research teams from multiple countries. Overall, experimental research employing eye-tracking technologies tends to be concentrated in economically developed regions, due to the substantial financial investment, infrastructure and technical expertise required to acquire, maintain and operate such equipment. Consequently, regions with low or middle incomes remain underrepresented in the literature, which may limit the generalisability of current findings.

As illustrated in Figure 3, the network structure revealed clear patterns of collaboration between different scientific disciplines in eye-tracking research. A small set of countries emerged as structurally prominent, with Germany, the Netherlands and China appearing as major nodes connected to multiple disciplinary fields, suggesting a broader cross-disciplinary reach in these contexts. The USA and Turkey were also linked to several fields, although comparatively to the most central nodes,

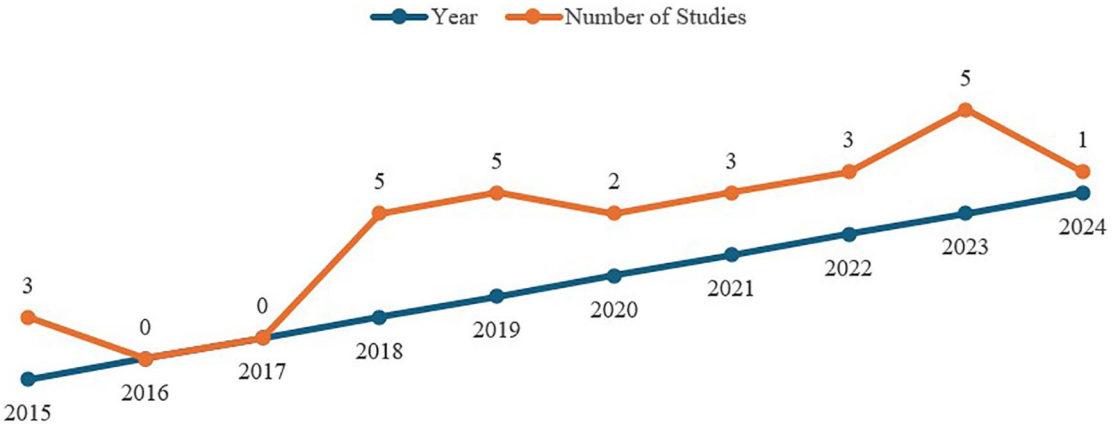


FIGURE 2
Distribution of research by years.



FIGURE 3
Network analysis of scientific disciplinary collaboration in eye-tracking research.

their connections appeared more limited. Educational Sciences was positioned as a key connecting node across the network, indicating that collaboration between disciplines in this field has been anchored in education-focused research while extending to adjacent domains. At the same time, discipline-specific linkages were distributed unevenly across countries, with stronger connections formed in some national profiles than in others to areas such as behavioural and social sciences, language sciences, computer science, and mathematics and information technology. These regularities were visible descriptively and were also supported by network metrics: communities identified through modularity suggested clusters organised around distinct country–discipline constellations, while eigenvector centrality highlighted the central role of countries embedded in highly connected neighbourhoods (notably Germany, the Netherlands, and China).

Analysis of the participant profiles showed that the 27 studies were conducted in higher education or adult professional learning contexts, including undergraduate and graduate students, pre-service teachers, in-service teachers, and university instructors.

TABLE 1 Distribution of eye-tracking feedback studies by physical setting and material type.

Physical setting	Interactive Digital Materials (IDM)	Standard/Static Digital Materials (SDM)	Traditional Materials (TM)	Total
Laboratory	12 (44.4%)	12 (44.4%)	0 (0%)	24 (88.8%)
Classroom	0 (0%)	0 (0%)	3 (11.2%)	3 (11.2%)
Total	12 (44.4%)	12 (44.4%)	3 (11.2%)	27 (100%)

IDM, interactive learning materials (intelligent tutoring systems, adaptive learning environments, educational games, simulations); SDM, standard digital materials (texts, diagrams, non-interactive videos, peer feedback on screen); TM, traditional materials (physical documents, face-to-face interactions). Percentages represent proportion of total studies.

The majority of the studies focused exclusively on undergraduate students ($n = 20$, 74.1%), although participant characteristics varied across disciplines and academic levels. A smaller proportion of studies included only university instructors ($n = 2$, 7.4%), while the remaining studies involved graduate students ($n = 3$, 11.1%) or in-service teachers/professional educators ($n = 2$, 7.4%). This distribution indicates that the evidence base is largely centred on undergraduate learning contexts, with comparatively limited attention given to instructors, graduate students, and professional teaching populations.

