**Supplementary Information 1:**

**Reference list of all papers included in our review study**

*Note*: Papers marked with an asterisk (*) were included in this review study.

* Abt, M., Reinhold, F., & Van Dooren, W. (2023). Revealing cognitive processes when comparing box plots using eye-tracking data—A pilot study. In *Proceedings of the 46th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 2, pp. 11–18). PME.

* Bartalis, Á., Péntek, I., & Zsoldos-Marchi, I. (2023). A pilot study on investigating primary school students' eye movements while solving compare word problems. *Open Education Studies, 5*(1), 20220207. https://doi.org/10.1515/edu-2022-0207

* Baumanns, L., Pitta-Pantazi, D., Christou, C., Lilienthal, A. J., Simon, A. L., & Schindler, M. (2023). Adaptive strategy use in pattern-recognition of first graders with and without risk of developing mathematical difficulties: An eye-tracking study. In *Proceedings of the 46th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 2, pp. 75–82). PME.

* Baumanns, L., Pitta-Pantazi, D., Demosthenous, E., Christou, C., Lilienthal, A. J., & Schindler, M. (2022). How do first-grade students recognize patterns? An eye-tracking study. In *Proceedings of the 45th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 2, pp. 59–66). PME.

* Baumanns, L., Pitta-Pantazi, D., Demosthenous, E., Christou, C., Lilienthal, A. J., & Schindler, M. (2024). Pattern-recognition processes of first-grade students: An explorative eye-tracking study. *International Journal of Science and Mathematics Education.* https://doi.org/10.1007/s10763-024-10441-x

* Becker, S., Knippertz, L., Ruzika, S., & Kuhn, J. (2023). Persistence, context, and visual strategy of graph understanding: Gaze patterns reveal student difficulties in interpreting graphs. *Physical Review Physics Education Research*, *19*(2), 020142. http://dx.doi.org/10.1103/PhysRevPhysEducRes.19.020142

* Becker, S., Küchemann, S., Klein, P., Lichtenberger, A., & Kuhn, J. (2022). Gaze patterns enhance response prediction: More than correct or incorrect. *Physical Review Physics Education Research*, *18*(2), 020107. http://dx.doi.org/10.1103/PhysRevPhysEducRes.18.020107

* Bhagat, K. K., Yang., F. Y., Cheng, C. H., Zhang, Y., & Liou, W. K. (2021). Tracking the process and motivation of math learning with augmented reality. *Educational Technology Research and Development*, *69*, 3153–3178. https://doi.org/10.1007/s11423-021-10066-9

* Bicer, A., & Bicer, A. (2023). Understanding young students' mathematical creative thinking processes through eye-tracking-stimulated recall interview. *Mathematics Education Research Journal*, *35*, 361–399. https://doi.org/10.1007/s13394-022-00429-7

* Biza, I., Hewitt, D., Watson, A., & Mason, J. (2020). Generalization strategies in finding the nth term rule for simple quadratic sequences. *International Journal of Science and Mathematics Education*, *18*, 1105–1126. https://doi.org/10.1007/s10763-019-10009-0

* Boels, L., Bakker, A., & Drijvers, P. (2019). Eye-tracking secondary school students' strategies when interpreting statistical graphs. In *Proceedings of the 43rd Conference of the International Group for the Psychology of Mathematics Education* (Vol. 2, pp. 113–120). PME.

* Boels, L., Lyford, A., Bakker, A., & Drijvers, P. (2023). Assessing students' interpretations of histograms before and after interpreting dotplots: A gaze-based machine learning analysis. *Frontline Learning Research, 11*(2), 1–30. https://doi.org/10.14786/flr.v11i2.1139

* Boels, L., Garcia Moreno-Esteva, E., Bakker, A., & Drijvers, P. (2023). Automated gaze-based identification of students' strategies in histogram tasks through an interpretable mathematical model

and a machine learning algorithm. *International Journal of Artificial Intelligence in Education*, 1–43. http://dx.doi.org/10.1007/s40593-023-00368-9

* Boels, L., & Van Dooren, W. (2023). Secondary school students interpreting and comparing dotplots: An eye-tracking study. In *Proceedings of the 45th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 2, pp. 123–130). PME.

* Bruckmaier, G., Binder, K., Krauss, S., & Kufner, H. M. (2019). An eye-tracking study of statistical reasoning with tree diagrams and 2 × 2 tables. *Frontiers in Psychology*, *10*, 436373. http://dx.doi.org/10.3389/fpsyg.2019.00632

* Brückner, S., Zlatkin-Troitschanskaia, O., Küchemann, S., Klein, P., & Kuhn, J. (2020). Changes in students' understanding of and visual attention on digitally represented graphs across two domains in higher education: A postreplication study. *Frontiers in Psychology*, *11*, 561779. http://dx.doi.org/10.3389/fpsyg.2020.02090

* Brunner, K., Obersteiner, A., & Leuders, T. (2024). How pedagogical content knowledge sharpens prospective teachers' focus when judging mathematical tasks: An eye-tracking study. *Educational Studies in Mathematics*, *115*, 177–196. http://dx.doi.org/10.1007/s10649-023-10281-6

* Casalvieri, C., & Gambini, A. (2022). Analysis of solving a cauchy problem using an eye-tracker. *International Journal for Technology in Mathematics Education*, *29*(4), 189–199.

* Chaudhuri, S., Muhonen, H., Pakarinen, E., & Lerkkanen, M. K. (2022). Teachers' visual focus of attention in relation to students' basic academic skills and teachers' individual support for students: An eye-tracking study. *Learning and Individual Differences*, *98*, 102179. http://dx.doi.org/10.1016/j.lindif.2022.102179

* Chen, Y. T., & Ho, M. C. (2022). Eye movement patterns differ while watching captioned videos of second language vs mathematics lessons. *Learning and Individual Differences*, *93*, 102106. http://dx.doi.org/10.1016/j.lindif.2021.102106

* Chumachenko, D., Shvarts, A., Dreneva, A., & Krichevets, A. (2024). Eye movements in the development of geometric shape recognition: from sensory-motor processes to theoretical perception. *Educational Studies in Mathematics*, 1–26. http://dx.doi.org/10.1007/s10649-024-10298-5

* Chvatal, R., Slezakova, J., & Popelka, S. (2023). Analysis of problem-solving strategies for the development of geometric imagination using eye-tracking. *Education and Information Technologies*, 1–19. http://dx.doi.org/10.1007/s10639-023-12395-z

* Da Silva Soares, R. [JR.], Ambriola Oku, A. Y., Barreto, C. S. F., & Ricardo Sato, J. (2022). Applying functional near-infrared spectroscopy and eye-tracking in a naturalistic educational environment to investigate physiological aspects that underlie the cognitive effort of children during mental rotation tests. *Frontiers in Human Neuroscience*, *16*, 889806. http://dx.doi.org/10.3389/fnhum.2022.889806

* De Mooij, S. M., Kirkham, N. Z., Raijmakers, M. E., van der Maas, H. L., & Dumontheil, I. (2020). Should online math learning environments be tailored to individuals' cognitive profiles? *Journal of Experimental Child Psychology*, *191*, 104730. http://dx.doi.org/10.1016/j.jecp.2019.104730

* Dirkx, K. J. H., Skuballa, I., Manastirean-Zijlstra, C. S., & Jarodzka, H. (2021). Designing Computer-Based Tests: Design Guidelines from Multimedia Learning Studied with Eye Tracking. *Instructional Science: An International Journal of the Learning Sciences*, *49*, 589–605. http://dx.doi.org/10.1007/s11251-021-09542-9

* Dröse, J., Prediger, S., Neugebauer, P., Delucchi Danhier, R., & Mertins, B. (2021). Investigating students' processes of noticing and interpreting syntactic language features in word problem solving through eye-tracking. *International Electronic Journal of Mathematics Education*, *16*(1).

* Dyrvold, A., & Bergvall, I. (2023a). Computer-based assessment in mathematics: Issues about validity. *LUMAT: International Journal on Math, Science and Technology Education*, *11*(3), 49–76.

* Dyrvold, A., & Bergvall, I. (2023b). Static, dynamic and interactive elements in digital teaching materials in mathematics: How do they foster interaction, exploration and persistence? *LUMAT: International Journal on Math, Science and Technology Education, 11*(3), 103–131.

* Garcia Moreno-Esteva, E., & Hannula, M. (2021). The development of ideas in geometry optimization problem as revealed with eye tracking. In *Proceedings of the 44th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 3, pp. 285–292). PME.

* Gomez, A., & Huron, C. (2020). Subitizing and counting impairments in children with developmental coordination disorder. *Research in Developmental Disabilities, 104*, 103717. http://dx.doi.org/10.1016/j.ridd.2020.103717

* Guarini, A., Tobia, V., Bonifacci, P., Faldella, G., & Sansavini, A. (2021). Magnitude comparisons, number knowledge and calculation in very preterm children and children with specific learning disability: A cross-population study using eye-tracking. *Journal of Learning Disabilities, 54*(2), 83–96. http://dx.doi.org/10.1177/0022219420950651

* Gulz, A., Londos, L., & Haake, M. (2020). Preschoolers' understanding of a teachable agent-based game in early mathematics as reflected in their gaze behaviors - An experimental study. *International Journal of Artificial Intelligence in Education, 30*, 38–73. http://dx.doi.org/10.1007/s40593-020-00193-4

* Haataja, E., Garcia Moreno-Esteva, E., Salonen, V., Laine, A., Toivanen, M., & Hannula, M. S. (2019). Teacher's visual attention when scaffolding collaborative mathematical problem solving. *Teaching and Teacher Education, 86*, 102877. http://dx.doi.org/10.1016/j.tate.2019.102877

* Haataja, E., Salonen, V., Laine, A., Toivanen, M., & Hannula, M. S. (2021).The relation between teacher-student eye contact and teachers' interpersonal behavior during group work: A multiple-person gaze-tracking case study in secondary mathematics education. *Educational Psychology Review, 33*(1), 51–67. http://dx.doi.org/10.1007/s10648-020-09538-w

* Haataja, E., Toivanen, M., Laine, A., & Hannula, M. S. (2019). Teacher-student eye contact during scaffolding collaborative mathematical problem-solving. *LUMAT: International Journal on Math, Science and Technology Education, 7*(2), 9–26.

* Hachaj, T., Stolinska, A., Andrzejewska, M., & Czerski, P. (2021). Deep convolutional symmetric encoder—Decoder neural networks to predict students' visual attention. *Symmetry, 13*(12), 2246. http://dx.doi.org/10.3390/sym13122246

* Hahn, L., & Klein, P. (2023). Clustering eye-movement data uncovers students' strategies for coordinating equations and diagrams of vector fields. *Educational Studies in Mathematics*, 1–27. http://dx.doi.org/10.1007/s10649-023-10243-y

* Hannula, M. S., & Toivanen, M. (2019). Making and observing visual representations during problem solving: An eye tracking study. In *Proceedings of the 43rd Conference of the International Group for the Psychology of Mathematics Education* (Vol. 2, pp. 328–335). PME.

