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Gaze sharing: A survey of its applications in education and future directions

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ABSTRACT

Technology-enhanced education can empower instructors and learners. Gaze sharing - the act of sharing information concerning one person's attention with another person, is an emerging practice in technology-enhanced education. Essentially, gaze information is collected from one party (learner/instructor) using an eye tracker then transferred to another party (learner/instructor), typically via readily interpretable visualizations. Gaze sharing has proven to be effective for supporting a diverse range of educational activities in multiple scenarios. Considering this diversity, researchers can benefit from a coherent description of the potential of the technology in pedagogy, to guide its future development and application. With this aim, we report on a PRISMA-style survey of gaze sharing in education, targeted at obtaining a broad perspective on the applications of the technology for pedagogical purposes. Our survey has yielded insights regarding the scope of application of gaze sharing in education, including its benefits, limitations, and underexplored educational domains. Understanding these is key to effectively applying the technology for educational purposes, as well as for developing it further to overcome current challenges. Our findings may be used by researchers who aim to develop better gaze sharing systems, as well as by policy makers and educators who wish to apply current technology for enhancing education, to reap the benefits of gaze sharing and empower learners and instructors.

1. Introduction

Gaze sharing refers to a family of technologies for visualizing information about the attention of one person to another (Fig. 1). This has become possible through advances in eye tracking, enabling us to measure and record our eye movements (Holmqvist et al., 2011), in combination with interactive technologies for sharing such information to others using monitors, head-mounted displays, etc. Over a decade ago, Brennan et al. have demonstrated the potential of sharing gaze information for supporting interpersonal coordination and communication (Brennan et al., 2008). Among its benefits are shortening task completion time (Siirtola et al., 2019), reducing workload and saccadic activity (Atweh & Riggs, 2025), enhancing our sense of perceived social presence (Maurer et al., 2018) and more. Overall, gaze sharing technology has multiple applications in gaming (Maurer et al., 2018; Špakov, Istance, et al., 2019), co-located collaboration (Zhang et al., 2017), remote collaborative work (Bai et al., 2020; Kütt et al., 2019) and education (Kahlon et al., 2023; Schneider et al., 2025; Sung et al., 2021).

When applied in educational settings, gaze sharing was shown to enhance engagement (He et al., 2021), help instructors guide their learners (Yao et al., 2018a), and shorten conversation time (Hu et al., 2023). Further, gaze sharing was found effective for education in a wide range of scenarios, from one-on-one teaching (Schneider et al., 2025) and up to group discussion scenarios (Langner et al., 2022). These reflect the potential of this technology to support instructors and learners in educational activities.

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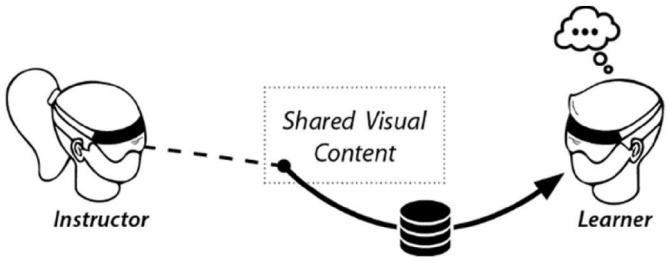

Fig. 1. A basic scenario of gaze sharing (instructor's focus of visual attention is sent to a learner).

The potential of gaze sharing systems as a pedagogical aid can be further understood through a theoretical lens, by considering its link with joint attention - the ability of an individual to coordinate their attention with others (Kaplan & Hafner, 2006). Interestingly, joint attention plays a critical role in human learning, due to various reasons. Among these are its importance for the development of essential cognitive abilities, e.g. language acquisition (Moore & Dunham, 1995), as well as its importance for social activity in a broader sense (Mundy & Acra, 2006). According to social learning theory, humans acquire new behaviors, skill or abilities through the observation of other (Bandura & Walters, 1977). While there are multiple interpretations for this theory in the literature, the principle which underpins it is the following - learning processes should be understood by looking beyond individual learners, and considering the social network of interacting actors that facilitate them (Reed et al., 2010), i.e. as process that pivots on an interactive exchange between several parties. Establishing joint attention requires humans to perceptually "pick up" information (Neisser, 1976) concerning a conversation partner's current focus, which then facilitates further interaction (Kidwell & Zimmerman, 2007). Therefore, the extent to which we are successful in establishing joint attention has implications for the quality of interpersonal communication, and thus for teaching and learning.

Furthermore, the utility of gaze sharing may also be understood via reference to cognitive load theory, which stipulates that limitations on the human working memory serve as a bottleneck for learning (Sweller, 2024). As high levels of cognitive load (burden on working memory) may be counterproductive for learning (Zeng et al., 2025), it is desirable to decrease it by controlling cognitive resource allocation, which correlates with the instructional format (Bannert, 2002). As mentioned above, gaze sharing can help streamline communication by reducing the need for gesturing, disambiguating references, etc., which can release mental resources that are critical for learning (Atweh & Riggs, 2025).

Although general surveys of gaze sharing are available (D'Angelo & Schneider, 2021), we lack an understanding of its overall contribution and limitations in educational scenarios. Addressing this, we report on a PRISMA-style survey of academic literature at the intersection of gaze sharing and education. By surveying three relevant online sources (Web of Science Core Collection, Science Direct and ACM Digital Library), we identify a diverse set of scenarios in which gaze sharing was applied for supporting educational activities, and its benefits and limitations in each. The findings of this study highlight opportunities for expanding the application of current technology, as well as for further development of future gaze sharing systems, to support education. The overarching research question addressed in this study is - how can we use gaze sharing for education? To answer it, three sub-questions were phrased, given in Table 1. The answers to these questions, which shed light on past development of gaze sharing in education, provided the basis for extrapolating regarding future trends, reported in the discussion section.

Table 1
Research questions addressed in this study.

ID	Research Question
RQ1	In what **educational contexts** is gaze sharing being used?
RQ2	What **kinds of gaze sharing systems** are being used in education?
RQ3	What are the **benefits and limitations** of gaze sharing in education

2. Background

2.1. Gaze sharing in education

Eye tracking technology enables to measure and record human eye movements (i.e., fixations, saccades), which provide information regarding attentional states (Holmqvist et al., 2011). Recorded information can be visualized in various ways, to facilitate its interpretation and usage for different purposes. For example, gaze behavior can be visualized as a general heatmap (which can show the distribution of attention), by marking a specific object (which can point to a specific item that is being focused on) (Stellmach et al., 2010) or even as a scatterplot (which can help identify patterns in gaze behavior) (Shantharam et al., 2024). Sharing such visualizations regarding the gaze of one person with another ("gaze sharing") can enhance communication and collaboration. For example, in a pioneering study, Brennan et al. have shown the potential of gaze sharing for coordinating participants engaging in collaborative search task and shortening the task completion time (Brennan et al., 2008). Note that gaze sharing systems can support unidirectional sharing of attentional information (Akkil et al., 2018) or bidirectional sharing (Špakov, Niehorster, et al., 2019). Also note that, with respect to gaze sharing, researchers are exploring a diverse set of applications, including the facilitation of group discussions (He et al., 2021), supporting remote collaboration (Jing et al., 2022) and more.

Considering the growing interest in technology-enhanced education (Bryson et al., 2025; Kirupainayagam & Sutha, 2022; Molabe et al., 2024; Qiu et al., 2021), researchers are also striving to understand the potential of gaze sharing as an aid for facilitating communication between learners and instructors in pedagogical scenarios (Schneider et al., 2025). Fig. 2 shows two typical scenarios of gaze sharing in education. In one, gaze information is collected from a learner at one location then sent to an instructor found at another location, who reads it from a computer monitor (Fig. 2, left). In another, gaze information is collected from a learner during one point in time (when engaged in an educational task) then shared with an instructor "offline", by visualizing patterns of eye movements in the form of heatmaps, etc. (Fig. 2 right). Note that, as the number of participants, equipment used and direction of sharing gaze information may vary, these scenarios are illustrative rather than exhaustive.

To date, the usage of gaze sharing for enhancing education has been approached from a diverse set of perspectives, including its implementation in co-located (Ramnauth et al., 2025) vs. remote (Langner et al., 2022) educational settings, in synchronous (Mahanama et al., 2023) or asynchronous (Špakov et al., 2017) modes of delivery, in one-to-one (Sung et al., 2021) vs. group settings (Yao et al., 2018b) and more. To understand how gaze sharing can be applied in education, it is important to synthesize current studies and uncover the unity underlying the diversity in the field.