Regarding the physical setting, the majority of the studies were conducted in laboratory environments ($n = 24$, 88.8%), whereas three studies (11.2%) took place in authentic classroom settings. The dominance of laboratory-based research reflects the technical requirements of eye-tracking data collection, including the need for precise calibration, controlled lighting conditions, and stable recording environments. However, this also suggests that authentic teaching and learning contexts remain underrepresented in the current literature. Table 1 presents the distribution of studies according to physical setting and material type.

The materials used in eye-tracking-based feedback research were classified into three distinct categories: interactive digital materials (IDM), standard/static digital materials (SDM), and traditional materials (TM). Analysis showed that 12 studies (44.4%) employed IDM, 12 studies (44.4%) used SDM, and three studies (11.2%) utilized TM. IDM included interactive systems such as intelligent tutoring systems, adaptive learning environments, educational games, and simulations. SDM comprised static or minimally interactive digital content, such as texts, diagrams, non-interactive videos, and peer feedback displayed on screen. TM, on the other hand, consisted of physical documents and face-to-face interactions.

Analysis of eye-tracking instrumentation revealed that researchers employed a range of screen-based and mobile eye-tracking systems across the 24 studies that reported device information (Table 2). In the remaining three studies, eye-tracking device specifications were not sufficiently reported. The diversity of instruments, including screen-based systems and mobile or wearable eye trackers, reflects the methodological variety of the reviewed studies and the different technical requirements associated with laboratory-based and classroom-based research contexts.

The analysis revealed a predominance of screen-based eye-tracking systems, particularly from manufacturers such as Tobii, EyeLink, and SMI, which require controlled laboratory conditions for precise calibration and stable viewing distances. These stationary systems (e.g., Tobii Pro Glasses 2 100 Hz, EyeLink 1000 Plus, SMI RED250/ RED500) accounted for the majority of instrumentation, reflecting the experimental nature of the research and the technical requirements for high-quality data collection.

TABLE 2 Eye-tracking tools used for data gathering and analysis in the research.

Instruments and tools	Model/ Technical specification	Category	Number of Research
ASL	Mobile Tracker	Mobile	1
NTNU	Eye-NTNU - 180/30-180 Hz	Screen-based	1
Eyetech Digital	QG-Plus Software/ 50 Hz	Screen-based	1
Ergoneers LCC	Dikablis/25-Hz	Mobile	3
	Dikablis/50 Hz	Mobile	1
LC Tech	Eye Follower/120 Hz	Screen-based	1
EyeLink	1,000 Plus/500 Hz – 1,000 Hz	Screen-based	5
SMI	REDn/60 Hz	Screen-based	1
	RED250/250 Hz	Screen-based	3
	RED500 250 Hz	Screen-based	1
Tobii	Pro Glasses 2/100 Hz	Mobile	1
	Pro Glasses 3/100 Hz	Mobile	1
	Pro Nano/60 Hz	Screen-based	1
	Pro X2-30/30 Hz	Screen-based	1
	T60 Eye Trackers/ 60 Hz	Screen-based	1
	Custom Tracker	Screen-based	1

Mobile eye-tracking devices, including wearable systems such as the ASL Mobile Eye Tracker and various Tobii Glasses models, were less frequently employed and were typically used in classroom observation studies where naturalistic teaching-learning interactions needed to be captured.

3.2 RQ2) What types of feedback are investigated in eye-tracking studies in higher education, and what are their reported effects on learners' cognitive, affective, and behavioral outcomes?

The study analyzed how research utilizing eye-tracking technology explores cognitive, behavioral, affective learning

characteristics in relation to feedback. To achieve this, the theoretical contexts, aims, and research questions of the studies were reviewed. Prominent conceptual structures were then tabulated and visualized through word clouds.

Eye-tracking studies in education have examined the effects of different types of feedback. These studies emphasize cognitive learning behaviors in the context of social interaction, collaboration, and assessment. They highlight that the timing and duration of feedback are critical in shaping students' cognitive orientation and persistence. Another dimension of feedback-focused eye-tracking research concerns learners' affective characteristics. Specifically, video-based and personalized feedback have been shown to bridge the gap between self-assessment, self-efficacy, and self-regulated learning. This links affective and metacognitive attributes to academic achievement.