* Heyd-Metzuyanim, E., Haataja, E. S. H., Hannula, M. S., & Garcia Moreno-Esteva, E. (2023). What can eye-tracking, combined with discourse analysis, teach us about the ineffectiveness of a group of students solving a geometric problem? *Instructional Science, 51*(3), 363–396. http://dx.doi.org/10.1007/s11251-023-09617-9

* Huh, D., Kim, J. H., & Jo, I. H. (2019). A novel method to monitoring changes in cognitive load in video-based learning. *Journal of Computer Assisted Learning, 35*(6), 721–730. http://dx.doi.org/10.1111/jcal.12378

* Kang, T., Tang, T., Zhang, P., Luo, S., & Qi, H. (2023). Metacognitive prompts and numerical ordinality in solving word problems: An eye-tracking study. *British Journal of Educational Psychology, 93*(3), 862–877. http://dx.doi.org/10.1111/bjep.12601

* Kim, J., & Jo, I. H. (2019). Feasibility and use of psychophysiological responses based on cognitive load theory. *Australasian Journal of Educational Technology, 35*(3). http://dx.doi.org/10.14742/ajet.4163

* Kim, S., Pollanen, M., Reynolds, M. G., & Burr, W. S. (2020). Problem solving as a path to comprehension: Mathematical software and structured symbolism. *Mathematics in Computer Science, 14*, 607–621. http://dx.doi.org/10.1007/s11786-020-00457-1

* Klein, P., Küchemann, S., Brückner, S., Zlatkin-Troitschanskaia, O., & Kuhn, J. (2019). Student understanding of graph slope and area under a curve: A replication study comparing first-year physics and economics students. *Physical Review Physics Education Research*, *15*(2), 020116. http://dx.doi.org/10.1103/PhysRevPhysEducRes.15.020116

* Klein, P., Viiri, J., & Kuhn, J. (2019). Visual cues improve students' understanding of divergence and curl: Evidence from eye movements during reading and problem solving. *Physical Review Physics Education Research, 15*(1), 010126. http://dx.doi.org/10.1103/PhysRevPhysEducRes.15.010126

* Kosel, C., Holzberger, D., & Seidel, T. (2021). Identifying expert and novice visual scanpath patterns and their relationship to assessing learning-relevant student characteristics. *Frontiers in Education, 5*, 612175. http://dx.doi.org/10.3389/feduc.2020.612175

*Lee, S., Ke, F., & Ryu, J. (2023). Engagement and effectiveness of symbolic and iconic learning support for math problem representation: an eye tracking study. *Interactive Learning Environments, 31*(3), 1514–1531. http://dx.doi.org/10.1080/10494820.2020.1848877

* Li, T., Quintero, M., Galvan, M., Shanafelt, S., Hasty, L. M., Spangler, D. P., Ian M., Mazzocco, M. M. M., Brockmole, J. R., Hart, S. A., & Wang, Z. (2023). The mediating role of attention in the association between math anxiety and math performance: An eye-tracking study. *Journal of Educational Psychology, 115*(2), 229–240. http://dx.doi.org/10.1037/edu0000759

* Li, R., Cao, Y., Tang, H., & Kaiser, G. (2024). Teachers' scaffolding behavior and visual perception during cooperative learning. *International Journal of Science and Mathematics Education, 22*(2), 333–352. http://dx.doi.org/10.1007/s10763-023-10379-6

* Liang, C. P., & She, H. C. (2023). Investigate the effectiveness of single and multiple representational scaffolds on mathematics problem solving: Evidence from eye movements. *Interactive Learning Environments, 31*(6), 3882–3897. http://dx.doi.org/10.1080/10494820.2021.1943692

* Lomos, C., Seineke, U., Kesting, F., & Luyten, J. W. (2023). The design of incentive systems in digital game-based learning: How primary school children interact with it. *Education Sciences*, *13*(7), 668. http://dx.doi.org/10.3390/educsci13070668

* Maatta, O., McIntyre, N., Palomäki, J., Hannula, M. S., Scheinin, P., & Ihantola, P. (2021). Students in sight: Using mMobile eye-tracking to investigate mathematics teachers' gaze behaviour during task instruction-giving. *Frontline Learning Research*, *9*(4), 92–115. https://doi.org/10.14786/flr.v9i4.965

* Males, L. M., & Setniker, A. (2019). Planning with curriculum materials: Interactions between prospective secondary mathematics teachers' attention, interpretations and responses. *International Journal of Educational Research, 93*, 153–167. http://dx.doi.org/10.1016/j.ijer.2018.09.016

* Malone, S., Altmeyer, K., Vogel, M., & Brünken, R. (2020). Homogeneous and heterogeneous multiple representations in equation-solving problems: An eye-tracking study. *Journal of Computer Assisted Learning, 36*(6), 781–798. http://dx.doi.org/10.1111/jcal.12426

* Moen, K. C., Beck, M. R., Saltzmann, S. M., Cowan, T. M., Burleigh, L. M., Butler, L. G., Ramanujam, J., Cohen, A. S., & Greening, S. G. (2020). Strengthening spatial reasoning: Elucidating the attentional and neural mechanisms associated with mental rotation skill development. *Cognitive Research: Principles and Implications*, *5*, 1–23. http://dx.doi.org/10.1186/s41235-020-00211-y

* Morris, B. J., Masnick, A. M., & Was, C. A. (2022). Making sense of data: Identifying children's strategies for data comparisons. *Journal of Cognition and Development*, *23*(5), 686–711. http://dx.doi.org/10.1080/15248372.2022.2100395

* Nazareth, A., Killick, R., Dick, A. S., & Pruden, S. M. (2019). Strategy selection versus flexibility: Using eye-trackers to investigate strategy use during mental rotation. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *45*(2), 232–245. http://dx.doi.org/10.1037/xlm0000574

* Norqvist, M., Jonsson, B., & Lithner, J. (2023). Shifts in student attention on algorithmic and creative practice tasks. *Educational Studies in Mathematics*, 1–20. http://dx.doi.org/10.1007/s10649-023-10250-z

* Norqvist, M., Jonsson, B., Lithner, J., Qwillbard, T., & Holm, L. (2019). Investigating algorithmic and creative reasoning strategies by eye tracking. *The Journal of Mathematical Behavior*, *55*, 100701. http://dx.doi.org/10.1016/j.jmathb.2019.03.008

* Own, C. M., Cai, T., & Hung, C. Y. (2022). Exploring the potential of tangible and multitouch interfaces to promote learning among preschool children. *IEEE Transactions on Learning Technologies*, *16*(1), 66–77. http://dx.doi.org/10.1109/TLT.2022.3170031

* Peake, C., Moscoso-Mellado, J., & Guerra, E. (2020). First fixation duration as a bottom-up measure during symbolic and non-symbolic numerical comparisons (La duración de la primera fijación como medida bottom-up al comparar cantidades simbólicas y no simbólicas). *Studies in Psychology*, *41*(3), 563–579. http://dx.doi.org/10.1080/02109395.2020.1794717

* Pitta-Pantazi, D., Demosthenous, E., Schindler, M., Lilienthal, A. J., & Christou, C. (2024). Structure sense in students' quantity comparison and repeating pattern extension tasks: An eye-tracking study with first graders. *Educational Studies in Mathematics*, 1–19. http://dx.doi.org/10.1007/s10649-023-10290-5

* Pouta, M., Lehtinen, E., & Palonen, T. (2021). Student teachers' and experienced teachers' professional vision of students' understanding of the rational number concept. *Educational Psychology Review*, *33*, 109–128. http://dx.doi.org/10.1007/s10648-020-09536-y

* Ranzato, E., Tolmie, A., & Van Herwegen, J. (2020). Perceptual subitizing and conceptual subitizing in Williams syndrome and Down syndrome: Insights from eye movements. *Research in Developmental Disabilities*, *106*, 103746. http://dx.doi.org/10.1016/j.ridd.2020.103746

* Ruf, V., Küchemann, S., Kuhn, J., & Klein, P. (2022). Comparison of written and spoken instruction to foster coordination between diagram and equation in undergraduate physics education. *Human Behavior and Emerging Technologies*, 5860936. http://dx.doi.org/10.1155/2022/5860936

* Salminen-Saari, J. F., Garcia Moreno-Esteva, E., Haataja, E., Toivanen, M., Hannula, M. S., & Laine, A. (2021). Phases of collaborative mathematical problem solving and joint attention: A case study utilizing mobile gaze tracking. *ZDM Mathematics Education*, *53*(4), 771–784. http://dx.doi.org/10.1007/s11858-021-01280-z

* Schindler, M., Schaffernicht, E., & Lilienthal, A. (2020). Identifying student strategies through eye tracking and unsupervised learning: The case of quantity recognition. In *Proceedings of the 44th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 4, pp. 9–16). PME.

* Schindler, M., Bader, E., Lilienthal, A. J., Schindler, F., & Schabmann, A. (2019). Quantity recognition in structured whole number representations of students with mathematical difficulties: An eye-tracking study. *Learning Disabilities: A Contemporary Journal*, *17*(1), 5–28.

* Schindler, M., Doderer, J. H., Simon, A. L., Schaffernicht, E., Lilienthal, A. J., & Schäfer, K. (2022). Small number enumeration processes of deaf or hard-of-hearing students: A study using eye tracking and Artificial Intelligence. *Frontiers in Psychology*, *13*, 909775. http://dx.doi.org/10.3389/fpsyg.2022.909775

* Schindler, M., & Lilienthal, A. J. (2019). Domain-specific interpretation of eye tracking data: towards a refined use of the eye-mind hypothesis for the field of geometry. *Educational Studies in Mathematics*, *101*, 123–139. http://dx.doi.org/10.1007/s10649-019-9878-z

* Schindler, M., & Lilienthal, A. J. (2020). Students' creative process in mathematics: Insights from eye-tracking-stimulated recall interview on students' work on multiple solution tasks. *International Journal of Science and Mathematics Education, 18*(8), 1565–1586. http://dx.doi.org/10.1007/s10763-019-10033-0

* Schindler, M., & Lilienthal, A. J. (2022). Students' collaborative creative process and its phases in mathematics: an explorative study using dual eye tracking and stimulated recall interviews. *ZDM Mathematics Education, 54*(1), 163–178. http://dx.doi.org/10.1007/s11858-022-01327-9

* Schindler, M., Schaffernicht, E., & Lilienthal, A. J. (2019). Differences in quantity recognition of students with and without mathematical difficulties: Analysis through eye-tracking and AI. In *Proceedings of the 43rd Conference of the International Group for the Psychology of Mathematics Education* (Vol. 3, pp. 281–288). PME.

* Schindler, M., Schovenberg, V., & Schabmann, A. (2020). Enumeration processes of children with mathematical difficulties: An explorative eye-tracking study on subitizing, groupitizing, counting, and pattern recognition. *Learning Disabilities: A Contemporary Journal, 18*(2), 193–211.

* Schnitzler, K., Holzberger, D., & Seidel, T. (2020). Connecting judgment process and accuracy of student teachers: Differences in observation and student engagement cues to assess student characteristics. *Frontiers in Education*, *5*, 602470. http://dx.doi.org/10.3389/feduc.2020.602470

* Schreiter, S., Vogel, M., Rehm, M., & Dörfler, T. (2021). Through the eyes of prospective teachers: Judging task difficulties in the domain of fractions. In *Proceedings of the 44th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 4, pp. 17–24). PME.

* Schreiter, S., & Vogel, M. (2023). Eye-tracking measures as indicators for a local vs. global view of data. *Frontiers in Education*, *7,* 1058150. http://dx.doi.org/10.3389/feduc.2022.1058150

* Schreiter, S., & Vogel, M. (2023). Statistical thinking and viewing patterns when comparing data distributions: An eye-tracking study with 6th and 8th graders. In *Proceedings of the 46th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 4, pp. 179–186). PME.

* Sharma, K., Lee-Cultura, S., & Giannakos, M. (2022). Keep calm and do not carry-forward: Toward sensor-data driven ai agent to enhance human learning. *Frontiers in Artificial Intelligence*, *4*, 713176. http://dx.doi.org/10.3389/frai.2021.713176

* Shojaeizadeh, M., Djamasbi, S., Paffenroth, R. C., & Trapp, A. C. (2019). Detecting task demand via an eye tracking machine learning system. *Decision Support Systems*, *116*, 91–101. http://dx.doi.org/10.1016/j.dss.2018.10.012

* Shvarts, A., & Abrahamson, D. (2019). Dual-eye-tracking Vygotsky: A microgenetic account of a teaching/learning collaboration in an embodied-interaction technological tutorial for mathematics. *Learning, Culture and Social Interaction*, *22*, 100316. http://dx.doi.org/10.1016/j.lcsi.2019.05.003

* Shvarts, A., & Abrahamson, D. (2023). Coordination dynamics of semiotic mediation: A functional dynamic systems perspective on mathematics teaching/learning. *Constructivist Foundations*, *18*(2), 220–234.