2.2. Related literature reviews

Related review papers, which may be of interest to researchers focusing on gaze sharing in education, can be divided into several main categories. We provide a concise overview of such surveys, and highlight their potential relevance for the development of gaze sharing systems in pedagogical settings. Here, we refer to surveys that are directly related to gaze sharing as well as to reviews that are indirectly related.

First, reviews that discuss the general applications of gaze analysis may be inspiring for extending gaze sharing practices (Lei et al., 2024), and especially when focusing on interactive applications (Bisogni et al., 2024). These can be complemented by surveys of gaze visualizations

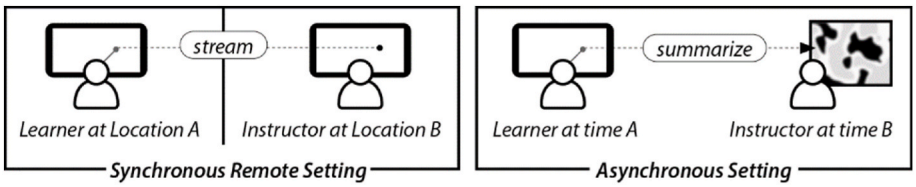

Fig. 2. Two typical scenarios of gaze sharing: left - gaze is recorded and immediately visualized at another location on a computer display; right - gaze is visualized as a heatmap for later use (in both, gaze is shared unidirectionally, for simplicity).

(Zhang et al., 2023), which play an important role in various types of gaze-based interactions, including gaze sharing. Similarly, reviews focusing on the application of eye tracking in other contexts such as computer programming (Obaidellah et al., 2019), can be informative for supporting real-time collaboration on coding in educational scenarios, reviews which focus on medical contexts may be informative for researchers who wish to employ gaze sharing in medical training, etc.

Second, surveys of technology-facilitated collaboration (Wang et al., 2021) may also be of importance to researchers interested in gaze sharing. For example, a review of multi-participant remote collaboration systems (Schäfer et al., 2023) can inform us regarding the potential of gaze sharing in remote scenarios where multiple learners interact, etc. Note that, works which focus specifically on user needs in such scenarios are available as well (Pfeil et al., 2021; Radu et al., 2021).

Third, works which have reviewed gaze metrics may also be of use for the evaluation of gaze sharing technology (Causer et al., 2013). Additionally, reviews of empirical data concerning related behaviors, such as leading vs. following (J. T. Cheng et al., 2023), can help us select metrics for measuring the impact of gaze sharing in education which go beyond standard pedagogical indicators, such as learning outcomes, etc. Notably, reviews which synthesize empirical data concerning our understanding of joint attention in educational scenarios (Schneider, 2025), which is an essential aspect of gaze sharing, are extremely valuable in determining how to measure such behaviors, especially when linked with pedagogical constructs. Note, however, that while the above study reports on the *analysis* of shared attention, our study focuses on the *facilitation* of shared attention in such context, via technological means.

Finally, surveys focusing directly on gaze sharing deal with specific interactive scenarios (e.g., when participants interact in extended reality while being co-present; Hays et al., 2022) or with its general applications (D'Angelo & Schneider, 2021). However, we lack a unified understanding regarding the range of applications of the technology and its potential benefits for *pedagogy*. Therefore, we have executed a literature review in this context, to support researchers in navigating the sub-field of gaze sharing in education. This article provides readers with an overview of the current applications of gaze sharing in pedagogy, and charts potential future paths for the development of this technology, to better support instructors and learners and enhance education.

2.3. Gaze sharing as a form of technology-enhanced communication and learning

The application of gaze sharing in education is motivated by several factors, which can be understood via two lenses: that of technology-enhanced learning, and that of computer-mediated communication (Fig. 3). Both viewpoints are considered hereafter.

Technology-enhanced learning, i.e. the usage of technological means to support learners and instructors, is becoming increasingly important in pedagogy (Duterte, 2024). Past work on technology-enhanced learning has demonstrated its potential benefits, e.g. in promoting active learning (Clark et al., 2007), as driver of innovation in pedagogy (Laurillard, 2008), or in boosting academic achievements among engaged learners (Dunn & Kennedy, 2019). As a practice which relies on technological means for supporting instructors and learners, gaze

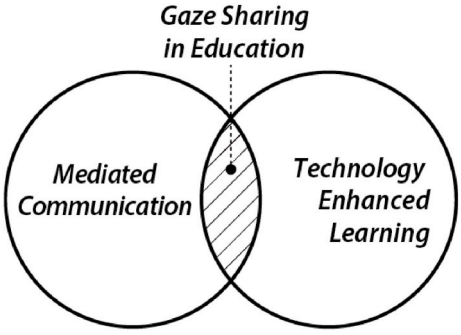

Fig. 3. Understanding gaze sharing in education via two lenses.

sharing can be seen as a form of technology-enhanced learning, in which communication is supported through digital means.

From the viewpoint of communication theory, gaze sharing can also be seen as a form of technology-mediated communication, i.e. the channeling of communication through electronic media (McQuail, 2010). As explained by Whittaker (2003, p. 35):

- technologies that facilitate sharing of visual content are helpful in tasks that involve complex referencing to objects or their physical manipulation
- for tasks that emphasize affect or attitude, transmission of visual information concerning gaze can be vital

Considering the important role of affect in learning (Linnenbrink, 2007), gaze sharing technology can aid communication in any educational discipline that involves complex visual referencing (keeping in mind that the introduction of new material is often accompanied by visual aids which are constantly referred to, such as slides, etc.). Furthermore, any discipline that involves the creation or assembly of objects (e.g., design, engineering etc.) is included within this group as well. Therefore, gaze sharing is potentially useful for mediating communication in a considerable number of pedagogical scenarios.

3. Method

A PRISMA-style literature review was executed, with the aim of answering our three research questions (RQ1, RQ2, and RQ3). Then, the results obtained from the review were used to extrapolate regarding potential future development of gaze sharing technology in education. PRISMA is an approach for executing literature reviews that helps to bring coherence and structure to surveys of academic literature through the specification of essential reporting items (Page et al., 2021). This approach has already been employed for executing surveys concerning topics at the intersection of education and technology (Debets et al., 2025; Díaz & Nussbaum, 2024; Mendoza-Chan & Pee, 2024).

As we aim to understand the potential of gaze sharing for supporting education, we set out to identify papers which report on the application of this technology in pedagogical contexts. Note that, rather than aiming for an exhaustive review of the literature, we strived to obtain a broad perspective of the various applications of the technology and the lessons

learned. Therefore, we have retrieved related articles from three different sources (Table 2), using the following search string: *("gaze sharing" OR "shared gaze" OR "shared-gaze" OR "mutual gaze perception")* ***AND*** *(education OR pedagogy OR learning OR teaching)*. This resulted in a total of 284 records for screening, determination of eligibility and selection, as explained below.

3.1. Paper selection

The complete set of records retrieved was initially searched for duplicate items, and these were removed (N = 13). Additionally, items that were not research papers (such as workshop proposals, abstracts, etc.; N = 17) or review papers (N = 14) were removed as well. Next, papers were screened by reading their abstracts (or, in cases of ambiguity in the abstract, by consulting the full text of the paper). In this, the following inclusion criteria were employed:

(1) the paper discusses gaze sharing (regardless of method/implementation/domain)
(2) the purpose of discussing gaze sharing is to support education (at least one learner/instructor is indicated as the target user)

Items that did not satisfy both criteria were then removed from the study (N = 224). For example, certain studies use the phrase "shared gaze" when referring to the ability to gaze at an object along with another individual, and are not concerned with sharing gaze information via technological means, e.g. Venkataraman (2019). Similarly, some papers focus on analyzing gaze behavior in dual eye tracking settings, yet the gaze is not shared among the participants, e.g., Bednarik et al. (2018).

Finally, to confirm the eligibility of the remaining items (N = 30) we read the content of each paper and verified that it reports on the development of gaze sharing technology, and two items were removed. This resulted in a set of (N = 28) records for a detailed review (Fig. 4).

3.2. Classification and synthesis

Classification and synthesis were done in several stages of: (A) team classification, (B) synthesis of results within teams, (C) synthesis of results across teams, and (D) visualization and identification of research gaps.