An analysis of the reviewed studies shows that the themes of peer feedback, corrective feedback, feedback timing and feedback-related dropout are the most frequently studied, reflecting dominant trends in the field. However, the affective and metacognitive dimensions of feedback receive comparatively less attention.

Analysis of the 27 included studies revealed four outcome domains characterising the impact of feedback modalities in educational contexts: cognitive processing and learning performance, attention allocation and engagement, affective states, and instructional skills and teaching quality. Rather than categorising findings by feedback type, this review adopts an outcome-oriented framework, focusing on the measurable impacts relevant to educational practice. This approach offers researchers and practitioners evidence-based insights aligned with specific learning goals.

3.2.1 Cognitive processing and learning performance

Eye-tracking research has provided substantial evidence that feedback design significantly impacts learners' cognitive processing mechanisms and learning performance. Nine studies examined how different feedback characteristics influence cognitive processes and educational outcomes, revealing three primary themes: feedback processing strategies, cognitive load management, and adaptive system effectiveness. Learners demonstrate distinct cognitive strategies when processing feedback, with profound implications for learning outcomes. Bouwer and Dirkx (2023) identified three primary processing approaches through eye-tracking analysis: superficial processing (single-pass reading), local processing (frequent text-feedback transitions), and deep processing (integration of multiple text elements with extensive transitions). Deep processors produced more substantial revisions despite similar reading times, indicating that processing strategy rather than duration determines effectiveness.

As shown in Appendix 1, multiple studies revealed a consistent pattern regarding feedback complexity and cognitive load. Berndt et al. (2018) demonstrated that longer glance durations on peer feedback were associated with lower text-revision performance, indicating that prolonged attention does not necessarily enhance learning outcomes. Furthermore, elaborated peer feedback, while providing more information, increased cognitive load without proportional benefits to recall or performance. The specificity of justifications in feedback also affects these processing patterns. Bolzer et al. (2015) found that when justifications were absent, students spent significantly longer fixating on feedback, and these extended fixation periods were associated with better recall performance. This surprising finding suggests that cognitive effort required to fill information gaps may enhance retention. However, this must be balanced with appropriate support, as Berndt et al. (2022) showed that concise justifications support understanding without cognitive overload, particularly when combined with prompts that encourage critical engagement.

Strategic design choices significantly impact cognitive load distribution. Burkhart et al. (2021) examined how spatial organization affects cognitive processing, showing that correspondence-enhanced concept-map feedback improved attention allocation, integration efficiency, and performance for global text organization, while spatially contiguous feedback was most effective for local cohesion. These results indicate that visual–textual alignment can reduce mental effort and support revision efficiency when matched to task demands. Conversely, adding complexity through multiple modalities can create cognitive interference.

Eye-tracking studies provide converging evidence that strategic feedback system design can enhance cognitive processing mechanisms and learning performance outcomes. In particular, adaptive feedback timing emerges as a critical factor in optimizing learning performance through more effective cognitive resource allocation. Taxipulati and Lu (2021) demonstrated that immediate feedback enabled participants to direct their attention more effectively to feedback content, whereas elaborated feedback elicited deeper cognitive processing, as reflected in greater fixation time and fixation count. Their findings suggest that adaptive timing strategies, such as providing immediate Knowledge of Correct Response (KCR) for accurate responses and Elaborated Feedback (EF) for incorrect responses, may help maximize both performance outcomes and germane cognitive load. These results indicate that the effectiveness of feedback depends not only on its content but also on when and how it is delivered in relation to learners' cognitive processing needs. Metacognitive feedback systems demonstrate significant potential for enhancing learning performance through improved cognitive strategy use. Tsai et al. (2019) showed that eye-tracking-based metacognitive feedback improved learners' scientific reasoning abilities and enhanced their visual attention. Taub and Azevedo (2019) demonstrated that prior knowledge significantly influences how learners process feedback within intelligent tutoring systems. Students with high prior knowledge engaged in sequences containing both accurate cognitive and metacognitive strategies, whereas students with low prior knowledge showed less effective processing patterns, suggesting that feedback systems may need to adapt to learners' existing knowledge levels. Extending beyond traditional approaches, Zhai et al. (2018) showed that biofeedback interventions led to significantly higher reading capacity and improved cognitive taxonomy performance, suggesting that feedback systems incorporating physiological and behavioral data can serve as effective metacognitive tools for recognizing and modifying personalized learning habits.