* Simon, A. L., Asghari, P., Lilienthal, A. J., & Schindler, M. (2023). Strategy use in number line tasks of students with and without mathematical difficulties: A study using eye tracking and AI. In *Proceedings of the 46th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 4, pp. 211–218). PME.

* Simon, A.L., Rott, B. & Schindler, M. (2021). Identification of geometric shapes: An eye-tracking study on triangles. In *Proceedings of the 44th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 4, pp. 57–64). PME.

* Simon, A. L. & Schindler, M. (2020). A comparative analysis of eye tracking and thinking aloud in number line estimation tasks: A study on students with and without mathematical difficulties. In *Proceedings of the 44th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 4, pp. 65–72). PME.

* Simon, A. L., & Schindler, M. (2022). Strategy use in number line tasks of students with mathematical difficulties: An eye-tracking study. In *Proceedings of the 45th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 4, pp. 3–10). PME.

* Simsek, I., Uygun, T., & Güner, P. (2020). Problem-solving performance and mathematics achievement: The mediating role of eye tracking measurements. *International Online Journal of Education and Teaching, 7*(3), 1111–1124.

* Skrabankova, J., Popelka, S., & Beitlova, M. (2020). Students' ability to work with graphs in physics studies related to three typical student groups. *Journal of Baltic Science Education, 19*(2), 298–316. http://dx.doi.org/10.33225/jbse/20.19.298

* Spagnolo, C., Capone, R., & Gambini, A. (2021). Where do students focus their attention on solving mathematical tasks? An eye tracker explorative study. In *Proceedings of the 44th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 4, pp. 89–96). PME.

* Sprenger, P., & Benz, C. (2020). Children’s perception of structures when determining cardinality of sets—Results of an eye-tracking study with 5-year-old children. *ZDM Mathematics Education, 52*(4), 753–765. http://dx.doi.org/10.1007/s11858-020-01137-x

* Stahnke, R., & Blömeke, S. (2021). Novice and expert teachers’ noticing of classroom management in whole-group and partner work activities: Evidence from teachers' gaze and identification of events. *Learning and Instruction, 74*, 101464. http://dx.doi.org/10.1016/j.learninstruc.2021.101464

* Stahnke, R., & Friesen, M. (2023). The subject matters for the professional vision of classroom management: an exploratory study with biology and mathematics expert teachers. *Frontiers in Education, 8*, 1253459. http://dx.doi.org/10.3389/feduc.2023.1253459

* Strobel, B., Grund, S., & Lindner, M. A. (2019). Do seductive details do their damage in the context of graph comprehension? Insights from eye movements. *Applied Cognitive Psychology, 33*(1), 95–108. http://dx.doi.org/10.1002/acp.3491

* Strohmaier, A. R., Lehner, M. C., Beitlich, J. T., & Reiss, K. M. (2019). Eye movements during mathematical word problem solving—Global measures and individual differences. *Journal für Mathematik-Didaktik, 2*(40), 255–287. http://dx.doi.org/10.1007/s13138-019-00144-0

* Strohmaier, A. R., Schiepe-Tiska, A., Chang, Y. P., Müller, F., Lin, F. L., & Reiss, K. M. (2020). Comparing eye movements during mathematical word problem solving in Chinese and German. *ZDM Mathematics Education, 52*, 45–58. http://dx.doi.org/10.1007/s11858-019-01080-6

* Susac, A., Planinic, M., Bubic, A., Jelicic, K., & Palmovic, M. (2023). Linking information from multiple representations: an eye-tracking study. *Frontiers in Education, 8*, 1141896. http://dx.doi.org/10.3389/feduc.2023.1141896

* Thomaneck, A., Vollstedt, M., & Schindler, M. (2022). What can eye movements tell about students’ interpretations of contextual graphs? A methodological study on the use of the eye-mind hypothesis in the domain of functions. *Frontiers in Education, 7*, 1003740. http://dx.doi.org/10.3389/feduc.2022.1003740

* Throndsen, T. U., Lindskog, M., Niemivirta, M., & Mononen, R. (2022). Does mathematics anxiety moderate the effect of problem difficulty on cognitive effort? *Scandinavian Journal of Psychology, 63*(6), 601–608. http://dx.doi.org/10.1111/sjop.12852

* Türkoğlu, H., & Yalçınalp, S. (2024). Investigating problem-solving behaviours of university students through an eye-tracking system using GeoGebra in geometry: A case study. *Education and Information Technologies*, 1–31. http://dx.doi.org/10.1007/s10639-024-12452-1

* Uygun, T., Guner, P., & Simsek, I. (2024). Examining students' geometrical misconceptions by eye tracking. *International Journal of Mathematical Education in Science and Technology, 55*(1), 68–93. http://dx.doi.org/10.1080/0020739X.2022.2101954

* van Leendert, A., Doorman, M., Drijvers, P., Pel, J., & van der Steen, J. (2019). An exploratory study of reading mathematical expressions by braille readers. *Journal of Visual Impairment & Blindness, 113*(1), 68–80. http://dx.doi.org/10.1177/0145482X18822024

* Viktorsson, C., Lindskog, M., Li, D., Tammimies, K., Taylor, M. J., Ronald, A., & Falck-Ytter, T. (2023). Infants' sense of approximate numerosity: Heritability and link to other concurrent traits. *Developmental Science*, *26*(4), e13347. http://dx.doi.org/10.1111/desc.13347

* Wang, J., Antonenko, P., Celepkolu, M., Jimenez, Y., Fieldman, E., & Fieldman, A. (2019). Exploring relationships between eye tracking and traditional usability testing data. *International Journal of Human–Computer Interaction, 35*(6), 483–494. http://dx.doi.org/10.1080/10447318.2018.1464776

* Wang, J., Antonenko, P., & Dawson, K. (2020). Does visual attention to the instructor in online video affect learning and learner perceptions? An eye-tracking analysis. *Computers & Education, 146,* 103779. http://dx.doi.org/10.1016/j.compedu.2019.103779

* Wang, T. H., & Kao, C. H. (2024). Pupil dilation as an index of examinee's cognitive load in answering a mathematics question: A comparison study of different approaches. *Mind, Brain, and Education, 18*(1), 43–47. http://dx.doi.org/10.1111/mbe.12388

* Wang, X., Kang, W., Huang, L., & Li, L. (2022). The impact of illustrations on solving mathematical word problems for Chinese primary school students: Evidence for a split attention effect on eye-movement research. *ZDM Mathematics Education, 54*(3), 555–567. http://dx.doi.org/10.1007/s11858-022-01357-3

* Wei, S., Lei, Q., Chen, Y., & Xin, Y. P. (2023). The effects of visual cueing on students with and without math learning difficulties in online problem solving: Evidence from eye movement. *Behavioral Sciences, 13*(11), 927. http://dx.doi.org/10.3390/bs13110927

* Woollacott, B., Alcock, L., & Inglis, M. (2023). The spatial contiguity principle in mathematics textbooks. *Research in Mathematics Education*, 1–21. https://doi.org/10.1080/14794802.2022.2158122

* Wu, C. J., Liu, C. Y., Yang, C. H., & Jian, Y. C. (2021). Eye-movements reveal children's deliberative thinking and predict performance on arithmetic word problems. *European Journal of Psychology of Education, 36*(1), 91–108. http://dx.doi.org/10.1007/s10212-020-00461-w

* Wu, H., Zhang, Y., Luo, Q., & Zhu, Z. (2024). The magnitude representations of fractions of Chinese students: Evidence from behavioral experiment and eye-tracking. *Current Psychology*, *43*(5), 4113–4128. http://dx.doi.org/10.1007/s12144-023-04627-9

* Zhang, L., Song, N., Wu, G., & Cai, J. (2023). Understanding the cognitive processes of mathematical problem posing: evidence from eye movements. *Educational Studies in Mathematics*, 1–30. http://dx.doi.org/10.1007/s10649-023-10262-9

* Zhang, L., Stylianides, A. J., & Stylianides, G. J. (2023). Identifying competent problem posers and exploring their characteristics. *The Journal of Mathematical Behavior*, *72*, 101086. http://dx.doi.org/10.1016/j.jmathb.2023.101086

* Zhu, R., You, X., Gan, S., & Wang, J. (2019). Spatial attention shifts in addition and subtraction arithmetic: evidence of eye movement. *Perception, 48*(9), 835–849. http://dx.doi.org/10.1177/0301006619865156

**Supplementary Information 2:**

**Category system of grade levels**

We coded ten categories of grade level, as follows:

1. **Preschool Level:** This category refers to studies including preschool children who do not yet visit primary school (e.g., Gulz et al., 2020). They are usually 6 years of age or younger.
2. **Primary Grade Level:** Recognizing that the length of primary education varies by country (e.g., in Germany, from Year 1 to Year 4 or up to Year 6; in Sweden, up to Year 9), we defined primary education to Grades 1–4.
3. **Lower Secondary Grade Level:** Some school systems differentiate between secondary education (e.g., USA with middle and high schools). To do justice to this distinction, we distinguish between lower and upper secondary grade levels. Lower secondary grade level in our review ranges from Grades 5–9.
4. **Upper Secondary Grade Level:** Accordingly, upper secondary grade level in our review ranges from Grades 10–12/13.
5. **University Level:** We differentiated between university students learning mathematics and university students in pre-service teacher education because pre-service teachers play a special role in mathematics education, as they are prepared for their future work as teachers. University students refer to all university students who are not part of the teacher training program (e.g., Klein, Viiri & Kuhn, 2019).
6. **Pre-service Teacher Students**: Pre-service teacher students refer to all university students in the teacher training program. Studies with this group of participants are characterized, among other things, by the fact that they examine specific content such as pedagogical content knowledge (e.g., Brunner et al., 2024).
7. **Vocational Education:** This category includes studies focusing on participants engaged in vocational training programs, often emphasizing practical and career-oriented mathematics education (Dirkx et al., 2021).
8. **Teacher Education:** If in-service teachers were participants in the study, this was marked with “Teacher Education” (e.g., Stahnke & Blömeke, 2021).
9. **Adult/Out-of-school Education:** This category includes studies involving adult learners out of school or another out-of-school education program for adults (e.g. Strohmaier et al., 2019).
10. **Other:** A residual category was added for “Other” to include special education or other non-standard educational settings.

**Supplementary Information 3:**

**Additional Data Sources (except from eye tracking)**

1. Thinking Aloud Interviews
    a. Concurrent
    b. Retrospective
2. Stimulated Recall Interviews
    a. ET Data as Stimulus
    b. Other Data as Stimulus
3. Interviews
4. Observations
    a. of Individual Students
    b. of Groups/Classroom
5. Product Collection and Analysis
6. Students' Work on Tasks
    a. Answers
    b. Response Times
7. Tests
8. Questionnaires
9. Online Measures