The procedures in stages A and B were devised to minimize the effect of bias on classification results, following the methodology developed by Ucci et al. (2015). Selected items were first reviewed by a small team of four members. All four reviewers are educators as well as researchers, and are experienced in developing interactive/computational systems for a wide range of applications, including architectural and urban design, pedagogy and more. Furthermore, all reviewers are familiar with eye tracking technology and have used it several times in the context of academic research. The reviewers were split into two teams consisting of two members each, according to members' geographic location (GMT; to minimize time-differences and ease communication). Each team reviewed exactly half of the records (N = 14).

In **stage A**, the complete set of records assigned to each team was reviewed independently by both team members, each record was classified by multiple criteria, and key information was extracted. The classification system used for this stage (Table 3) was constructed in order to collect the essential information for answering our three research questions: concerning the educational setting (RQ1), concerning the type of gaze sharing system employed (RQ2) and concerning the results of the study (RQ3).

Note that certain papers included multiple implementations of different systems. When reviewing these, each system was examined individually and treated as a single case. In **stage B**, each team convened to compare members' results, resolved intra-team differences via discussion and merged them into a single result. In **stage C**, inter-team differences regarding the classification system were resolved by adding missing criteria or removing redundant ones, and the classification system was finalized and applied to all selected papers based on the results produced by both teams. Finally, in **stage D**, the results were visualized, research gaps were identified, and the first three research questions were answered. Based on these, conclusions were derived for the future research and development of gaze sharing systems for education.

Table 2
Sources and search results prior to screening and selection (search conducted on June 2nd, 2025).

Source	No. of Search Results
ACM Digital Library	157
Science Direct	98
Web of Science (Core Collection)	29
Total Records	**284**

4. Results

The main results of our analysis are presented in three sub-sections, in accordance with our three research questions, focusing on the portion of the selected papers which included the implementation of a system for gaze sharing (4.1, 4.2, 4.3). Each subsection concludes with a visual synthesis of the findings in the form of a tree, which provides an overview of the various considerations in current work on gaze sharing in education. Finally, we provide a concise presentation of the papers which only reported on a proposal for a computational system that was not yet implemented, and could inspire future development of this technology (4.4). Note that approximately three quarters of the papers included an implementation of a computational system for supporting gaze sharing (N = 22, 78.5%). Among these, 25 implemented systems were identified in total. Also note that all implemented systems but one were empirically evaluated (i.e., 95.5% out of the implemented systems were also evaluated).

4.1. RQ1 - In what educational contexts is gaze sharing is being used?

To answer RQ1, we have extracted key information concerning the educational context in which each system was used, including the type of pedagogical usage (academic/non-academic), the academic level (where applicable), the task studied, the discipline, the setting (synchronous/asynchronous), the mode of delivery (co-located/remote), and the number of participants involved. A decomposition of the pedagogical scenarios in which the technology was applied is provided in Fig. 5.

4.1.1. Type of pedagogical usage and discipline

The majority of systems were developed for usage in an academic setting (N = 19, 84%). Among the rest of the systems, one targeted a task performed at home outside of any formal educational framework (Ramnauth et al., 2025), a few involved a task which is not academic in nature, e.g. making a sandwich (Andrist et al., 2017) or did not specify where instruction takes place (Akkil et al., 2018). Further, within the group of systems focusing on academic settings, most cases targeted higher-education (N = 15, 78.9%), while the rest (N = 4, 21.1%) targeted special education for children (Dæhlen et al., 2024) or teaching basic literacy skills (Śpakov et al., 2017) (Fig. 6).

Within the portion of papers focusing on academic settings, the disciplines in which gaze sharing was tested were also identified. Papers focusing on teaching scientific content, such as neuroscience (Schneider & Pea, 2013) or biochemistry (Darbar et al., 2024) made up for almost half of the population (N = 9, 47.7%). These were followed by papers teaching multidisciplinary content such as Human-Computer Interaction (HCI) and those focusing on special education (N = 3 in each,

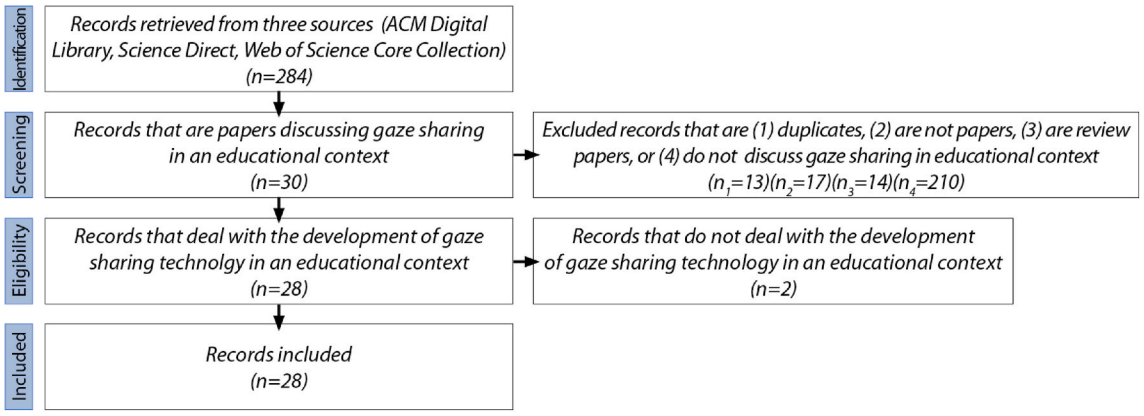

Fig. 4. Information flow in paper selection.

Table 3
Classification criteria employed and information extracted at team review stage.

Research Question	Criteria	Explanation/Comment
RQ1	Task studied	The educational activity supported by gaze sharing
	Discipline	The discipline of the content being taught/ learned
	Mode of delivery	Synchronous/asynchronous
	Setting	Co-located/remote
	No. of Participants	How many learners/instructors are using the system
RQ2	Mobility	Are users static (e.g. seated) or mobile during the task?
	Sharing direction	Gaze sharing is unidirectional/bidirectional/ other
	Equipment	The device used to display gaze information (screen, HMD)
	Immersion	Is the system immersive? (uses Extended Reality, XR)
	Kind of XR used	Virtual Reality (VR), Augmented Reality etc.; If applicable
RQ3	Hypothesis	With respect of the impact of gaze sharing on education
	Type of study	With respect to method (quantitative/ qualitative/mixed)
	Findings	Key results of the study
	Effect sizes	If reported

15.8%). Additionally, two papers have focused on teaching engineering-related content, such as assembling a microcontroller (Sung et al., 2021). Finally, one paper focusing on teaching literacy skills (reading) (Špakov et al., 2017) and one focusing on teaching design (Kahlon et al., 2024) were identified (Table 4).

4.1.2. Educational setting, mode of delivery and participants

With respect to the educational setting, most systems focused on gaze sharing in a synchronous setting (N = 17, 68%). In these, learners interact with instructors or with other learners (or both), in real-time. For example, an instructor supporting a learner in editing software code (Yang et al., 2023), or holding a discussion among learners concerning biochemistry (Darbar et al., 2024). The rest of the systems (N = 8, 32%) focused on education in asynchronous settings. Here, gaze data was generally pre-recorded from an instructor and then displayed to a learner (Bednarik et al., 2018; Kim et al., 2022). Conversely, gaze data was also recorded from learners then shown to an instructor, to inform them regarding learners' progress (Dæhlen et al., 2024).

Out of the studies focusing on synchronous settings, the majority of papers explored scenarios of remote communication (N = 11, 64.7%), e.g. developing a collaborative gaze sharing system for learning to review computer code (S. Cheng et al., 2022). A few papers focused on co-located scenarios, i.e. where participants are found in the same physical environment (N = 2, 11.8%), e.g. a one-on-one discussion between a learner and an instructor concerning architectural design principles (Kahlon et al., 2024). The rest of the papers exploring communication in synchronous settings focused on interaction between a human being and a digital agent (rendering the remote/co-located distinction irrelevant). Concerning the number of learners and instructors participating in each task, the majority of papers focused on one-to-one meetings (N = 13, 86.7%) either between two learners (Mahanama et al., 2023) or between one learner and one instructor (Ramnauth et al., 2025). The rest of the systems were designed for multi-participant scenarios, allowing up to eight participants (Bednarik et al., 2018). In all cases, the maximal number of instructors was one. Note that in asynchronous settings, participants join the activity at different times, which renders the participant count irrelevant, especially with respect to instructors. For example, the study by Špakov et al. (2017) reported on recording gaze information captured from a learner practicing their reading skills, then using it to inform an instructor regarding learners' performance. As the data was pre-recorded, it could be distributed and shared with any number of instructors (Fig. 7).