These findings regarding cognitive domain highlight the importance of aligning feedback design with learners' cognitive processing capabilities. The eye tracking evidence suggests that optimal feedback systems should incorporate adaptive timing, strategic complexity management, and metacognitive support, with eye-tracking data serving as a valuable tool for understanding and optimizing these cognitive processes in educational contexts.

3.2.2 Attention allocation and engagement

Eye-tracking studies demonstrated how feedback attributes systematically affect observable learning behaviors, specifically patterns of attention allocation and engagement measures. Studies using behavioral measures, and more directly interrogating how different feedback strategies affect visual attention distribution, patterns of engagement, and observable learning behaviors, have provided strong evidence in this area.

Eye-tracking studies showed that specific feedback content characteristics such as valence, personalization, and gamification systematically influence how attention is allocated and hence, they have unique visual engagement impacts. To illustrate, feedback valence can change attention distribution and depth of processing. According to Cutumisu et al. (2019), feedback valence or type (critical and confirmatory) significantly impacted where students allocated visual attention and the depth of processing used to assimilate visual information. For instance, students allocated significantly more visual attention to critical feedback compared to confirmatory feedback. The increase in attention was noted through number of fixations, total viewing time, and more revisits to the critical feedback; however, first pass dwell time did not differ between the critical feedback and confirmatory feedback. This means that even though the processing changed depending on the feedback valences or types, the initial processing was fundamentally the same.

Moreover, gamification and performance feedback create distinct attention redirection patterns. For instance, Pi et al. (2024) found that leaderboard rank feedback significantly increased students' dwell time on learning content while simultaneously decreasing the number of fixations on irrelevant blank areas, which indicates an improved attentional focus toward task-relevant information. Eye tracking data demonstrated how competitive elements can strategically guide visual attention toward educational objectives.

Alongside the feedback content, the presentation and design of feedback can also impact attention allocation and learning. Research in attention-accuracy relationships and modality effects in learning contexts has demonstrated the power of design features in feedback practices. Hsu et al. (2018) found that students whose visual attention was directed to important key design areas provided feedback more consistent with expert evaluation. Ritzhaupt et al. (2018) also demonstrated that narrated verbal feedback generated more visual attention directed at organizational pictures than on-screen text feedback, which improved both learner comprehension and learner satisfaction. Thus, both studies emphasize that feedback presentation choices provide helpful evidence that offers support to attention and learning.

Although feedback features and design options provide external influences on attention, learner differences also influence how an individual learner will response and engage with feedback. Learner characteristics act as moderators to attention responses (fixation duration) in comparative feedback contexts. Michinov et al.'s (2015) research demonstrated that high-creative participants in upward comparisons had significantly longer fixation durations on their peers' ideas and subsequently produced more original outcomes, while low-creative participants had no such attention-performance relationships. The finding indicates that an individual's level of creativity relates to the direct visual engagement with the peer-generated content; therefore, feedback systems must consider variability and individual characteristics in addition to design optimization.

On the other hand, eye-tracking research revealed further behavioral challenges regarding the actual use of feedback. Understanding what feedback formats can effectively engage and retain learners becomes crucial for optimizing learning outcomes. For example, Sharma et al. (2019) identified fixation count, saccade duration, and blink presence as reliable behavioral predictors of learning effort and performance, which might enable real-time instructional adjustments.

In collaborative learning environments, feedback engagement becomes more complex due to peer interactions and social dynamics. Peer feedback contexts create distinct processing behaviors based on feedback quality and discrepancy. Van Meenen et al. (2023) showed that discrepant peer feedback prompted extensive gaze transitions and longer fixations, while skilled revisers devoted more attention to higher-order elements and incorporated additional proofreading beyond provided feedback. Hayashi (2020) demonstrated that gaze-aware feedback combined with metacognitive support effectively facilitated collaborative learning processes, optimizing peer coordination and outcomes.

Collectively, the behavioral evidence demonstrates that feedback effectiveness depends not only on content quality but also on strategic attention management and engagement design. These findings suggest that feedback systems should prioritize visual salience, cognitive accessibility, and behavioral scaffolding to bridge the gap between feedback delivery and learning action.