## Supplementary Information 4:

## Eye-tracking related characteristics of the studies

**Table 1:** Eye-tracking related characteristics of the studies

| Eye-tracking systems (sampling rates) | | | Total |
|---|---|---|---|
| **Static eye-tracking devices** | | | **71** |
| EyeLink 1000 Plus (1000 Hz) | T. Li et al. (2023)<br>J. Wang et al. (2019) | J. Wang et al. (2020) | 3 |
| EyeLink 1000 (500-1000 Hz) | Chen & Ho (2022)<br>Norqvist et al. (2023)<br>Norqvist et al. (2019) | C. J. Wu et al. (2021)<br>H. Wu et al. (2021) | 5 |
| EyeLink Portable Duo (2000 Hz) | Kang et al. (2023) | | 1 |
| Tobii Pro X3-120 (120 Hz) | Baumanns et al. (2023)<br>Baumanns et al. (2022)<br>Baumanns et al. (2024)<br>Becker et al. (2023)<br>Becker et al. (2022)<br>Brückner et al. (2020)<br>Hahn & Klein (2023)<br>Klein, Küchemann, et al. (2019)<br>Klein, Viiri & Kuhn (2019)<br>Lomos et al. (2023) | Pitta-Pantazi et al. (2024)<br>Ruf et al. (2022)<br>Schindler, Schaffernicht, & Lilienthal (2019)<br>Schindler, Schaffernicht, & Lilienthal (2020)<br>Schindler et al. (2022)<br>Simon et al. (2023)<br>Simon et al. (2021)<br>Simon & Schindler (2022)<br>Wei et al. (2023) | 19 |
| Tobii Pro TX300 (120-300 Hz) | De Mooij et al. (2020)<br>Gomez & Huron (2020) | Shojaeizadeh et al. (2019) | 3 |
| Tobii Pro T120 (60-120 Hz) | Ranzato et al. (2020) | Viktorsson et al. (2023) | 2 |
| Tobii Pro Fusion (120-250 Hz) | Bartalis et al. (2023)<br>Schreiter et al. (2021) | Schreiter & Vogel (2023a)<br>Schreiter & Vogel (2023b) | 4 |
| Tobii Pro X2-30 (30 Hz) | Huh et al. (2019) | J. Kim & Jo (2019) | 2 |
| Tobii Pro X2-60 (60 Hz) | Boels et al. (2019)<br>Boels, Lyford, et al. (2023)<br>Boels, Garcia Moreno-Esteva, et al. (2023)<br>Boels & Van Dooren (2023) | Malone et al. (2020)<br>Throndsen et al. (2022)<br>Woolacott et al. (2023) | 7 |
| Tobii Pro Nano (60 Hz) | Casalvieri & Gambini (2022) | | 1 |
| Tobii Pro T60XL (60 Hz) | Morris et al. (2022) | | 1 |
| Tobii Pro X60 (60 Hz) | Nazareth et al. (2019) | | 1 |
| SMI RED-m (129 Hz) | Stahnke & Blömeke (2021)<br>Stahnke & Friesen (2023) | Strobel et al. (2019)<br>Susac et al. (2023) | 4 |
| SMI RED (120-250 Hz) | Chumachenko et al. (2024) | Dirkx et al. (2021) | 2 |
| SMI RED250 (250 Hz) | Bruckmaier et al. (2019)<br>Brunner et al. (2024) | Dröse et al. (2021)<br>Gulz et al. (2020) | 4 |
| SMI RED500 (500 Hz) | Kosel et al. (2021)<br>Schnitzler et al. (2020) | Strohmaier et al. (2019)<br>Strohmaier et al. (2020) | 4 |
| SMI iView Hi-Speed (500 Hz) | Hachaj et al. (2021) | Susac et al. (2023) | 2 |
| ASL Model 504 (120 Hz) | Guarini et al. (2021) | | 1 |
| VT3 mini (200 Hz) | T. H. Wang et al. (2024) | | 1 |

| Eye-tracking systems (sampling rates) | | | Total |
|---|---|---|---|
| GazePoint GP3 (60 Hz) | S. Kim et al. (2020) | Skrabankova et al. (2020) | 2 |
| GazePoint GP3 HD (150 Hz) | Chvatal et al. (2023) | | 1 |
| Eye Tribe tracker (30 Hz) | Liang & She (2023) | | 1 |
| **Head-mounted eye-tracking devices** | | | **20** |
| EyeLink-II (500-1000Hz) | Peake et al. (2020)<br>Zhang, Song, et al. (2023) | Zhang, Stylianides, & Stylianides (2023)<br>Zhu et al. (2019) | 4 |
| Tobii Pro Glasses 2 (25-50 Hz) | Bhagat et al. (2021)<br>Chaudhuri et al. (2022)<br>R. Li et al. (2024)<br>Own et al. (2022)<br>Pouta et al. (2021) | Schindler, Bader, et al. (2019)<br>Schindler & Lilienthal (2022)<br>Schindler, Schovenberg, & Schabmann (2020)<br>Simon & Schindler (2020)<br>Thomaneck et al. (2022) | 10 |
| ASL Mobile Eye-5 (60 Hz) | Da Silva Soares et al. (2022) | | 1 |
| Self-made (30 Hz) | Haataja et al. (2021)<br>Hannnula & Toivanen (2019) | Heyd-Metzuyanim et al. (2023)<br>Maatta et al. (2021) | 4 |
| Pupil Labs Goggles (60 Hz) | Shvarts & Abrahamson (2019) | | 1 |

*Note: Only studies that reported both the eye-tracking device and the sampling rate of the device are listed here. The reference list for these studies can be found in the online supplement.*

| Eye-tracking data and data representations | | | Total |
|---|---|---|---|
| **Data representations displaying trajectory data or gaze distributions** | | | **60** |
| Gaze Plots | Abt et al. (2023)<br>Becker et al. (2023)<br>Boels et al. (2019)<br>Boels & Van Dooren (2023)<br>Casalvieri & Gambini (2022)<br>Chvatal et al. (2023) | Dirkx et al. (2021)<br>Heyd-Metzuyanim et al. (2023)<br>Maata et al. (2021)<br>Garcia Moreno-Esteva & Hannula (2021)<br>Skrabankova et al. (2020) | 11 |
| Eye-tracking videos | Baumanns et al. (2023)<br>Baumanns et al. (2022)<br>Baumanns et al. (2024)<br>Becker et al. (2023)<br>Bicer & Bicer (2023)<br>Biza et al. (2020)<br>Boels et al. (2019)<br>Boels, Lyford, et al. (2023)<br>Boels, Garcia Moreno-Esteva, et al. (2023)<br>Boels & Van Dooren (2023)<br>Casalvieri & Gambini (2022)<br>Chumachenko et al. (2024)<br>Chvatal et al. (2023)<br>Dröse et al. (2021)<br>Haataja, Garcia Moreno-Esteva et al. (2019)<br>Haataja et al. (2021)<br>Hannula & Toivanen (2019) | Heyd-Metzuyanim et al. (2023)<br>S. Kim et al. (2020)<br>Pitta-Pantazi et al. (2024)<br>Salminen-Saari et al. (2021)<br>Schindler, Bader, et al. (2019)<br>Schindler & Lilienthal (2019)<br>Schindler & Lilienthal (2020)<br>Schindler & Lilienthal (2022)<br>Schindler, Schovenberg, et al. (2020)<br>Shvarts & Abrahamson (2019)<br>Shvarts & Abrahamson (2023)<br>Simon et al. (2021)<br>Simon & Schindler (2020)<br>Simon & Schindler (2022)<br>Sprenger & Benz (2020)<br>Thomaneck et al. (2022) | 33 |
| Heatmaps | Biza et al. (2020)<br>Boels et al. (2019)<br>Boels & Van Dooren (2023)<br>Bruckmaier et al. (2019)<br>Casalvieri & Gambini (2022)<br>Hachaj et al. (2021) | Schindler, Schaffernicht & Lilienthal (2019)<br>Schindler, Schaffernicht & Lilienthal (2020)<br>Simon et al. (2023)<br>Spagnolo et al. (2021)<br>Sprenger & Benz (2020)<br>Uygun et al. (2024) | 16 |

| Eye-tracking data and data representations | | | Total |
| --- | --- | --- | --- |
| | Males & Setniker (2019) | Zhang, Song et al. (2023) | |
| | Schindler et al. (2022) | Zhang, Stylianides, & Stylianides (2023) | |
| **Fixation/saccadic measures** | | | **97** |
| Fixation measures | Bartalis et al. (2023) | Morris et al. (2022) | 73 |
| | Becker et al. (2023) | Nazareth et al. (2019) | |
| | Becker et al. (2022) | Norqvist et al. (2019) | |
| | Bhagat et al. (2021) | Norqvist et al. (2023) | |
| | Bicer & Bicer (2023) | Own et al. (2023) | |
| | Bruckmaier et al. (2019) | Peake et al. (2020) | |
| | Brückner et al. (2020) | Pouta et al. (2021) | |
| | Brunner et al. (2024) | Ranzato et al. (2020) | |
| | Chaudhuri et al. (2022) | Ruf et al. (2022) | |
| | Chen & Ho (2022) | Schnitzler et al. (2020) | |
| | Chumachenko et al. (2024) | Schreiter & Vogel (2023a) | |
| | Chvatal et al. (2023) | Schreiter & Vogel (2023b) | |
| | De Mooij et al. (2020) | Schreiter et al. (2021) | |
| | Dirkx et al. (2021) | Sharma et al. (2022) | |
| | Dröse et al. (2021) | Shojaeizadeh et al. (2019) | |
| | Dyrvold & Bergvall (2023b) | Simsek et al. (2020) | |
| | Gomez & Huron (2020) | Skrabankova et al. (2020) | |
| | Guarini et al. (2021) | Sprenger & Benz (2020) | |
| | Haataja, Toivanen et al. (2019) | Stahnke & Blömeke (2021) | |
| | Haataja, Garcia Moreno-Esteva et al. (2019) | Stahnke & Friesen (2023) | |
| | Haataja et al. (2021) | Strobel et al. (2019) | |
| | Hahn & Klein (2023) | Strohmaier et al. (2019) | |
| | Heyd-Metzuyanim et al. (2023) | Strohmaier et al. (2020) | |
| | Kang et al. (2023) | Susac et al. (2023) | |
| | S. Kim et al. (2020) | Türkoğlu & Yalçınalp (2024) | |
| | Klein, Viiri et al. (2019) | Uygun et al. (2024) | |
| | Klein, Küchemann et al. (2019) | van Leendert et al. (2019) | |
| | Kosel et al. (2021) | Viktorsson et al. (2022) | |
| | Lee et al. (2023) | J. Wang et al. (2019) | |
| | R. Li et al. (2024) | J. Wang et al. (2020) | |
| | T. Li et al. (2023) | X. Wang et al. (2022) | |
| | Liang & She (2023) | Wei et al. (2023) | |
| | Lomos et al. (2023) | Woollacott et al. (2023) | |
| | Maatta et al. (2021) | C. J. Wu et al. (2021) | |
| | Males & Setniker (2019) | Zhang, Song et al. (2023) | |
| | Malone et al. (2020) | Zhang, Stylianides, & Stylianides (2023) | |
| | Moen et al. (2020) | | |
| Saccadic measures | Boels, Lyford et al. (2023) | Schreiter et al. (2021) | 24 |
| | Boels, Garcia Moreno-Esteva et al. (2023) | Sharma et al. (2022) | |
| | Hahn & Klein (2023) | Shojaeizadeh et al. (2019) | |
| | Kang et al. (2023) | Simsek et al. (2020) | |
| | Klein, Viiri et al. (2019) | Strohmaier et al. (2019) | |
| | Klein, Küchemann et al. (2019) | Strohmaier et al. (2020) | |
| | Moen et al. (2020) | Susac et al. (2023) | |
| | Nazareth et al. (2019) | J. Wang et al. (2019) | |
| | Own et al. (2023) | J. Wang et al. (2020) | |
| | Ruf et al. (2022) | X. Wang et al. (2022) | |
| | Schreiter & Vogel (2023a) | H. Wu et al. (2024) | |
| | Schreiter & Vogel (2023b) | Zhu et al. (2019) | |
| **AOIs** | Bartalis et al. (2023) | R. Li et al. (2024) | **61** |
| | Becker et al. (2022) | Lomos et al. (2023) | |
| | Becker et al. (2023) | Maatta et al. (2021) | |
| | Bruckmaier et al. (2019) | Males & Setniker (2019) | |
| | Brückner et al. (2020) | Malone et al. (2020) | |
| | Brunner et al. (2024) | Morris et al. (2022) | |
| | Chaudhuri et al. (2022) | Nazareth et al. (2019) | |
| | Chen & Ho (2022) | Norqvist et al. (2019) | |
| | Chumachenko et al. (2024) | Norqvist et al. (2023) | |
| | Chvatal et al. (2023) | Own et al. (2023) | |
| | De Mooij et al. (2020) | Pouta et al. (2021) | |
| | Dirkx et al. (2021) | Ruf et al. (2022) | |