4.1.3. Tasks supported

Concerning the educational task supported by gaze sharing, six different tasks were identified (Table 5). For clarity, by "educational task" we refer to the activity which learners are engaged in. Evidently, most systems were developed to support learners participating in a lecture (N = 8, 32%), typically by overlaying the gaze of the instructor onto presentation slides (Kim et al., 2022). This category was followed by systems that support activities involving the assembly of physical or virtual parts, in different scenarios (N = 7, 28%). For instance, in the study by Sung et al. an instructor supported a learner in assembling a microcontroller (Sung et al., 2021), while in Andrist et al. the instructed person was tasked with preparing a sandwich (Andrist et al., 2017). Next were systems that focused on supporting reading activity (N = 4, 16%), and primarily dealt with reading textual information, e.g., in coding (S. Cheng et al., 2022) or in language training (Špakov et al., 2017). Note, however, that a scenario of reading and interpreting diagrams in the context of neuroscience was included as well (Schneider & Pea, 2013). Discursive activity was also supported by gaze sharing (N = 2, 8%), including a system for domain-specific discussion in the context of biochemistry (Darbar et al., 2024) and a system for general meetings among learners in the context of higher education (Langner et al., 2022). In several studies, the educational task focused on learning to gaze, commonly in cases of children with Autism Spectrum Disorder (ASD) who may need support to develop the ability to gaze at objects along with their conversation partner (Ramnauth et al., 2025). Finally, coding activity was supported by one study, focusing on collaborative

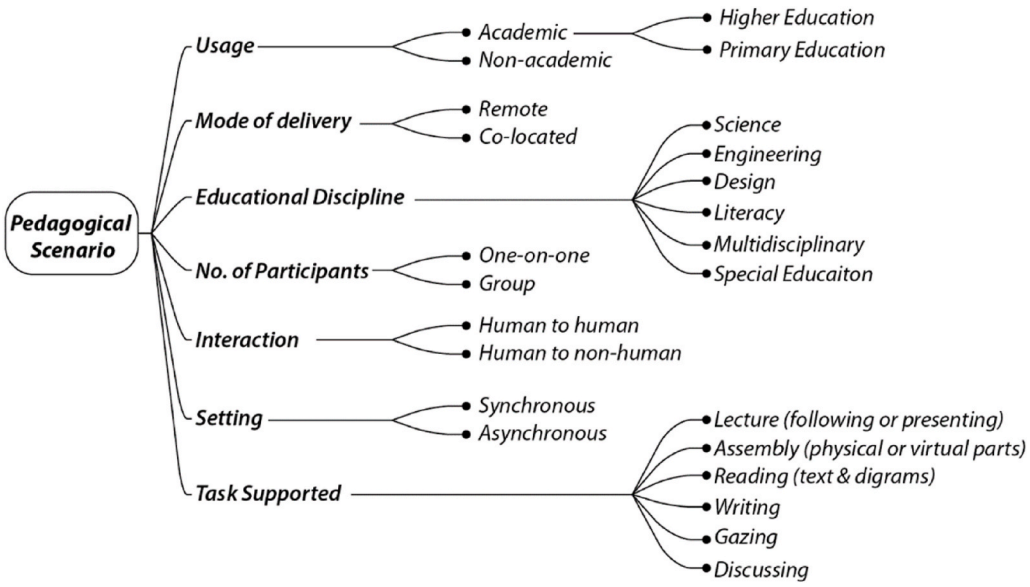

Fig. 5. In what educational contexts is gaze sharing being used.?.

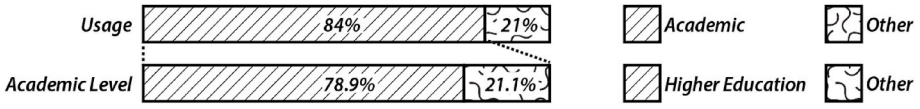

Fig. 6. Usage of gaze sharing for educational purposes.

Table 4
Educational disciplines in which gaze sharing was tested.

Educational Discipline	Portion of Papers Focusing on an Academic Setting (%)
Science	47.7%
Special Education	15.8%
Multidisciplinary	15.8%
Engineering	10.5%
Literacy	5.3%
Design	5.3%

synchronous code writing in software development (Yang et al., 2023).

4.2. RQ2 - What kinds of gaze sharing systems are being used in education?

To answer RQ2, we have extracted key information concerning the type of gaze sharing system/s utilized in each paper, including the direction of sharing gaze information, users' mobility, the means of gaze visualization and the parties involved. An overview of the factors extracted is given in Fig. 8. The results of this subsection are presented hereafter in 4.2.1 and 4.2.2.

4.2.1. Device, content delivery and involved parties

In most cases, gaze was displayed using a computer monitor (N = 20, 80%), while in some cases a head-mounted display (HMD) was used. The latter group represents studies that involve gaze sharing in an immersive environment (N = 5, 20%). Out of these, four papers implemented gaze sharing using Virtual Reality (VR) technology, e.g. Darbar et al. (2024),

Table 5
The task supported by gaze sharing.

Task Supported	Portion of Surveyed Studies (%)
Lecture	32%
Assembly	28%
Reading	16%
Gazing	12%
Discussion	8%
Coding	4%

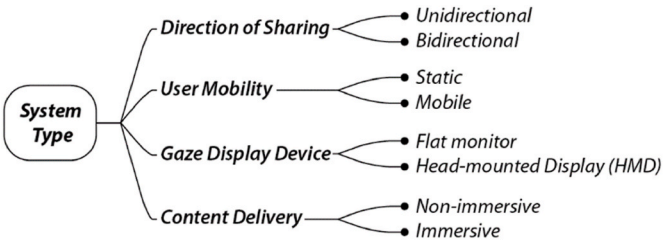

Fig. 8. Device and content delivery.

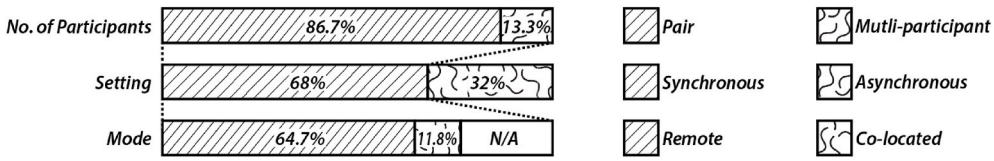

Fig. 7. The mode of delivery and setting in which gaze sharing was used, and the number of participants.

and one paper has used Mixed Reality (MR) technology (Kahlon et al., 2024). Note that, in one study, two similar systems in immersive and non-immersive settings were examined (Andrist et al., 2017).

Further, concerning the parties involved in gaze sharing, most of the studies consisted of sharing gaze information among human participants (N = 19, 76%). Yet, several studies involved gaze sharing among a human being and a non-human agent. For example, Amat et al. have proposed an assistive avatar to help children with ASD improve gaze perception (Amat et al., 2018). Similarly, the work by Darbar et al. (mentioned earlier) reported on two experiments, one of which involved sharing the gaze of a pre-recorded instructor, who was displayed as an avatar (Darbar et al., 2024). While the former involved displaying the avatar as a 2D figure on a computer monitor, the latter included an embodied virtual agent representing the instructor in 3D (Fig. 9).

4.2.2. Gaze sharing direction and users' mobility

Both unidirectional systems (sharing gaze information from party A to B) and bidirectional systems (sharing gaze information both from A to B and from B to A) were explored. For example, Kim et al. have supported online learning by sharing the instructor's recorded gaze with learners (Kim et al., 2022), while Langner et al. have facilitated a remote discussion among learners by mutually sharing their gaze online (Langner et al., 2022). Notice that the number of papers exploring the former category (N = 13, 52%) is almost equal to those exploring the latter (N = 12, 48%). Furthermore, considering that gaze can be measured while users are static or mobile, and that this requires different types of equipment etc., we have examined the distribution of papers with respect to users' mobility. Notably, most of the systems surveyed (N = 22, 88%) focused on scenarios where gaze is being measured from a static user. For instance, both of the above-mentioned studies by Kim et al. and Langner et al. fall into this category. By contrast, several studies did explore gaze sharing among mobile users. For instance, in one of the first examples of using dual mobile eye trackers for gaze sharing among a learner and an instructor, Sung et al. have examined its potential to enhance the process of learning to assemble a microcontroller in a remote scenario (Sung et al., 2021).