3.2.3 Affective states

Eye-tracking studies revealed valuable links between the feedback and affective state of learners including motivation, self-efficacy, and other emotional experiences. Specifically, three studies focused on examining how specific feedback format or approaches could influence affective outcomes. Studies showed that feedback emotional factors attach great importance when it comes to feedback effectiveness and learning engagement.

Motivational reactions may appear in several forms depending on the type of feedback and participant characteristics. For instance, Kakinuma et al. (2020) presented evidence that ability-oriented praise feedback can occasionally have a negative effect on intrinsic motivation. The study reported that the attentional engagement of the participants decreased with the presence of appraise feedback, which was evident in eye tracker data (i.e., reduced counts of fixation and duration). However, this negative

motivational effect did not appear to diminish self-reported enjoyment indicating a complex effect of motivational feedback.

The study of Sharma et al. (2020) provided strong evidence that gaze behaviours such as content coverage, conceptual and perceptual with-me-ness can fully mediate the relationship between learning and motivation. Eye-tracking data revealed that motivated students not only processed more content but also followed instructions more closely. These results suggest that gaze analytics can be utilized to provide learners with gaze-aware feedback in order to help them regulate their attention allocation.

Beyond detecting motivational states through gaze patterns, researchers have developed systems that actively respond to learners' emotions during the learning process. Lin et al. (2022) investigated an affective tutoring system that combined emotion recognition with intelligent tutoring to transform learners' emotional experiences. The system employed virtual agent feedback that identified and responded to students' emotional states through text-based interaction. Eye-tracking analysis revealed that students using the affective tutoring system demonstrated significantly longer engagement durations with course content compared to traditional tutoring approaches. The study found high system usability and demonstrated that real-time affective feedback mechanisms can effectively improve students' interest in learning by helping them shift from negative to positive emotional states during challenging learning moments.

These findings indicate that eye-tracking technology serves dual roles in affective learning contexts both as a diagnostic tool for detecting learners' motivational and emotional states, and as a mechanism for delivering emotionally responsive feedback. Eye-tracking data provides behavioral indicators of affective states, enabling more emotionally intelligent feedback design that supports learners' motivation and emotional well-being during the learning process.

3.2.4 Instructional skills and teaching quality

Eye-tracking studies provide important insights into teaching quality by making teachers' visual behaviours and attention patterns observable and measurable. Research has emphasized that the use of wearable eye-tracking technologies as training and assessment tools can improve teachers' classroom management skills and support the development of professional vision (e.g., Coskun and Cagiltay, 2021; Schweinberger et al., 2023).

Gaze distribution patterns provide evidence of systematic attention or bias of attention that affect teaching equity. For instance, Cortina et al. (2015) discovered that experienced teachers allocated their visual attention more uniformly among students while sustaining whole-class oversight, even during detailed feedback sessions. In contrast, student teachers tended to concentrate their focus when providing high-quality feedback, potentially overlooking other students. This pattern indicates that expert teachers have developed advanced attention management skills that facilitate simultaneous individual assistance and classroom awareness.

Although eye-tracking studies showed that teachers' attention allocation skills may vary depending on experience, potentially harming educational equity, these biases can be reduced through eye-tracking based feedback practices. For example, Coskun and Cagiltay (2021) demonstrated that instructors' gaze was initially unevenly distributed across students, but eye-tracking and video-based feedback raised their awareness through self-reflection and improved classroom management behaviors. Similarly, Kaminskienė et al. (2023) found that eye-tracking feedback revealed differences between teachers' perceived and actual gaze allocation and triggered critical self-reflection on student engagement and more balanced attention distribution.

Teacher skill development benefits significantly from eye-tracking-based interventions. Schweinberger et al. (2023) demonstrated that eye-tracking-based feedback improved teacher candidates' verbal guidance and moderation skills, indicating that awareness of attention patterns can enhance specific instructional competencies beyond general classroom management.

These findings highlight the transformative potential of eye-tracking technology in teacher professional development, revealing systematic attention patterns that can inform training programs and enhance instructional effectiveness. The evidence suggests that eye-tracking feedback serves as a powerful tool for developing professional vision, promoting self-awareness, and supporting reflective practice across different stages of teaching expertise.