| **Eye-tracking data and data representations** | | | **Total** |
|---|---|---|---|
| | Dröse et al. (2021)<br>Dyrvold & Bergvall (2023a)<br>Dyrvold & Bergvall (2023b)<br>Garcia Moreno-Esteva & Hannula (2021)<br>Gomez & Huron (2020)<br>Guarini et al. (2021)<br>Gulz et al. (2020)<br>Haataja, Toivanen et al. (2019)<br>Haataja, Garcia Moreno-Esteva et al. (2019)<br>Haataja et al. (2021)<br>Hahn & Klein (2023)<br>Heyd-Metzuyanim et al. (2023)<br>Kang et al. (2023)<br>S. Kim et al. (2020)<br>Klein, Viiri et al. (2019)<br>Klein, Küchemann et al. (2019)<br>Kosel et al. (2021)<br>Lee et al. (2023)<br>T. Li et al. (2023) | Schnitzler et al. (2020)<br>Schreiter & Vogel (2023a)<br>Schreiter & Vogel (2023b)<br>Schreiter et al. (2021)<br>Sharma et al. (2022)<br>Skrabankova et al. (2020)<br>Sprenger & Benz (2020)<br>Stahnke & Blömeke (2021)<br>Stahnke & Friesen (2023)<br>Strobel et al. (2019)<br>Susac et al. (2023)<br>Türkoğlu & Yalçınalp (2024)<br>Uygun et al. (2024)<br>J. Wang et al. (2020)<br>X. Wang et al. (2022)<br>Woollacott et al. (2023)<br>H. Wu et al. (2024)<br>Zhang, Song et al. (2023) | |
| **Features apart from foveal vision** | | | **12** |
| Pupil dilation | Da Silva Soares et al. (2022)<br>Huh et al. (2019)<br>Kang et al. (2023)<br>J. Kim & Jo (2019)<br>Sharma et al. (2022) | Shojaeizadeh et al. (2019)<br>Throndsen et al. (2022)<br>T. H. Wang et al. (2024)<br>C. J. Wu et al. (2021) | 9 |
| Blinks | Shojaeizadeh et al. (2019)<br>Simsek et al. (2020) | Strohmaier et al. (2020) | 3 |

| **Data sources in addition to eye tracking** | | | **Total** |
|---|---|---|---|
| **Thinking aloud interviews** | | | **17** |
| Concurrent | Biza et al. (2020)<br>Dirkx et al. (2021)<br>Males & Setniker (2019)<br>Salminen-Saari et al. (2021)<br>Shvarts & Abrahamson (2019)<br>Shvarts & Abrahamson (2023) | Sprenger & Benz (2020)<br>Stahnke & Friesen (2023)<br>Thomaneck et al. (2022)<br>Türkoğlu & Yalçınalp (2024)<br>Uygun et al. (2024) | 11 |
| Retrospective | Brunner et al. (2024)<br>Casalvieri & Gambini (2022)<br>Hahn & Klein (2023) | Lomos et al. (2023)<br>Simon & Schindler (2020)<br>Simsek et al. (2020) | 6 |
| **Stimulated Recall interviews** | | | **16** |
| Eye-tracking data | Becker et al. (2023)<br>Bicer & Bicer (2023)<br>Boels & Van Dooren (2023)<br>Boels et al. (2019)<br>Boels, Lyford et al. (2023)<br>Boels, Garcia Moreno-Esteva et al. (2023)<br>Haataja, Garcia Moreno-Esteva et al. (2019) | Schindler & Lilienthal (2019)<br>Schindler & Lilienthal (2020)<br>Schindler & Lilienthal (2022)<br>Schreiter & Vogel (2023a)<br>Schreiter & Vogel (2023b)<br>Schreiter et al. (2021)<br>Thomaneck et al. (2022) | 14 |
| Other data | Haataja, Garcia Moreno-Esteva et al. (2019) | Pouta et al. (2021) | 2 |
| **Interviews** | Own et al. (2023)<br>Schindler, Bader, et al. (2019) | Schindler, Schovenberg & Schabmann (2020)<br>Zhang, Song et al. (2023) | **4** |
| **Observations of groups of participants or whole classes** | Haataja, Toivanen et al. (2019)<br>Haataja, Garcia Moreno-Esteva et al. (2019)<br>Haataja et al. (2021)<br>Hannula & Toivanen (2019)<br>Heyd-Metzuyanim et al. (2023) | Maatta et al. (2021)<br>Garcia Moreno-Esteva & Hannula (2021)<br>Pouta et al. (2021)<br>Schindler & Lilienthal (2022)<br>Stahnke & Blömeke (2021) | **12** |

| **Data sources in addition to eye tracking** | | | **Total** |
|---|---|---|---|
| | R. Li et al. (2024) | Stahnke & Friesen (2023) | |
| **Product collection and analysis** | Bicer & Bicer (2023) | Garcia Moreno-Esteva & Hannula (2021) | **9** |
| | Hannula & Toivanen (2019) | Schindler & Lilienthal (2020) | |
| | Heyd-Metzuyanim et al. (2023) | Schindler & Lilienthal (2022) | |
| | Lee et al. (2023) | Schnitzler et al. (2020) | |
| | Males & Setniker (2019) | | |
| **Participants' work on tasks** | | | **71** |
| Answers | Abt et al. (2023) | Liang & She (2023) | 55 |
| | Bartalis et al. (2023) | Malone et al. (2020) | |
| | Becker et al. (2022) | Moen et al. (2020) | |
| | Becker et al. (2023) | Morris et al. (2022) | |
| | Boels & Van Dooren (2023) | Nazareth et al. (2019) | |
| | Boels et al. (2019) | Norqvist et al. (2019) | |
| | Boels, Garcia Moreno-Esteva, et al. (2023) | Norqvist et al. (2023) | |
| | Boels, Lyford, et al. (2023) | Own et al. (2023) | |
| | Bruckmaier et al. (2019) | Peake et al. (2020) | |
| | Brückner et al. (2020) | Pitta-Pantazi et al. (2024) | |
| | Brunner et al. (2024) | Ranzato et al. (2020) | |
| | Casalvieri & Gambini (2022) | Schindler, Bader, et al. (2019) | |
| | Chen & Ho (2022) | Schindler, Schovenberg & Schabmann (2020) | |
| | Chvatal et al. (2023) | Simsek et al. (2020) | |
| | Da Silva Soares et al. (2022) | Skrabankova et al. (2020) | |
| | De Mooij et al. (2020) | Spagnolo et al. (2021) | |
| | Dirkx et al. (2021) | Sprenger & Benz (2020) | |
| | Dröse et al. (2021) | Strobel et al. (2019) | |
| | Gomez & Huron (2020) | Strohmaier et al. (2019) | |
| | Guarini et al. (2021) | Strohmaier et al. (2020) | |
| | Gulz et al. (2020) | Uygun et al. (2024) | |
| | Hachaj et al. (2021) | van Leendert et al. (2019) | |
| | Hahn & Klein (2023) | X. Wang et al. (2022) | |
| | S. Kim et al. (2020) | Wei et al. (2023) | |
| | Klein, Viiri et al. (2019) | Woollacott et al. (2023) | |
| | Klein, Küchemann et al. (2019) | C. J. Wu et al. (2021) | |
| | Kosel et al. (2021) | H. Wu et al. (2024) | |
| | T. Li et al. (2023) | | |
| Response times | Bartalis et al. (2023) | Ranzato et al. (2020) | 16 |
| | Bruckmaier et al. (2019) | Schindler, Bader, et al. (2019) | |
| | De Mooij et al. (2020) | Schindler, Schovenberg & Schabmann (2020) | |
| | Gomez & Huron (2020) | Skrabankova et al. (2020) | |
| | Guarini et al. (2021) | Strobel et al. (2019) | |
| | S. Kim et al. (2020) | van Leendert et al. (2019) | |
| | Moen et al. (2020) | H. Wu et al. (2024) | |
| | Peake et al. (2020) | Zhu et al. (2019) | |
| **Tests** | Baumanns et al. (2022) | Norqvist et al. (2019) | **38** |
| | Baumanns et al. (2023) | Norqvist et al. (2023) | |
| | Baumanns et al. (2024) | Own et al. (2023) | |
| | Bhagat et al. (2021) | Ranzato et al. (2020) | |
| | Boels et al. (2019) | Ruf et al. (2022) | |
| | Chaudhuri et al. (2022) | Schindler, Bader, et al. (2019) | |
| | Da Silva Soares et al. (2022) | Schindler, Schaffernicht & Lilienthal (2019) | |
| | De Mooij et al. (2020) | Schindler, Schovenberg & Schabmann (2020) | |
| | Dröse et al. (2021) | Schindler, Schaffernicht & Lilienthal (2020) | |
| | Gomez & Huron (2020) | Schindler et al. (2022) | |
| | Guarini et al. (2021) | Simon & Schindler (2020) | |
| | Hahn & Klein (2023) | Simon & Schindler (2022) | |
| | Huh et al. (2019) | Simon et al. (2023) | |
| | Kang et al. (2023) | Throndsen et al. (2022) | |
| | J. Kim & Jo (2019) | Uygun et al. (2024) | |
| | Klein, Viiri et al. (2019) | Viktorsson et al. (2022) | |
| | T. Li et al. (2023) | J. Wang et al. (2020) | |
| | Liang & She (2023) | Wei et al. (2023) | |
| | Malone et al. (2020) | C. J. Wu et al. (2021) | |

| **Data sources in addition to eye tracking** | | | **Total** |
|---|---|---|---|
| **Questionnaires** | Becker et al. (2023)<br>Bhagat et al. (2021)<br>Brückner et al. (2020)<br>Brunner et al. (2024)<br>Chaudhuri et al. (2022)<br>Chen & Ho (2022)<br>Dyrvold & Bergvall (2023a)<br>Hachaj et al. (2021)<br>Hahn & Klein (2023)<br>Klein, Viiri et al. (2019)<br>Klein, Küchemann et al. (2019)<br>T. Li et al. (2023) | Malone et al. (2020)<br>Morris et al. (2022)<br>Own et al. (2023)<br>Ruf et al. (2022)<br>Strohmaier et al. (2019)<br>Strohmaier et al. (2019)<br>Strohmaier et al. (2020)<br>Throndsen et al. (2022)<br>J. Wang et al. (2019)<br>Zhang, Song et al. (2023)<br>Zhang, Stylianides, & Stylianides (2023) | **23** |
| **Online measures** | Da Silva Soares et al. (2022)<br>Dyrvold & Bergvall (2023a)<br>J. Kim & Jo (2019)<br>Moen et al. (2020) | Salminen-Saari et al. (2021)<br>Sharma et al. (2022)<br>Türkoğlu & Yalçınalp (2024)<br>van Leendert et al. (2019) | **8** |

*Note: Studies that could not be assigned to a specific category are not listed here. The reference list for these studies can be found in the online supplement.*

**Supplementary Information 5:**

**Content areas and topics addressed by the eye-tracking studies**

A comprehensive table presenting all content areas, the detailed topics and all studies addressing these topics can be found below (Tab. 1). The results of categorizing content areas and topics are summarized in the following.

*Numbers and Operations:* At 40, most studies were conducted within the content area of Numbers and Operations. Eight topics were identified within Numbers and Operations (the number of studies in parentheses): Enumeration and quantity recognition (14), (Basic) arithmetic operations (11), Arithmetic word problems (8), Number line estimation (4), and Rational numbers (3). While studies on enumeration and quantity recognition address, for example, the topics of enumeration (counting) of objects, the Approximate Number System, or quantity recognition in whole number representations, studies addressing (Basic) Arithmetic Operations contained studies investigating addition or subtraction (e.g., Zhu et al., 2019) and multiplication or division (e.g., T. Li et al., 2023) of whole numbers. The studies on the topic of (Basic) Arithmetic Operations mostly use symbolic representation. Within the topic of Arithmetic word problems, studies examine the effects of visual cueing and illustrations on students' problem-solving processes and their ability to focus on relevant information (Wei et al., 2023; Wang et al., 2022). Other studies investigate the differences in students' fixations on specific words and how this is related to their mathematization processes (Dröse et al., 2021). Furthermore, research explores the impact of metacognitive prompts and numerical ordinality on primary school students' understanding and processing of word problems (Kang et al., 2023). Simon et al. (2020; 2022) investigates strategy use of students with and without mathematical difficulties on number line tasks.