4.3. RQ3 - What are the benefits and limitations of gaze sharing in education?

To answer RQ3, we have extracted key information concerning current empirical evidence for the effectiveness of gaze sharing in education, including the hypothesis, the methodology employed to examine it (qualitative/quantitative/mixed methods), the key findings and the main limitations. Overall, all implemented systems but one were empirically evaluated (24/25, 95.5%). Among the papers which empirically evaluated the proposed system, the smallest subgroup included systems that were evaluated by using a qualitative approach (N = 2, 8.3%), followed by those which employed a quantitative approach, that composed a third of the total (N = 8, 33.3%). Almost two thirds of the systems were evaluated using a mixed methods approach (N = 14, 58.3%). Note that, among all cases in which a quantitative approach was employed (N = 14 + 8 = 22), approximately a third included the effect size (N = 8, 36.6%).

The rest of this section is organized as follows. First, we describe the hypotheses concerning the application of gaze sharing in education across the spectrum of tasks supported (4.3.1). Then, we organize the primary findings from current studies according to the two settings in which gaze sharing can be used – synchronous and asynchronous settings, and address each in a separate subsection (4.3.2 and 4.3.3, accordingly). We conclude this subsection by providing an overview of the purposes of applying of gaze sharing technology in education (4.3.4).

4.3.1. Hypotheses explored concerning the effects of gaze sharing in educational contexts

The studies surveyed are organized in Table 6, according to the task addressed and the hypothesis examined (where applicable). Overall, three kinds of hypotheses were identified – those regarding the effectiveness of a specific gaze sharing technique on education, those concerning the superiority of one gaze sharing technique over others (including the comparison with other attention-sharing techniques, such as using a mouse pointer, etc.), and those concerning the acceptance of this technology by its users.

Concerning tasks of assembly, all studies focused on synchronous settings. In these, one study examined the possibility of using remote gaze sharing to increase learning gains (Sung et al., 2021). Further, other studies hypothesized that it will improve coordination among learners and instructors in various online scenarios, such as in collaboration among multiple learners (Mahanama et al., 2023) or when one learner communicates with one instructor (Akkil et al., 2018). Finally, one study examined the hypothesis that gaze sharing can support instruction by improving coordination between a human learner a virtual avatar instructor (Andrist et al., 2017).

With respect to supporting lecture delivery, gaze sharing in synchronous settings was assumed useful in aiding instructors to identify difficulties among learners (Špakov, Niehorster, et al., 2019). Additionally, it was hypothesized that instructors and learners in such settings may demonstrate different levels of acceptance (Kahlon et al., 2024), as well as that gaze sharing would be preferred over other types of pointers in presentations (Špakov et al., 2016). Studies that focused on lecture delivery in asynchronous settings have examined the hypothesis that this technology can improve users' experience (UX) among learners (Wagner et al., 2023), increase the sense of presence (Kim et al., 2022), and may be superior to only showing the instructors' face (Schneider & Sung, 2024). Additionally, one study hypothesized that the mode of visualization employed when sharing recorded gaze information from an instructor is related with perceived workload, and examined multiple visual representation of gaze information (Darbar et al., 2024). Interestingly, historical data from peers' learning journey was also examined with respect to its potential to support learners in these settings (Xu et al., 2025).

With respect to supporting discussion in pedagogical contexts, both related studies have focused on a synchronous setting. Among these, one study hypothesized that gaze sharing can improve focus when holding online discussions among learners (Langner et al., 2022). The other study examined the hypothesis that gaze sharing technology will be accepted by learners as a means for improving their experience of live discussions with peers, as indicated by the perceived contribution to the mutual understanding of references, awareness of visual attention, etc. (Darbar et al., 2024).

Works focusing on the usage of gaze sharing for improving gazing skills among humans examined two hypotheses. In a synchronous setting, it was hypothesized that an assistive avatar can enhance joint

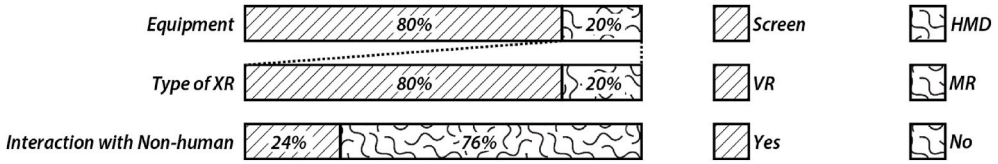

Fig. 9. Device, content delivery and involved parties.

Table 6
Overview of hypotheses examined concerning gaze sharing across tasks.

Supported Activity	Surveyed Work	Hypotheses (gaze sharing may…)																	
		help coordinate multiple learners	help coordinate learners & instructors	help coordinate humans & avatars	increase learning gains	help instructors identify issues	be accepted as a presentation aid	be accepted differently (learn./instruct.)	improve learners' UX in online settings	increase sense of presence	related with perceived workload	help learners learn from peers	be superior to showing instructors' face	improve quality of collaboration	be accepted as a tool for collaboration	assist text comprehension	assess learner' s skills	improve gaze in neurodiverse individuals	be affected by the task
Assembly	(Akkil et al., 2018)[S]	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	(Sung et al., 2021)[S]	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	(Mahanama et al., 2023)[S]	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Lecture	(Špakov et al., 2016)[S]	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-
	(Andrist et al., 2017)[S]	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	(Špakov, Niehorster, et al.,	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-
	(Kim et al., 2022)[A]	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-
	(Wagner et al., 2023)[A]	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-
	(Darbar et al., 2024) [A]	-	-	-	-	-	-	-	-	-	x	-	-	x	-	-	-	-	-
	(Kahlon et al., 2024)[S]	-	-	-	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-
	(Schneider & Sung, 2024)[A]	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-
	(Schneider et al., 2025)[A]	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	(Xu et al., 2025)[A]	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-	-	-
Reading	(Schneider & Pea, 2013)[S]	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-	-
	(Špakov et al., 2017)[A]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-
	(Bednarik et al., 2018)[A]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-
	(S. Cheng et al., 2022)[S]	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-	-	-
Gazing	(Amat et al., 2018)[S]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-
	(Dæhlen et al., 2024)[A]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-	-
	(Ramnauth et al., 2025)[A]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x	-
Coding	(Yang et al., 2023) [A]	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	(Deitelhoff, 2018)[A]*	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	(Deitelhoff & Harrer, 2018)[A]*	-	-	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Discussion	(Langner et al., 2022) [A]	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	(Szwoch, 2024)[B]*	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surgery	(Popov et al., 2022)[A]*	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
	(Popov et al., 2024)[A] *	-	x	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
N/A	(D'Angelo, 2017)[N]*	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	x

Mode: S = synchronous, A =asynchronous, B=both, N= unspecified; *Implementation not included

attention capabilities among children with ASD (Amat et al., 2018). In an asynchronous setting, researchers have hypothesized that gaze information collected from children with a potential neurodevelopmental disorder can help instructors identify issues and cater to their needs (Dæhlen et al., 2024).

Regarding works that focus on supporting reading activity using gaze sharing, one study hypothesized that gaze sharing can increase the quality of collaboration on a reading task, as indicated by shared attention (Schneider & Pea, 2013). Additionally, a study focusing on such activities in asynchronous settings hypothesized that sharing learners' gaze information with instructors can help the latter with assessing literacy skills (Špakov et al., 2017).

Finally, in several studies which employed gaze sharing for supporting coding-related activities in a synchronous setting, researched have examined the hypothesis that this technology will be found helpful by novice learners in collaborative code review (S. Cheng et al., 2022), or that gaze sharing will improve learning gains when remotely editing code in a synchronous setting (Yang et al., 2023). Relatedly, using recorded gaze data as a model for learners was hypothesized to be effective for teaching code comprehension skills (Bednarik et al., 2018).