4 Discussion

The integration of eye-tracking technology into higher education represents a significant advance in understanding and improving learning processes. This technology facilitates the transition from traditional assessment methods, such as Likert scales, to more complex and dynamic measurements derived from multiple data sources. Our synthesis of 27 studies presents several key conclusions regarding the relationship between feedback, visual attention and learning outcomes.

4.1 Feedback types and learner responses

The results of the review showed that feedback type has a significant impact on their engagement and cognitive performance. Eye-tracking evidence shows that students devote more attention and time to critical and detailed feedback than to positive reinforcement (e.g., Cutumisu et al., 2019). This finding suggests that constructive criticism not only engages students but also promotes deeper cognitive processing. Furthermore, different types of feedback influence students' motivational and affective states in complex ways. While gaze-aware feedback can support motivation regulation (Sharma et al., 2020), ability-focused praise may sometimes have unintended effects on attentional engagement (Kakinuma et al., 2020). Moreover, eye-tracking based meta-cognitive feedback can facilitate attention, awareness and reasoning skills of learners (Tsai et al. 2019; Zhai et al., 2018). These findings indicate that educators should consider utilizing cognitive, affective and meta-cognitive dimensions when designing feedback strategies, balancing critical content that promotes

deep processing with supportive elements that maintain motivation.

The role of peer feedback in the learning process also deserves attention. While structured peer feedback has been shown to improve learning outcomes (Van Meenen et al., 2023), research indicates that high cognitive load can reduce the benefits of feedback justifications (Berndt et al., 2022). This suggests that the complexity and content of peer feedback must be carefully calibrated to avoid overwhelming students. Educators therefore need to consider the cognitive demands placed on learners when implementing peer feedback mechanisms.

Despite several converging findings, the reviewed literature also reveals some interpretive inconsistencies that warrant attention. For example, Berndt et al. (2018) found that longer gaze durations on peer feedback were negatively associated with text revision performance, suggesting that prolonged visual attention may sometimes indicate cognitive overload or difficulty in processing feedback rather than deeper engagement. By contrast, Bolzer et al. (2015) reported that longer fixation durations were positively associated with feedback recall. These findings should not be interpreted as a direct contradiction, since the two studies examined different outcome variables and differed in task characteristics, feedback complexity, and participant profiles. Rather, they illustrate that similar eye-tracking indicators may have different meanings depending on the learning task, feedback design, and performance measure under investigation. This highlights the need for caution when interpreting fixation duration or gaze time as straightforward indicators of cognitive engagement. Future studies should therefore combine eye-tracking metrics with performance data, learner characteristics, qualitative evidence, and more controlled replication designs to better clarify how learners process and use feedback.

Recent evidence from online eye-tracking research also supports the need for caution when interpreting longer fixation durations or extended visual engagement as indicators of successful learning. In a study with pre-service chemistry teachers from non-science backgrounds, Muna et al. (2025) found that participants required comparatively longer time to observe, read, and solve chemistry problems, yet their problem-solving outcomes remained in the medium and low performance categories. Although this study was based on a very small sample and focused on a specific chemistry problem-solving context, its findings suggest that prolonged visual attention may sometimes reflect processing difficulty, uncertainty, or less efficient problem-solving strategies rather than deeper or more effective cognitive engagement. This reinforces the argument that eye-tracking indicators should be interpreted together with performance data, task characteristics, prior knowledge, and qualitative evidence rather than being treated as direct measures of learning effectiveness.

4.2 Design principles for feedback and learning materials

The review reveals important insights regarding the design of learning materials and feedback presentation. In scenarios where verbal presentations are combined with visual content, students tend to focus predominantly on the visual elements. Conversely, when written text is paired with images, participants show a preference for the textual content. These observations (e.g., Ritzhaupt et al., 2018), highlight the importance of presentation design in capturing students' attention and suggest that educators should strategically balance visual and textual elements to maximise engagement and comprehension.

Eye-tracking studies examining cognitive outcomes further demonstrate that feedback design significantly impacts learners' cognitive load and information processing strategies. Research shows that well-designed feedback can reduce extraneous cognitive load while supporting deeper processing of learning materials (e.g., Berndt et al., 2018, 2022). Additionally, gamification elements in feedback design can strategically redirect attention. Pi et al. (2024) found that leaderboard rank feedback significantly increased students' dwell time on learning content while reducing fixations on irrelevant areas, indicating improved attentional focus toward task-relevant information. Understanding how learners visually process feedback in relation to primary learning content can inform the design of more cognitively efficient feedback mechanisms.