*Algebra:* Seventeen studies were conducted in the content area of Algebra. Within Algebra, we identified five topics (number of studies in parentheses): Integer sequences (5), Patterns (4), Equations (4), Vector fields (3), Graphs & Matrices (1). Integer sequences are ordered lists of integers that are formed according to a specific rule (e.g., Fibonacci sequence: 0, 1, 1, 2, 3, 5, 8, 13, ...). Studies on the topic of integer sequences use different representations. While Biza et al. (2020) use symbolic representations for, for example, $n^2 - 2$ (i.e., tabular, scattered data pairs, and sequential), Norqvist et al. (2023) additionally use illustrations (i.e., a series of matches from which squares are laid). The topic patterns (Baumanns et al., 2024, Pitta-Pantazi et al., 2024) contains tasks on repeating patterns (blue–yellow–red–blue–yellow–red–blue–...) that have to be extended by participants. The equations topic contains studies on equations (Wei et al., 2023) or systems of equations (Malone et al., 2020) that contain variables. Malone et al. (2020), for example, investigated university students solving linear systems of equation problems with different representations (i.e., single representations (graphic, text, or formula) or a heterogeneous (e.g., text + graphic) or homogeneous (text + formula) combination). The research group in the topic of vector field investigates, among other things, differences in understanding vector fields between students instructed with and without visual cues (Ruf et al. 2019) and students' coordination strategies in translating between vector field diagrams and equations (Hahn & Klein, 2023).

*Functions and Calculus:* Fourteen studies were conducted in the content area of Functions and Calculus. In order to take account of the diversity of functions, we have differentiated between function types and categorized the following topics (the number of studies in parentheses): Graph interpretation (various) (5), Graph interpretation (linear) (3), Trigonometry (3), Differentiation & Integration (2), Parabolas (1), Relations (1). Several studies investigate the interpretation of graphs in different contexts like racetracks (Thomaneck et al. 2022) or filling of containers (Susac et al., 2023). These tasks are also commonly used in PISA Mathematics and Science. These graphs are in context and cannot be assigned to a common function type (e.g. linear, quadratic). Three studies particularly use graphs of linear functions as representation for interpretation (e.g., Becker et al. 2023; Klein, Küchemann et al., 2019). All of these latter studies are in the context of physics.

*Geometry:* With 27 studies conducted, Geometry is the second most addressed content area. The studies are categorized in the following topics (the number of studies in parentheses): Figures (14), Steiner problem (8), Mental rotation (3), Solids (2). The studies within the topic of figures primarily aim to explore how students visually engage with geometric problems and the cognitive processes underlying these interactions. Specifically, these studies investigate the development of geometric reasoning and problem-solving strategies, such as the effect of problem order on visual attention (Chvátal et al., 2023) and students' strategies when identifying (non-)prototypical triangles. Schindler and Lilienthal (2019) investigate the eye-mind hypothesis in the context of geometry. Additionally, studies study the coordination dynamics of semiotic mediation in geometric tasks, contributing to a deeper comprehension of embodied cognition in mathematics education (Shvarts & Abrahamson, 2019; 2023). A research group around Hannula and colleagues investigate processes when solving the Steiner problem and focusses, among other things, on teachers' visual attention when when scaffolding students' problem-solving processes (Haataja, Garcia Moreno-Esteva et al., 2019), or phases of the collaborative problem-solving process in the context of joint attention (Salminen-Saari et al., 2021). Studies on tasks on mental rotation investigate strategies (Nazareth et al., 2019) or the impact of trainings on the ability in mental rotation (Moen et al., 2020).

*Measurement:* Twelve studies were conducted in the content area of Measurement. There are two topics in this content area (the number of studies in parentheses): Word problem (various) (5), and Word problem (areas) (2). Studies on various word problems have different measurements. Kang et al. (2023), for example, investigate metacognitive prompts and numerical ordinality in information searching and cognitive processing using quantity, weight, and price problems. Wu et al. (2021) investigate the regulation of cognitive load and eye-movement indicators of successful solving for word problems of various topics, including comparison, baseline amount, and cost and selling prices. Two studies exclusively use word problems in the context of areas. Bicer and Bicer (2023), for example, explore the creative processes of four primary school students by using, among other tasks, an open task on areas.

*Probability and Statistics:* Ten studies were conducted in the content area of Probability and Statistics. There are five topics (the number of studies in parentheses): Histograms (data distribution) (6), Boxplots (1), Tree diagrams and Tables (1), Bar Graphs (1), and Data comparison (symbolic) (1). In Probability and Statistics, most studies investigate the interpretation of diagrams. Research from Boels and colleagues (e.g., Boels et al., 2019), as well as Schreiter & Vogel (2023a; 2023b), investigate histograms. Other studies use boxplots (Abt et al., 2023), tree diagrams and tables (Bruckmaier et al.; 2019), or bar graphs (Strobel et al., 2019). Morris et al. (2022), on the other hand, investigate the accuracy of children's data comparison strategies using symbolic representation.

**Table 2:** Content areas and topics addressed by the eye-tracking studies

| **Content and topic** | | | **Total** |
|---|---|---|---|
| **Numbers and Operations** | | | **40** |
| Enumeration / Quantity recognition | Bicer & Bicer (2023)<br>Gomez & Huron (2020)<br>Guarini et al. (2021)<br>Guiz et al. (2020)<br>Peake et al. (2020)<br>Pitta-Pantazi et al. (2024)<br>Ranzato et al. (2020) | Schindler, Schaffernicht, & Lilienthal (2019)<br>Schindler, Bader, et al. (2019)<br>Schindler, Schaffernicht, & Lilienthal (2020)<br>Schindler, Schovenberg, & Schabmann (2020)<br>Schindler et al. (2022)<br>Sprenger & Benz (2020)<br>Viktorsson et al. (2022) | 14 |
| (Basic) arithmetic operations | De Mooji et al. (2020)<br>Dryvold & Bergvall (2023a)<br>Dryvold & Bergvall (2023b)<br>T. Li et al. (2023)<br>Lomos et al. (2023)<br>Own et al. (2023) | Peake et al. (2020)<br>Sharma et al. (2022)<br>Throndsen et al. (2022)<br>Van Leendert et al. (2019)<br>Zhu et al. (2020) | 11 |
| Arithmetic word problems | Bartalis et al. (2023)<br>Dröse et al. (2021)<br>Kang et al. (2023)<br>X. Wang et al. (2022) | Wei et al. (2023)<br>C. J. Wu et al. (2021)<br>Zhang, Song et al. (2023)<br>Zhang, Stylianides, & Stylianides (2023) | 8 |
| Number line estimation | Bicer & Bicer (2023)<br>Simon et al. (2020) | Simon et al. (2022)<br>Simon et al. (2023) | 4 |
| Rational numbers | Pouta et al. (2021)<br>Schreiter et al. (2021) | H. Wu et al. (2024) | 3 |
| **Algebra** | | | **17** |
| Integer sequences | Bicer & Bicer (2023)<br>Biza et al. (2020)<br>Huh et al. (2019) | Norqvist et al. (2023)<br>Norqvist et al. (2019) | 5 |
| Patterns | Baumanns et al. (2022)<br>Baumanns et al. (2023) | Baumanns et al. (2024)<br>Pitta-Pantazi et al. (2024) | 4 |
| Equations | Malone et al. (2020)<br>Wang & Kao (2024) | Wei et al. (2023)<br>Woollacott et al. (2023) | 4 |

| Content and topic | | | Total |
|---|---|---|---|
| Vector fields | Hahn et al. (2023)<br>Klein, Viiri & Kuhn (2019) | Ruf et al. (2022) | 3 |
| Graphs & matrices | S. Kim et al. (2020) | | 1 |
| **Functions and Calculus** | | | **14** |
| Graph interpretation (various) | Becker et al. (2022)<br>Brunner et al. (2024)<br>Skrabankova et al. (2020) | Susac et al. (2023)<br>Thomaneck et al. (2022) | 5 |
| Graph interpretation (linear) | Becker et al. (2023)<br>Brückner et al. (2020) | Klein, Küchemann et al. (2019) | 3 |
| Trigonometry | Chen & Ho (2022)<br>Shvarts & Abrahamson (2023) | Woollacott et al. (2023) | 3 |
| Differentiation & Integration | Woollacott et al. (2023)<br>Casalvieri & Gambini (2022) | | 2 |
| Parabolas | Shvarts & Abrahamson (2019) | | 1 |
| Relations | S. Kim et al. (2020) | | 1 |
| **Geometry** | | | **27** |
| Figures | Chumachenko et al. (2024)<br>Chvátal et al. (2023)<br>Liang & She (2023)<br>Schindler & Lilienthal (2019)<br>Schindler & Lilienthal (2020)<br>Schindler & Lilienthal (2022)<br>Shvarts & Abrahamson (2019) | Shvarts & Abrahamson (2023)<br>Simon et al. (2021)<br>Simsek et al. (2020)<br>Spagnolo et al. (2021)<br>Turkoglu & Yalcinalp (2024)<br>Uygun et a. (2024)<br>J. Wang et al. (2019) | 14 |
| Steiner problem | Garcia Moreno-Esteva & Hannula (2021)<br>Haataja, Garcia Moreno-Esteva et al. (2019)<br>Haataja, Toivanen et al. (2019)<br>Haataja et al. (2021) | Hannula & Toivanen (2019)<br>Heyd-Metzuyanim et al. (2023)<br>Maatta et al. (2021)<br>Salminen-Saari et al. (2021) | 8 |
| Mental rotation | Da Silva Soares et al. (2022)<br>Moen et al. (2020) | Nazareth et al. (2019) | 3 |
| Solids | Bhagat et al. (2021)<br>Chen & Ho (2022) | | 2 |
| **Measurement** | | | **7** |
| Word problem (various) | Dirkx et al. (2021)<br>Kang et al. (2023)<br>Wu et al. (2021) | Zhang, Song et al. (2023)<br>Zhang, Stylianides, & Stylianides (2023) | 5 |
| Word problem (areas) | Bicer & Bicer (2023)<br>Lee et al. (2023) | | 2 |
| **Probability and Statistics** | | | **10** |
| Histograms (data distribution) | Boels et al. (2019)<br>Boels & Van Dooren (2023)<br>Boels, Lyford et al. (2023) | Boels, Garcia Moreno-Esteva et al. (2023)<br>Schreiter & Vogel (2023a)<br>Schreiter & Vogel (2023b) | 6 |
| Boxplots | Abt et al. (2023) | | 1 |
| Tree diagrams and Tables | Bruckmaier et al. (2019) | | 1 |
| Bar Graphs | Strobel et al. (2019) | | 1 |
| Data comparision (symbolic) | Morris et al. (2022) | | 1 |

*Note: Studies may be assigned to multiple contents and/or topics. Studies that could not be assigned to a specific content are not listed in this table. The complete reference list for the studies can be found in the online supplement.*

**Supplementary Information 6:**

**Phenomena addressed in the eye-tracking papers**

Our inductive analysis of didactical or pedagogical phenomena revealed a diverse set of phenomena. Some of them addressed characteristics of the task: *representations* (*n*=17), *contexts* (*n*=3), and *word problems* (*n*=8): Some studies investigated how multiple representations are linked or studied/compared different contexts. Also, in 13 studies eye tracking was used to investigate *mathematical processes*, for example, mathematical creativity, problem posing, generalization, or adaptivity.

Ten studies focused on *affective aspects*, which comprised different constructs from the affective field, such as motivation, interest and feelings, or math anxiety.

Another cluster of phenomena addressed difficulties: *mathematical (learning) difficulties* (*n*=11), *specific conditions or handicaps*, such as deaf or hard-of-hearing children or students with Williams and Down Syndrome (*n*=4), or *student difficulties and misconceptions* (*n*=3). Furthermore, 13 studies focused on other *group differences*, predominantly based on participants' expertise, or their prior knowledge or performance.