4.3.2. *Benefits and limitations of gaze sharing in synchronous settings*

With respect to the utilization of gaze sharing for supporting synchronous learning, researchers have identified various benefits as well as limitations, as described hereafter. First, studies exploring the usefulness of gaze sharing for enhancing synchronous lectures have reported on several findings both in co-located and in remote scenarios. In co-located scenarios, a gaze pointer used as a visual aid for lecturing was rated as easily identifiable, when compared with a laser pointer (Špakov et al., 2016). Additionally, both learners and instructors expressed interest in continuing to use the technology beyond the experimental session, implying at its potential for acceptance among users (Kahlon et al., 2024). In a remote setting, instructors have found the technology useful in informing them about visual attention among learners in one-to-one interactions. On the negative side, in remote teaching, learners have found gaze pointers distracting when attempting to read

text on lecture slides (Špakov, Niehorster, et al., 2019). Further, in a co-located setting, learners have found gaze sharing technology more difficult to use than did instructors, despite the fact that no technical operation was required, as gaze was automatically continuously displayed (Kahlon et al., 2024).

Second, studies focusing on using gaze sharing to support reading activity have found it beneficial for facilitating better collaboration among leaners (in collaborative search for code bugs), reflected not only in performance but also in the subjective positive feedback collected from its users (S. Cheng et al., 2022). Similar findings concerning enhancing collaborative activity were reported by Schneider and Pea, who have also highlighted a relative increase in learning gains in a gaze sharing condition (Schneider & Pea, 2013).

Third, studies which have examined the impact of gaze sharing on assembly tasks have reported on several useful findings, both when the technology was used for supporting interaction among human participants, and when utilized to facilitate better communication between a human and an avatar. In instructional scenarios that did not involve avatars, one study reported that instructors have preferred to not see their own gaze during remote instruction, despite the fact that task performance in this condition was similar to another condition in which their gaze was visible, implying on the impact of certain modes of display on users' experience (Akkil et al., 2018). In another study, gaze sharing was found effective in increasing learning gains, and especially for learners evaluated as low-achievers. Here, gaze sharing was also reported as helpful for instructors in supporting the prediction of learners' performance, and was preferred over the usage of a webcam video or a field-of-view video (Sung et al., 2021). Similar results concerning the usefulness of the technology in increasing learning gains and in aiding instructors to predict learners' performance were also reported more recently by Schneider et al. (2025). Additionally, in a scenario involving an interaction between a human learner and an avatar instructor, gaze sharing was found to shorten the time taken to identify an object indicated by the instructor in cases where the reference was ambiguous, thus reducing the investment of attentional resources on irrelevant objects (Andrist et al., 2017). Alongside these advantages, gaze sharing was found inferior to a mouse pointer in terms of shortening assembly completion time. Also, the passive production of gaze sharing visualizations was found less effective than intentional production (Akkil et al., 2018). Note that, in one study focusing on assembly, testing focused on estimating the systems' performance (latency), rather than on its pedagogical contribution (Mahanama et al., 2023).

Fourth, the two studies exploring the usage of gaze sharing for supporting discursive activity have reported on an increase in focus and in joint attention among learners over the course of a four week activity, as well as on positive feedback regarding the acceptance of this technology (Langner et al., 2022). The positive feedback in the latter study was echoed by learners' feedback collected by Darbar et al., which reflected an acknowledgement of the value of the technology in facilitating better communication, referring to shared gaze cues as "implicit" (i.e., non-distracting) but useful in live discussions (Darbar et al., 2024).

Fifth, two studies have focused on utilizing gaze sharing for improving learners' gaze behavior itself. Among these, one study has demonstrated the potential of robot companions in promoting the ability of children with ASD to follow their conversation partner's gaze, reflected in increased frequency and duration of eye contact (Ramnauth et al., 2025). In the other study, Amat et al. have suggested that an avatar can be used to train children with ASD in following gaze, showing improvement in performance as the task progressed (Amat et al., 2018). Note that, the evaluation of this system was comparable with a pilot study (three participants), and the data collected from participants was not compared, which limits the generalizability of these findings.

Finally, one study which tested the usefulness of gaze sharing for supporting coding (synchronous code editing) by Yang et. has reported on a significant positive impact on the sense of presence from the perspective of instructors (feeling "in the same place" with the learner), on the increased ability of instructors to verify comprehension, as well as on the ease of communication with learners. Note that, in this study, gaze sharing was integrated with additional indicators for the interlocutors' attention (e.g., mouse position), which may contribute to the resulting positive impact. Also note that the researchers have found the technology to be more useful to instructors, as some learners raised privacy issues and/or found it distracting (Yang et al., 2023).

4.3.3. *Benefits and limitations of gaze sharing in asynchronous settings*

Concerning the utilization of gaze sharing for supporting asynchronous learning, various benefits and challenges were reported in lecture-related activities. Schneider and Sung have observed a positive effect of overlaying gaze information onto lecture videos in terms of learners' learning, and reported that gaze visualization was superior to the addition of the instructor's face to the video. They concluded that superimposition of gaze information can aid in material comprehension (Schneider & Sung, 2024). In line with these findings, gaze cues from peers were also found useful in facilitating material comprehension (Xu et al., 2025). Relatedly, Kim et al. have examined two different modes of visualizing instructors' gaze, and found both superior to a no-gaze condition in terms of aiding learners to concentrate on the lecture content (Kim et al., 2022). Darbar et al. have also reported that, regardless of the mode of representation tested, gaze visualizations were useful for learners following a recorded explanation, with one mode ("surface model") ranked highest among the alternatives tested (Darbar et al., 2024). Also, Wagner et al. have demonstrated that alternating between different types of shared information (gaze, hand gesture) can be superior to constant sharing of either (Wagner et al., 2023). Contrary to the above, in some cases, gaze visualizations were found to interfere with learning, as well as to contribute little to increasing the sense of participation (Kim et al., 2022). Further, gaze sharing in asynchronous lectures did not correlate with decreased mental effort (Wagner et al., 2023).

Finally, the two studies focusing on utilizing gaze sharing in reading activity have highlighted the potential of providing models for gaze behavior in supporting learners, as well as the benefits of sharing learners' gaze patterns with instructors as a way to inform them

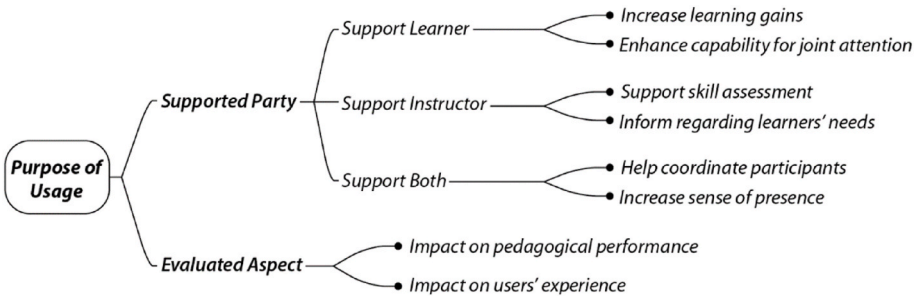

Fig. 10. An overview of the purposes of applying gaze sharing technology.

regarding learners' progress (Špakov et al., 2017). Relatedly, one study focusing on the act of gazing itself has suggested that sharing information recorded from learners with their instructors can help identify learners with neurodevelopmental disorders (Dæhlen et al., 2024).

4.3.4. An overview of current applications of gaze sharing in education by purpose

We summarize the key findings from surveying current literature on gaze sharing in education, focusing on the purpose for using the technology (Fig. 10). Two key aspects are identified. First, the supported party who directly benefits from using the system (instructor/learner/both) and the expected impact of using gaze sharing on their educational experience. Second, the aspect which studies have focused on when evaluating gaze sharing systems, to deliver value to the supported party.

4.4. Gaze sharing system proposals (not implemented)

Among the selected items, six papers included proposals for gaze sharing systems which were not implemented, but may nonetheless be informative regarding the potential range of applications of this technology in education.

In one study, gaze sharing was proposed as an aid for surgical residents (doctors under training in a specific surgical area), to facilitate better communication with attending surgeons (doctors overseeing the training). Here, feedback was collected from both parties regarding the potential usage of the technology in live surgery (Popov et al., 2022). The same topic was explored by another study, which included the observation of multiple surgeries as well as interviews with the target users. The study identified gaps between residents' needs and the training received, which can potentially be mitigated via synchronous gaze sharing, and recommended to empower users' via gaze sharing by analyzing the data prior to visualization, to support its interpretation (Popov et al., 2024). Furthermore, a system for gaze sharing was proposed with the aim of facilitating attitude change toward burning climate issues, under the assumption that joint attention can promote a shared understanding, and thus lead to reconsideration of one's position toward such matters (Szwoch, 2024). Additional two studies have proposed to employ gaze sharing for supporting the learning journey of programmers, by using historical data collected from peers to guide their eye movements during programming exercises (Deitelhoff & Harrer, 2018), or for facilitating better comprehension of programs (Deitelhoff, 2018). Finally, one study presented a proposal for exploring the enhancement of remote learning via gaze sharing, with an emphasis on learning about the relation between the density of interactions among users or the mode of gaze visualization and the resulting impact on education (D'Angelo, 2017).