4.3 Implications for higher education and technology-enhanced learning

The findings of this systematic review offer various important implications for higher education settings. First, eye-tracking studies indicate that effective feedback delivery requires attention to timing, modality choices. Studies reveal that narrated verbal feedback directs more attention toward organizational visuals compared to on-screen text feedback (Ritzhaupt et al., 2018), that critical and detailed feedback leads to more cognitive processing time than positive reinforcement (Cutumisu et al., 2019), and that high cognitive load conditions can reduce the benefits of feedback justifications (Berndt et al., 2022). These findings indicate that educators need to carefully consider the balance between modality and complexity in feedback design. This interpretation is also consistent with broader bibliometric evidence on eye-tracking research in science education. Muna and Bahit (2023) emphasized that eye-tracking can provide educators with information about learners' visual attention, focus duration, and potential comprehension difficulties. Although their analysis focused on chemistry learning, their conclusion supports the broader argument that eye-tracking data can inform the development of learning innovations and more adaptive instructional materials. In the context of the present review, this suggests that eye-tracking can help higher education instructors and instructional designers identify when and how learners engage with feedback, where cognitive difficulties emerge, and how feedback presentation can be adapted to support learning.

The review also reveals the importance of individual differences in feedback design. Michinov et al. (2015) demonstrated that learner characteristics moderate attention responses to feedback. For instance, high-creative participants showed significantly longer fixation durations on peer ideas and produced more original outcomes, while low-creative participants showed no such attention-performance relationship.

Similarly, Taub and Azevedo (2019) found that prior knowledge levels influenced how effectively learners processed pedagogical agent feedback. These findings suggest that feedback systems should consider individual learner characteristics rather than adopting one-size-fits-all approaches.

For educational technology developers, the synthesis provides clear design principles emphasizing gaze-aware features that detect learner difficulties and provide just-in-time support. The prevalence of interactive digital platforms in laboratory studies (44.4% of included studies) suggests that authentic learning technologies (e.g., simulations, games, and intelligent tutoring systems) provide ecologically valid contexts for both research and practical implementation. For example, gaze-aware collaborative learning systems can enhance interaction quality by monitoring students' attention distribution (Hayashi, 2020). Future systems may integrate real-time attention tracking to provide adaptive feedback based on learners' gaze patterns. The differences in feedback delivery between experienced and novice teachers further illustrate the importance of teacher expertise in fostering a supportive learning environment (Cortina et al., 2015). Experienced teachers tend to distribute their attention across the classroom, ensuring that all students benefit from the feedback. In contrast, novice teachers often focus on individual students, which may limit the engagement of the rest of the class. This discrepancy highlights the need for targeted professional development to help novice teachers improve their feedback delivery techniques and classroom engagement strategies. For institutions, investing in eye-tracking technologies can support both research and teaching staff development. Research indicates that eye-tracking-based feedback increases the awareness of attention distribution patterns (Coskun and Cagiltay, 2021; Kaminskienė et al., 2023). These findings suggest that this approach can foster more inclusive and equitable teaching practices in higher education.

4.4 Directions for future research

Several gaps in the literature warrant attention in future studies. First, the limited number of studies examining affective and motivational outcomes represents a significant opportunity for further investigation. Future research should place particular emphasis on the affective and motivational dimensions of feedback suggesting that the emotional and motivational dimensions of feedback processing have not yet received sufficient empirical attention. Emerging affective computing approaches that combine eye-tracking with emotion recognition show promise for delivering emotionally responsive feedback (Lin et al., 2022). At the same time, the way in which motivation shapes the visual interaction form of feedback also warrants systematic research. Gaze-aware systems capable of detecting motivational decline could pave the way for timely and personalised interventions. Addressing these gaps will significantly enrich the evidence base and enhance the practical value of eye-tracking research for feedback design in higher education. Second, research conducted in authentic online and blended learning environments is notably scarce, despite the growing prevalence of these modalities in higher education. Future studies should prioritise naturalistic settings to strengthen the ecological validity of eye-tracking research in educational contexts.