Other studies focused on *teachers or teaching aspects* in classroom (*n*=21), for example, on teacher noticing, on teachers' instructions or support for students, or their assessment of students. Furthermore, eleven studies focused on aspects of *collaboration and group* work in mathematics class.

Another cluster of studies focused on *digital learning* in mathematics (*n*=15). These studies addressed, for example, digital learning software, online learning systems, teaching videos, digital game design, or computer-based assessment.

Furthermore, 14 studies addressed task or *textbook design*, focusing, for example, on visual cues. Other studies focused on *embodied learning* activities (*n*=4), on *gender and intercultural aspects* (*n*=3), on *reading and linguistic aspects* (*n*=5). Finally, 14 studies focused on *cognitivist aspects*, such as cognitive load, intelligence, inhibitory control, or working memory.

**Table 3:** Phenomena addressed in the eye-tracking papers

| **Phenomena** | | | **Total** |
|---|---|---|---|
| **Representations** | Biza et al. (2020) | Ruf et al. (2022) | **17** |
| | Bruckmaier et al. (2019) | Shvarts & Abrahamson (2023) | |
| | Hahn et al. (2023) | Skrabankova et al. (2020) | |
| | Hannula & Toivanen (2019) | Spagnolo et al. (2021) | |
| | Lee et al. (2023) | Strobel et al. (2019) | |
| | Liang & She (2023) | Susac et al. (2023) | |
| | Malone et al. (2020) | Van Leendert et al. (2019) | |
| | Moen et al. (2020) | H. Wu et al. (2021) | |
| | Peake et al. (2020) | | |
| **Contexts (of Tasks)** | Brückner et al. (2020) | | **3** |
| | Klein, Küchemann et al. (2019) | | |
| | Thomaneck et al. (2022) | | |
| **Word Problems** | Bartalis et al. (2023) | Strohmaier et al. (2020) | **8** |
| | Dröse et al. (2021) | X. Wang et al. (2022) | |
| | Kang et al. (2023) | Wei et al. (2023) | |
| | Strohmaier et al. (2019) | C. J. Wu et al. (2021) | |
| **Mathematical Processes** | | | **13** |
| Creativity / Flexibility | Bicer & Bicer (2023) | Norqvist et al. (2019) | 6 |
| | Nazareth et al. (2019) | Schindler & Lilienthal (2020) | |
| | Norqvist et al. (2023) | Schindler & Lilienthal (2022) | |
| Emergence of New Ideas | Garcia Moreno-Esteva & Hannula (2021) | | 1 |
| Adaptivity | Baumanns et al. (2023) | | 1 |
| Problem Posing | Zhang, Song et al. (2023) | | 2 |
| | Zhang, Stylianides, & Stylianides (2023) | | |
| Generalization | Biza et al. (2020) | | 1 |
| Structure Sense / Perception | Pitta-Pantazi et al. (2024) | | 2 |
| | Sprenger & Benz (2020) | | |
| **Affective Aspects** | Bhagat et al. (2021) | Maatta et al. (2021) | **10** |
| | Brückner et al. (2020) | Schnitzler et al. (2020) | |
| | J. Kim & Jo (2019) | Strohmaier et al. (2020) | |
| | T. Li et al. (2023) | Throndsen et al. (2022) | |
| | Lomos et al. (2023) | J. Wang et al. (2020) | |
| **Mathematical Difficulties** | Baumanns et al. (2022) | Schindler, Schovenberg & Schabmann (2020) | **11** |
| | Baumanns et al. (2023) | Simon et al. (2020) | |
| | Baumanns et al. (2024) | Simon et al. (2022) | |
| | Guarini et al. (2021) | Simon et al. (2023) | |
| | Schindler, Bader, et al. (2019) | Wei et al. (2023) | |
| | Schindler, Schaffernicht & Lilienthal (2019) | | |
| **Specific Conditions or Handicaps** | Gomez & Huron (2020) | | **4** |
| | Guarini et al. (2021) | | |
| | Ranzato et al. (2020) | | |
| | Schindler et al. (2022) | | |
| **Student Difficulties / Misconceptions** | Becker et al. (2023) | | **3** |
| | Casalvieri & Gambini (2022) | | |
| | Uygun et al. (2024) | | |
| **Group Differences** | | | **13** |
| Expertise | Casalvieri & Gambini (2022) | Stahnke & Blömeke (2021) | 8 |
| | S. Kim et al. (2020) | Stahnke & Friesen (2023) | |
| | Kosel et al. (2021) | Zhang, Song et al. (2023) | |
| | Pouta et al. (2021) | Zhang, Stylianides, & Stylianides (2023) | |
| Prior Knowledge | Huh et al. (2019) | | 2 |
| | J. Kim & Jo (2019) | | |

| Phenomena | | Total |
|---|---|---|
| Performance | Lee et al. (2023)<br>Susac et al. (2023) | 2 |
| Study Program | Klein, Küchemann et al. (2019) | 1 |
| **Teachers and Teaching Aspects** | | **21** |
| Teacher-Student Interaction | Haataja, Garcia Moreno-Esteva et al. (2019)<br>Haataja, Toivanen et al. (2019)<br>Haataja et al. (2021)<br>Kosel et al. (2021)<br>Pouta et al. (2021) | 5 |
| Tutor-Student Interaction | Shvarts & Abrahamson (2019) | 1 |
| Classroom Management | Stahnke & Blömeke (2021)<br>Stahnke & Friesen (2023) | 2 |
| Scaffolding | Haataja, Garcia Moreno-Esteva et al. (2019)<br>Haataja, Toivanen et al. (2019)<br>R. Li et al. (2024) | 3 |
| Teacher Noticing / Teachers' Attention | Chaudhuri et al. (2022)<br>Stahnke & Blömeke (2021)<br>Stahnke & Friesen (2023) | 3 |
| Teachers' Support for Students / Instructions | Chaudhuri et al. (2022)<br>Maatta et al. (2021) | 2 |
| Teachers' Attention to Curriculum Materials | Males & Setniker (2019) | 1 |
| Teachers' Judgment / Assessment of Students | Kosel et al. (2021)<br>Schnitzler et al. (2020)<br>Schreiter et al. (2021) | 3 |
| Pedagogical Content Knowledge | Brunner et al. (2024) | 1 |
| **Collaboration and Group Work** | | **11** |
| Collaboration and Group Work | Haataja, Garcia Moreno-Esteva et al. (2019)<br>Haataja, Toivanen et al. (2019)<br>Haataja et al. (2021)<br>Hannula & Toivanen (2019)<br>Heyd-Metzuyanim et al. (2023)<br>R. Li et al. (2024)<br>Salminen-Saari et al. (2021)<br>Schindler & Lilienthal (2022)<br>Stahnke & Blömeke (2021) | 9 |
| Joint Attention | Salminen-Saari et al. (2021) | 1 |
| Discourse | Heyd-Metzuyanim et al. (2023) | 1 |
| **Digital Learning / Game-Based Learning** | | **15** |
| Digital Game-Based Learning | De Mooji et al. (2020)<br>Gulz et al. (2020)<br>Lomos et al. (2023)<br>Sharma et al. (2022) | 4 |
| Digital Learning System /Software | Türkoğlu & Yalçınalp (2024)<br>Own et al. (2023)<br>J. Wang et al. (2019) | 3 |
| Video-Based Learning | Chen & Ho (2022)<br>Huh et al. (2019)<br>J. Wang et al. (2020) | 3 |
| Game Design | De Mooji et al. (2020)<br>Lomos et al. (2023) | 2 |
| Computer-Based Assessment | Dirkx et al. (2021)<br>Dyrvold & Bergvall (2023a) | 2 |
| Multi-Media Learning | Dirkx et al. (2021) | 1 |

| Phenomena | | | Total |
| --- | --- | --- | --- |
| **Task Design or Other Materials** | | | **14** |
| Task Design | Brunner et al. (2024)<br>Dirkx et al. (2021)<br>Dyrvold & Bergvall (2023b)<br>Lee et al. (2023)<br>Strobel et al. (2019) | X. Wang et al. (2022)<br>Wei et al. (2023)<br>Woollacott et al. (2023)<br>Zhang, Song, et al., 2023 | 9 |
| Visual Cues | Klein, Viiri & Kuhn (2019)<br>Ruf et al. (2022) | | 2 |
| Task Demand | Shojaeizadeh et al. (2019) | | 1 |
| Text Books / Curriculum Materials | Woollacott et al. (2023)<br>Males & Setniker (2019) | | 2 |
| **Embodied Learning** | Chumachenko et al. (2024)<br>Sharma et al. (2022)<br>Shvarts & Abrahamson (2019)<br>Shvarts & Abrahamson (2023) | | **4** |
| **Gender & Intercultural Aspects** | | | **3** |
| Gender Differences | Chvátal et al. (2023)<br>Nazareth et al. (2019) | | 2 |
| Intercultural Comparison | Strohmaier et al. (2020) | | 1 |
| **Reading and Language** | | | **5** |
| Reading / Instruction Reading | Klein, Viiri & Kuhn (2019)<br>Strohmaier et al. (2019)<br>Strohmaier et al. (2020) | | 3 |
| Second Language Learning | Chen & Ho (2022) | | 1 |
| Linguistic Aspects | Dröse et al. (2021) | | 1 |
| **Cognitivist Aspects** | | | **14** |
| Cognitive Load | Chen & Ho (2022)<br>De Mooji et al. (2020)<br>Dirkx et al. (2021)<br>Huh et al. (2019) | J. Kim & Jo (2019)<br>Malone et al. (2020)<br>T.-H. Wang et al. (2024)<br>C. J. Wu et al. (2021) | 8 |
| Cognitive Effort | Da Silva Soares et al. (2022) | | 1 |
| Intelligence | Throndsen et al. (2022) | | 1 |
| Working Memory | De Mooji et al. (2020)<br>Throndsen et al. (2022) | | 2 |
| Inhibitory Control | De Mooji et al. (2020) | | 1 |
| Learning Style | Türkoğlu & Yalçınalp (2024) | | 1 |

*Note: Studies may be assigned to multiple phenomena. Studies that could not be assigned to a specific phenomenon are not listed here. The reference list for these studies can be found in the online supplement.*

# Supplementary Information 7: ChatGPT-4o Evaluation of Future Trends

## Approach (Collecting Trends)

LLM used: "ChatGPT 4o" (https://chatgpt.com/?model=gpt-4o)

- Repeat for each batch of discussions [:START:]
- Delete previous context ("New Chat")
- Extract the discussion sections from a batch of N[1] randomly selected[2] publications (considered in the ZDM Article “Eye-tracking research in mathematics and statistics education: Recent developments and future trends. A systematic literature review”)
- Upload the discussion sections of the N randomly selected publications
- Enter Prompt 1
- Collect responses and manually correct obvious mistakes
- Repeat for each batch of discussions [:END:]

All the responses were then compiled into a final document ($PDF_{Responses}$).

### Prompt 1 (Identification of Trends for each Batch of Publications)

What future trends in eye-tracking research in mathematics education can be derived from the discussion in this paper? Future trends are expected developments in the field. Please refer explicitly to the paper for each trend.

## Approach (Compiling a Summary of the Results)

We used "ChatGPT 4o" (https://chatgpt.com/?model=gpt-4o)

- Collection of the individual trends/responses (as outlined in “Approach (Collecting Trends)”) in one document ($PDF_{Responses}$)
- Delete previous context ("New Chat")
- Enter Prompt 2 and the text in $PDF_{Responses}$
- Manual merging and polishing of the trend categories

### Prompt 2 (Identification of Trend Categories)

Below are 12 summaries of discussions of 10 journal articles each on future trends in eye-tracking research in mathematics education. Develop categories within the 12 summaries by synthesizing future trends that appear in multiple abstracts. For each future trend, indicate how frequently it occurred and give the respective references.

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[1] N was usually chosen to be 10. For three batches, less than 10 discussions were chosen to realize a more even distribution between the batches.

[2] Random numbers were chosen on https://www.random.org/.