5. Discussion

This section consists of four sub-sections. First, we interpret the results with respect to research questions 1, 2 and 3 (given in subsections 5.1, 5.2 and 5.3, accordingly). Then, we discuss potential future directions for the development of gaze sharing technology, to benefit learners and instructors, and ultimately, to support education (5.4).

5.1. Pedagogical contexts in which gaze sharing is being used (RQ1)

The exploration of gaze sharing in education is not limited to a specific educational context, discipline, mode of delivery, age etc. In fact, the technology has been applied in a wide range of educational contexts, including both academic and non-academic scenarios that nonetheless involve a pedagogical aspect, and for a wide range of ages (from children to adults).

While most studies did focus on usage in an academic context, usage in non-academic contexts that involve a person receiving instructions regarding a specific task were noted (e.g., using gaze sharing for instruction in culinary). Such studies highlight the potential of gaze sharing to be employed outside of academic contexts, in professional instruction regarding tasks requiring skill acquisition, such as in vocational schools, etc.

Further, concerning the variation in terms of usage by age group, applications for children (primary education) have mainly focused on supporting literacy (reading) or on special education, with emphasis on acquiring the ability to jointly gaze at targets along with a conversation partner. By contrast, the range of application explored with adult learners was more diverse, and included reading, coding, assembly and more. Further, among the applications for adult learners, most systems were employed in higher education, implying on researchers' interest in supporting higher learning using gaze sharing, alongside a gap in terms of applying the technology for lower educational levels.

Finally, while gaze sharing is applicable for multi-participant scenarios, it was primarily explored in one-to-one settings. Therefore, it remains to examine whether key findings concerning the benefits of the technology (e.g., increasing learning gains etc.), which were repeatedly reported in one-on-one settings, are generalizable to settings with a larger number of participants. Similarly, the body of knowledge concerning the usage of gaze sharing in synchronous remote settings is significantly larger than that of synchronous co-located settings, implying that further inquiry is required to determine the usefulness of the technology when participants share their physical environment.

5.2. Types of gaze sharing systems used in pedagogy (RQ2)

Systems for gaze sharing in education diverge in several aspects, including: the direction of sharing gaze information, the restrictions placed on users' mobility, the equipment used for displaying gaze information (and the UX it facilitates), and more.

Overall, systems for unidirectional gaze sharing were only slightly more common than those enabling bidirectional sharing. However, regardless of the direction of sharing, almost all of the systems catered for participants who were static during the educational task (either seated or standing in the same place). This may be due to the nature of many educational tasks which are done in a static pose, or due to the relatively high costs of mobile eye trackers, which are required to enable gaze sharing when users are free to move around the space. Regardless, expanding the range of usage of gaze sharing in education into scenarios where users are mobile may be essential for utilizing the technology in programs which emphasize active learning in a co-located setting, as these often involve users roaming the space while collaborating (for example, during brainstorming sessions, which are common in design studies, etc.). At the same time, scenarios in which users are mobile introduce new challenges that may require us to reconsider "traditional" gaze sharing technology, which is limited to situations in which both parties are viewing the same object. Therefore, we propose that gaze information will be integrated with shared information from other modalities, to overcome the barrier of forcing learners and instructors to gaze in the same direction as a precondition for benefiting from the technology.

Additionally, the usage of gaze sharing in immersive settings was relatively underexplored, a fact which may be attributed to the technical complexities involved in setting up and managing immersive environments, as compared with displaying gaze information on a flat monitor. Nevertheless, as the usage of immersive environments in educational practices increases, knowledge concerning the application of the technology in these settings will become essential. As gaze sharing is not limited to education, findings from other areas in which gaze sharing was applied (which were not surveyed here) may become valuable sources for learning about the potential of the technology in pedagogy.

Finally, while gaze sharing is commonly perceived as the sharing of information among human users, studies which focus on exchanging gaze information between a human learner and a non-human instructor were identified (e.g., a virtual avatar presented on a screen instructing a

person). As avatars can be augmented by Large Language Models (LLMs), they are increasingly becoming useful in enhancing self-learning experiences (Hadiatmadja, 2024). In these settings, gaze sharing may be beneficial for synchronously redirecting learners' attention or adjusting the pace of learning, as needed. Moreover, the gaze data collected during such activity can serve as the basis for asynchronous evaluation of learners' progress, which may be done by a human instructor or in an automated manner, for devising ways to support learners in their journey. Indeed, advances in eye tracking technology that enable to capture our gaze behavior using a simple webcam (Valliappan et al., 2020) are making such systems feasible in cases where the educational task is conducted in a static position using a computer monitor.

5.3. Benefits and limitations of gaze sharing in pedagogy (RQ3)

Empirical research regarding the usefulness of gaze sharing in educational scenarios has yielded a body of knowledge concerning possible applications and their expected benefits for learners and instructors. The distinction between synchronous and asynchronous gaze sharing (which can be otherwise regarded as "online" vs. "offline" sharing of information) is useful in discussing the benefits of the technology, as each affords different kinds of interactions, and therefore different kinds of value for learners and instructors. Among these two settings, studies of synchronous learning were larger in number and more diverse in terms of the task studied.

Gaze sharing systems which support synchronous learning were found effective in remote as well as in co-located scenarios. For examples, when interacting with an individual learner, gaze sharing has enabled an instructor to "dynamically adjust … explanations" (Darbar et al., 2024, p. 19). Beyond the dynamic nature of gaze, a possible explanation for the positive experience of the instructor may be related with a reduced need to interpret the referent which is focused on by the learner, which can release mental resources that are invaluable in synchronous scenarios. The above study has examined the relations between cognitive load and gaze sharing by comparing differences in cognitive load across different types of gaze markers, yet adding a baseline condition in which the technology is not used can help to shed light on the relations between (dual) gaze sharing and cognitive performance. Overall, the key benefits of using the technology for synchronous learning lie in: **(1) real-time feedback:** gaze sharing allows the instructor/learner to shift their course of action during the educational process, to enhance teaching and learning; **(2) disambiguation of references:** gaze sharing reduces the need to attend to irrelevant objects, which enables us repurpose our cognitive resources, that are critical when participating in synchronous educational activities. **Considering (1)**, future work can consider linking the usage of the technology with our ability to "reflect-in-action" (Schön, 2017) - one of the pillars of reflective practice in education, that is currently being facilitated by other technological means such as AI (Wei et al., 2025). **Considering (2)**, it seems important to understand and quantify the effects of the technology on cognitive load, which plays an important role in pedagogy, and especially on the learner's side. Moreover, as current studies have shown an asymmetry between instructors and leaners in terms of their expectations and preferences concerning the technology (e.g., instructor may prefer to not see their own gaze), future studies can establish deeper knowledge of the differences among the parties and their needs, to identify how to effectively support each in pedagogical settings. More concretely, developing systems which enable the user to customize the manner of gaze display (e.g., filter it, change its appearance etc.) and adapt it to their needs can help direct the technology towards a user-centered path. Despite these insights concerning one-to-one synchronous scenarios, we know less regarding the impact of gaze sharing in multi-participant scenarios (for example, sharing the gaze of an instructor and two learners, such that all parties can see each other's gaze points, etc.).