5 Limitations

This study has several methodological limitations that should be taken into account when interpreting its findings. First, the literature search was limited to peer-reviewed journal articles indexed in the Web of Science Core Collection and published by selected international academic publishers. This decision was made in order to establish a more transparent, traceable, and quality-controlled corpus for the review process. The rationale behind this choice was that Web of Science-indexed journals have strong international academic visibility, are widely considered in academic evaluation and promotion processes in many countries, and generally follow recognized standards regarding impact factors, publication procedures, and peer-review practices.

Second, the inclusion of English-language publications only constitutes a language-related limitation. Limiting the review to English-language publications was related to the fact that most of the international journals considered in this review publish primarily in English, and that the research team was able to assess English-language academic literature more directly and reliably. However, this choice may have resulted in the exclusion of studies published in other languages, some of which may offer important findings, particularly in national or regional contexts. Consequently, the findings of this review may reflect, to some extent, the countries, institutions, and research traditions that are more strongly represented in English-language academic publishing.

Third, the studies included in this review were highly heterogeneous in terms of research design, sample size, participant profile, feedback type, learning environment, eye-tracking device, gaze metrics, and outcome variables. This diversity made it difficult to conduct direct comparisons across studies or to calculate common effect sizes. For this reason, the review was designed as a thematic synthesis rather than a statistical meta-analysis. While this approach is useful for identifying broad tendencies, conceptual relationships, and methodological patterns in the field, it does not allow the findings to be interpreted as quantitatively generalizable conclusions.

Fourth, the methodological quality and reporting practices of the included studies varied considerably. As shown in Appendix 2, many studies relied on relatively small and homogeneous samples, often recruited from a single discipline, department, or university cohort. In some cases, the number of participants included in the eye-tracking analysis was considerably smaller than the initial sample, which may have reduced statistical power and limited the representativeness of the findings. In addition, several studies focused on specific participant groups, such as psychology undergraduates, pre-service teachers, or students from a single academic domain. These characteristics limit the extent to which the findings can be generalized to broader and more diverse higher education populations.

Fifth, a substantial proportion of the reviewed studies were conducted in controlled laboratory settings, which may limit

the transferability of the findings to authentic higher education contexts. Although laboratory-based studies provide detailed and controlled data on eye movements, attention allocation, and cognitive processing, the behaviours of students and instructors in real classroom, online, blended, or naturalistic learning environments are shaped by more complex social, technological, and contextual factors. Only a limited number of studies were conducted in authentic classroom settings, and relatively few examined feedback processes in naturally occurring online or blended learning environments. Therefore, while the findings offer meaningful evidence regarding the potential of eye-tracking-based feedback practices, they should be interpreted with caution when transferred to real educational settings.

Sixth, the diversity of eye-tracking systems and measurement procedures across the included studies also limits comparability and replicability. The studies used different types of screen-based and mobile eye-tracking devices, with sampling rates ranging from low-frequency systems to high-frequency devices. In some studies, technical specifications were not fully reported, and in others, data loss, calibration issues, manual coding procedures, or participant exclusion affected the final eye-tracking dataset. These variations make it difficult to determine whether differences across studies reflect genuine differences in feedback processing or are partly related to instrumentation, data quality, or analytic procedures.

Finally, some of the reviewed studies used artificial, simulated, or highly task-specific learning situations, such as fictional peer feedback scenarios, short experimental tasks, simulated applications, or game-based environments. Such designs are useful for isolating specific variables and testing causal mechanisms under controlled conditions, but they may not fully reflect the complexity of feedback practices in authentic higher education contexts. Consequently, the conclusions of this review should be understood as evidence-informed tendencies rather than definitive generalizations about the effects of eye-tracking-based feedback practices across all higher education settings.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Author contributions

OA: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review & editing. EE: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. CS-K: Conceptualization, Data curation, Formal analysis, Investigation, Resources, Validation, Visualization, Writing – original draft, Writing – review & editing.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Correction Note

This article has been corrected with minor changes. These changes do not impact the scientific content of the article.

Generative AI statement

The author(s) declared that generative AI was used in the creation of this manuscript. The authors used a large language model (Claude, Sonnet 4.5) and AI-based language tools (Quillbot and DeepL) exclusively for translating, reduction, correcting grammar, spelling, and style to improve readibility. The authors read the last version of the manuscript and agreed on its content All authors take full responsibility for the final version of the manuscript.

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Supplementary material

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