Regarding gaze sharing systems for asynchronous learning, several promising results concerning the potential of the technology were reported, both when the recorded gaze information was captured from an instructor and transferred to a learner (Schneider & Sung, 2024), or when a learner received information regarding their peers' past gaze patterns (Xu et al., 2025). One study has even shown that such results may be independent from the mode of visualization, as two types of gaze visualization were found to be superior to a no-gaze condition (Kim et al., 2022). Overall, aside from the positive effect on disambiguating references (mentioned above), the benefits of gaze sharing in asynchronous settings are: **(1) increased concentration and comprehension for learners:** gaze sharing was found helpful in assisting learners remain focused on learned material and in raising academic performance levels; **(2) offline assessment support for instructors**: historical information from learners can help instructors assess their progress without the pressure that accompanies teaching a live class. **Considering (1)**, future research can attempt to further boost concentration levels and academic performance by examining a wider range of visualization techniques, which may be operationalized by allowing interactive user control over the mode of visualization. **Considering (2)**, as pre-recorded gaze information was found to be useful for instructors, it is likely that such information would be valuable for other related parties as well, such as caretakers and medical personnel supporting the learner (e.g., in special education), given that appropriate ethical measures have been established to guarantee the protection of learners' privacy. Therefore, future work can consider relaying such information to other stakeholders, and even presenting a learner with their own gaze behavior as a form of "offline" reflective practice. Note that, specific tasks in asynchronous settings which seem strongly related with gaze behavior, such as reading texts and diagrams, have been underexplored by the studies surveyed, implying on the potential to expand the breadth of investigation regarding the effectiveness of gaze sharing for supporting such activities.

Finally, the fact that gaze sharing was occasionally found to be inferior to existing solutions for sharing attention information raises questions concerning the design and utilization of future gaze sharing systems. As noted above, students attending a lecture have found it distracting when trying to read information from the slides (Špakov, Niehorster, et al., 2019), rated it as less preferrable than gestures (Wagner et al., 2023) or a PowerPoint pointer, even when the gaze marker was evaluated as more easily noticed than the alternative (Špakov et al., 2016). In addition to highlighting the negative effects on attention, the latter study has also provided us with an important clue regarding the way in which learners experience gaze markers, as some described it as "too intrusive" (Špakov et al., 2016, p. 2653), a perspective that was shared by learners and instructors in immersive environments as well (Kahlon et al., 2024). While the above examples concern with lecture activities, a mouse pointer was also preferred over a gaze marker in an assembly task as well (Akkil et al., 2018). Thus, we can identify at least three possible foci for future research regarding the application of gaze sharing in education: **(1) relation with cognitive performance**: certain types of gaze visualization can have negative implications on learners'/instructors' cognition, attentional mechanisms etc.; **(2) sense of presence:** the visualization of eye movement may be subjectively experienced as unpleasant; **(3) task relevance:** the fact that, for some tasks, the technology provides information which is unnecessary from the learners' perspective, as in the case of reading text from lecture slides. **Considering (1)**, we may further develop the technology by comparing different gaze visualization in search for modes of visualization which minimize distraction - an emerging research direction (Rahman et al., 2020). Such work can benefit from estimating cognitive load via neurocognitive measurement (Li et al., 2024), to help identify modes of display which minimize it (update rate, form etc.). Further, specifically with respect the issue of visual distraction, researchers may also consider the possibility of allowing users to actively fix certain gaze points in an interactive manner, until the

learner is able to identify the target of the reference, followed by the erasure of the gaze marker from the display. **Considering (2)**, based on learners' negative feedback, it seems important to render a sense of presence that is not experienced as intrusive. As a sense of presence can be conducive for learning in virtual environments (Mikropoulos & Strouboulis, 2004), we should avoid throwing the baby out with the bathwater. **Concerning (3)**, we may systematically review the complete body of literature with a task-based lens, to determine where and when gaze sharing is most effective. As the body of literature of gaze sharing in pedagogy is relatively small (as compared with application in other domains), we may consider to extend the investigation into other domains, with the aim of mobilizing the findings to effectively support pedagogy.

5.4. The future of gaze sharing in education

The findings from our survey concerning current usage of gaze sharing in education have enabled to extrapolate regarding potential future directions for the development of the technology. Several key observations concerning the limitations of applying gaze sharing in education are made, each paired with a recommendation regarding the future of utilizing the technology for the benefit of learners and instructors, given in Table 7.

Additionally, it is crucial to bear in the mind the key limitations of gaze sharing technology, which also point to future directions for research and development of next-gen systems:

- As gaze sharing technology was shown to be suboptimal compared to other means for sharing attention in certain scenarios, it is important to map the scope of applicability, and determine the specific tasks and scenarios in which it excels, to guide its effective application in real-world educational settings.
- The fundamental limitation of employing gaze sharing in education is that it forces the instructor and learner to view the same visual content. Therefore, to integrate it into tasks in which users may not look at the same content continuously (e.g., when moving around the space), it may be necessary to augment it by sharing additional information from other modalities.
- More generally, the introduction of any technology into educational scenarios poses the risk of over-instrumentation in the classroom (Medina-Torres et al., 2024), which may be counterproductive or even detrimental to learning. Thus, when applying gaze sharing in education, it is important to identify and mitigate the potential negative implications of this technology, such as over-information which may lead to cognitive load, etc.

Table 7
Future directions for application of gaze sharing technology in education.

Observation	Opportunity
As gaze sharing is applicable both in academic and non-academic scenarios, it is potentially useful for vocational studies, yet few studies have explored this activity from an educational viewpoint	Apply gaze sharing for supporting vocational studies involving a visual aspect (e.g., cosmetology, carpentry, culinary arts etc.)
Applications for younger age groups (children) were limited to supporting literacy and enhancing joint attention in special education	Expand the usage of gaze sharing among younger age groups into other educational activities in which it is known to be effective (e.g., collaborative tasks)
Regardless of a specific age group, the surveyed studies have focused primarily on one-to-one educational scenarios	Examining the effects of gaze sharing in group settings
Based on the surveyed works, the body of knowledge concerning the application of gaze sharing in co-located scenarios may be limited	With advances in mobile eye tracking, co-located participants can engage in a broader range of tasks, enabling us to examine the potential of gaze sharing in co-located settings
Based on the surveyed works, the usage of gaze sharing in immersive environments for supporting education may be limited	Expand our body of knowledge concerning gaze sharing in pedagogy within immersive environments
While gaze sharing is commonly regarded as an activity that involves only human participants, is has been successfully applied in scenarios in which one of the interlocutors in a non-human agent (robot, avatar, etc.)	Explore any of the above opportunities in scenarios that involves a non-human agent contributing to the educational experience
The effectiveness of gaze sharing may be limited when it results in visual distraction	Study the negative implications of gaze sharing on attention, e.g. by matching modes of display with frequency of distraction
The effectiveness of gaze sharing may be limited by the cognitive load incurred when using the technology	Compare non-gaze sharing conditions with gaze sharing conditions, to determine impact on cognitive load (especially in synchronous settings)

6. Conclusion

A literature review of gaze sharing technology in education was reported, focusing on three dimensions: (1) the educational context, (2) the type of gazing sharing systems employed, and (3) the benefits and limitations of these. For each dimension, the distribution of current works by subcategories was noted, and existing applications were discussed. Based on these, recommendations regarding the future research and development of gaze sharing technology were made. Primarily:

(1) Expanding the range of application of gaze sharing systems into under-supported educational activities, such as vocational studies involving a visual aspect
(2) Utilizing knowledge concerning the usefulness of gaze sharing among adult learners to hypothesize regarding promising areas of application among younger age groups
(3) Considering the integration of gaze sharing capabilities into educational scenarios in which a non-human agent is involved (e.g. avatar instructors)
(4) Quantifying and mitigating the impact of the technology on cognitive performance (e.g., as can be measured by cognitive load), potentially through neurocognitive measurement
(5) Producing a task-based map of gaze sharing and its relative effectiveness for distinct educational purposes

Additionally, areas which may be under addressed and thus invite further inquiry include the usage of gaze sharing in multi-participant educational scenarios, co-located settings and immersive environments. Finally, the integration of additional modalities into current gaze sharing systems was proposed as a way to overcome the current fundamental restriction of the technology (i.e. forced shared view). These recommendations may help us utilize existing gaze sharing technology, as well as direct its further development, for the benefit of instructors and learners alike.

CRediT authorship contribution statement

Yuval Kahlon: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Investigation, Funding acquisition, Data curation, Conceptualization. **Stephen Law:** Methodology, Investigation. **Maki Kishimoto:** Methodology, Investigation. **Anubhab Majumder:** Writing – review & editing, Investigation. **Michal Gath-Morad:** Writing – review & editing, Conceptualization. **Toshihiro Osaragi:** Supervision, Resources, Conceptualization. **Mitsue Nagamine:** Writing – review & editing, Validation, Conceptualization. **Christiane Herr:** Writing – review & editing, Validation, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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