# Identification of Trends for each Batch of Publications

## Batch #01 (10 discussions)

Hahn & Klein (2023).pdf | Chumachenko et al. (2024).pdf | Brunner et al. (2024).pdf | Brückner et al. (2020).pdf | van Leendert et al. (2019).pdf | Türkoğlu & Yalçınalp (2024).pdf

Susac et al. (2023).pdf | Salminen et al. (2021).pdf | Moen et al. (2020).pdf | Klein, Viiri & Kuhn (2019).pdf

- From the analysis of the provided papers, several future trends in eye-tracking research in mathematics education can be identified:
  1. **Integration of Eye-Tracking with Other Data Sources**
     - Eye-tracking research in mathematics education is increasingly integrating with other data sources like learning traces and behavior attributes to enhance the accuracy of predicting student performance. This trend highlights a more comprehensive approach to understanding how students interact with mathematical tasks by combining eye-gaze data with additional contextual information (Türkoğlu & Yalçınalp (2024)).
  2. **Focus on Collaborative Problem Solving**
     - There is a growing interest in exploring joint attention and representational attention during collaborative problem-solving tasks. Research indicates that understanding how students coordinate their attention and interact with different representations during group work can provide deeper insights into their learning processes and the effectiveness of collaborative learning environments (Salminen et al. (2021)).
  3. **Investigating Diagnostic Processes and Task Judgment**
     - Future research is likely to focus on how eye movements reflect diagnostic processes in task judgment. Studies have shown that fixation durations on areas critical for typical student errors correlate with accurate interpretations of task difficulty. This trend suggests that eye-tracking can be an effective tool for understanding how teachers and students diagnose and interpret mathematical tasks, potentially leading to improved instructional strategies (Brunner et al. (2024)).
  4. **Use of Visual Cues and Instructional Support**
     - There is evidence that incorporating visual cues and targeted instructional support can significantly enhance students' understanding and performance in mathematics. Future research may continue to explore how different types of visual aids and instructional methods can be optimized to support the learning of complex mathematical concepts through eye-tracking data (Klein, Viiri & Kuhn (2019)).
  5. **Analysis of Individual Differences and Learning Styles**
     - Research is increasingly focusing on how individual differences, such as learning styles, affect problem-solving behaviors and performance in mathematics. Eye-tracking studies are being used to identify patterns in how different types of learners approach and solve mathematical problems, which can inform more personalized and effective teaching strategies (Türkoğlu & Yalçınalp (2024)).
  6. **Advancements in Methodological Approaches**
     - Methodological advancements, such as the development of new techniques for tracking and analyzing eye movements, are likely to continue. For example, methods like GMESS (Gaze-based Metrics for Eye-Tracking Studies) are being recommended for more precise detection of joint attention occurrences and for analyzing problem-solving phases in collaborative settings. These advancements will enhance the robustness and applicability of eye-tracking research in diverse educational contexts (Salminen et al. (2021)).
  7. **Focus on Representational Competence**
     - Future studies may place more emphasis on the role of representational competence in learning mathematics. Eye-tracking research is highlighting the challenges students face in coordinating multiple representations of mathematical concepts and how instructional interventions can support the development of this critical skill (Klein, Viiri & Kuhn (2019)).
- These trends indicate a promising direction for eye-tracking research in mathematics education, with an emphasis on integration with other data sources, collaborative learning, diagnostic processes, personalized instruction, methodological advancements, and representational competence.

## Batch #02 (10 discussions)

Skrabanova et al. (2020).pdf | Klein, Küchemann, et al. (2019).pdf | Kang et al. (2023).pdf | Dyrvold & Bergvall (2023a).pdf | C. J. Wu et al. (2021).pdf | Bruckmaier et al. (2019).pdf

Bhagat et al. (2021).pdf | Boels, Lyford, et al. (2023).pdf | Uygun et al. (2024).pdf | Strohmaier et al. (2020).pdf

- From the analysis of the provided documents, several future trends in eye-tracking research in mathematics education can be derived. Here are the trends explicitly mentioned in the papers:
  1. **Integration with Real-Time Learning Systems**
     - Future research could focus on integrating eye-tracking indicators with real-time learning systems or digital scaffolding. This would enable the provision of individualized learning materials and feedback based on real-time analysis of students' eye movements, helping them to become successful problem-solvers (C. J. Wu et al. (2021)).
  2. **Adoption of In Vivo Methodology**
     - While current research predominantly uses in vitro methodologies, future studies should adopt in vivo methodologies to explore learners' deliberative thinking in real-world contexts. This shift could open new avenues for research and application of findings in more practical, everyday learning environments (C. J. Wu et al. (2021)).
  3. **Machine Learning Analysis of Eye-Tracking Data**
     - Combining machine learning algorithms (MLA) with eye-tracking data can reveal phenomena of interest to researchers in education. This method can help interpret graphical representations and subtle differences in students' strategies that are hard to detect through other research methods (Boels, Lyford, et al. (2023)).
  4. **Assessment of Digital Literacy and Test Validity**
     - With the increasing use of computer-based assessments, future research should ensure the validity of these assessments by addressing the digital skills required. Studies should explore the impact of dynamic and interactive elements in tests and how students' familiarity with these elements influences their performance (Klein, Küchemann, et al., 2019).
  5. **Exploration of Metacognitive Processes**
     - Future studies should investigate the relationship between metacognitive processes and problem-solving strategies by using ERP[3] techniques in combination with eye-tracking. This would help to understand how cognitive and metacognitive strategies are employed during mathematical tasks (Kang et al. (2023)).
  6. **Cross-Disciplinary Applications**
     - Eye-tracking research should expand beyond mathematics to include other subjects such as biology, physics, economics, and geography. This cross-disciplinary approach can help understand how students interpret different types of graphical representations and improve instructional methods across various fields (Boels, Lyford, et al. (2023)).
  7. **Use of Qualitative Insights**
     - Future studies should combine quantitative analysis of eye-tracking data with qualitative insights to enhance the validity and reliability of the research. This approach can provide a deeper understanding of students' thought processes and strategies during problem-solving (Boels, Lyford, et al. (2023)) (Bruckmaier et al. (2019)).
  8. **Cognitive Load and Instructional Design**
     - Research should focus on how different instructional designs impact cognitive load and learning effectiveness. Eye-tracking can help design better instructional materials that align with students' cognitive processes and reduce unnecessary cognitive load (Skrabanova et al. (2020)).
- These trends highlight the potential of eye-tracking technology to revolutionize educational research by providing deeper insights into students' cognitive processes and improving instructional methods across various disciplines.

[3] ERP = event-related potential

## Batch #03 (10 discussions)

Wei et al. (2023).pdf | Strobel et al. (2019).pdf | Sharma et al. (2022).pdf | Schintzler et al. (2020).pdf | Schindler, Schovenberg, & Scha | Schindler et al. (2022).pdf

Hannula & Toivanen (2019).pdf | Haataja, Garcia Moreno-Esteva, et al. | Boels et al. (2019).pdf | Biza et al. (2020).pdf

- From the provided papers, several future trends in eye-tracking research in mathematics education can be identified. Here are some expected developments in the field, derived explicitly from the papers:
  1. **Exploration of Cognitive Load and Learning Performance**
     - Eye-tracking research will continue to explore the relationship between cognitive load and learning performance. High cognitive load has been found detrimental to learning outcomes, and future studies will likely focus on strategies to manage cognitive load through guided attention and feedback mechanisms. This involves using eye-tracking data to understand how students interact with educational content and to develop interventions that prevent cognitive overload (Sharma et al. (2022)).
  2. **Integration with Other Biometric Data**
     - There is a trend towards integrating eye-tracking data with other biometric measurements, such as heart rate and electrodermal activity (EDA), to gain a comprehensive understanding of students' engagement and stress levels during mathematical tasks. Future research will likely focus on creating multi-modal systems that combine these data sources to provide a holistic view of the learning process and improve the design of educational interventions (Sharma et al. (2022)).
  3. **Focus on Teacher Gaze and Scaffolding Interactions**
     - Eye-tracking studies will continue to investigate how teachers' gaze patterns relate to their scaffolding interactions with students. Research suggests that teachers' gaze behavior provides insights into their attentional focus and instructional intentions. Future research will explore how teachers distribute their attention across students and how this impacts student engagement and learning outcomes. This could lead to professional development programs that train teachers to use gaze more effectively in the classroom (Haataja, Garcia Moreno-...) (Schintzler et al. (2020)).
  4. **Advanced Data Analysis Techniques**
     - The application of advanced data analysis techniques, such as clustering methodologies and epistemic network analysis, will become more prevalent. These methods allow for a more detailed and nuanced understanding of eye-tracking data, revealing patterns in student behavior and cognition that are not apparent through traditional analysis. Future research will likely refine these techniques and apply them to larger datasets to uncover new insights into mathematical learning processes (Schindler et al. (2022))(Schintzler et al. (2020)).
  5. **Impact of Visual Cues on Learning**
     - The use of visual cues to guide students' attention and enhance learning is a significant trend. Research indicates that visual cues can reduce off-task behavior and improve engagement, especially for students with learning difficulties. Future studies will explore the long-term effects of visual cueing and develop best practices for incorporating these cues into educational materials and technology (Schindler, Schovenb. ...).
  6. **Real-time and Mobile Eye-tracking**
     - There will be a growing emphasis on real-time and mobile eye-tracking technologies that can be used in authentic classroom settings. These tools will enable researchers to study naturalistic learning environments and provide immediate feedback to students and teachers. Developing more comfortable and less obtrusive eye-tracking devices will also facilitate this trend (Haataja, Garcia Moreno-...).
  7. **Focus on Individual Differences**
     - Future research will pay more attention to individual differences in eye-tracking patterns, such as those related to students' cognitive abilities, prior knowledge, and emotional states. Understanding these differences will help tailor educational interventions to meet the diverse needs of learners, making personalized learning more effective (Haataja, Garcia Moreno-...) (Schintzler et al. (2020)).
- These trends reflect a growing interest in using eye-tracking technology to gain deeper insights into the cognitive and emotional processes underlying mathematical learning and teaching. By integrating eye-tracking with other data sources and applying advanced analytical techniques, researchers aim to improve educational outcomes and develop more effective teaching strategies.

## Batch #04 (10 discussions)

Bicer & Bicer (2022).pdf
Sprenger & Benz (2020).pdf
Dirkx et al. (2021).pdf
Gulz et al. (2020).pdf
Shojaeizadeh et al. (2019).pdf
Maatta et al. (2021).pdf
T. H. Wang et al. (2024).pdf
Chen & Ho (2022).pdf
Baumanns et al. (2024).pdf
Lee et al. (2020).pdf

- Based on the provided documents, several future trends in eye-tracking research in mathematics education can be identified:
  1. **Integration with Artificial Intelligence for Personalized Learning**
     - Eye-tracking data, when combined with AI, can create more robust and adaptive educational systems. This integration can lead to real-time adaptation of educational software to individual students' needs and understanding levels. This approach can significantly enhance personalized learning experiences and provide insights into students' cognitive processes and learning trajectories (Gulz et al. (2020)).
  2. **Ecological Validity and Real-World Applications**
     - Future research will likely focus on increasing the ecological validity of eye-tracking studies by conducting them in more naturalistic settings, such as classrooms, rather than controlled laboratory environments. This shift aims to gather more relevant and applicable data regarding how students interact with educational content in real-world scenarios (Gulz et al. (2020)).
  3. **Multimodal Data Integration**
     - Combining eye-tracking data with other data types, such as behavioral logs, video recordings, and verbal reports, is expected to provide a more comprehensive understanding of learning processes. This multimodal approach will help triangulate data and offer deeper insights into students' cognitive and emotional states during learning (Gulz et al. (2020)) (Lee et al. (2020)) (Baumanns et al. (2024)).
  4. **Task-Specific Eye-Tracking Metrics**
     - Future studies will likely explore the development of task-specific eye-tracking metrics. This includes investigating how different eye metrics, such as fixation duration, saccade patterns, and pupil dilation, correlate with various cognitive demands and task complexities in mathematical problem-solving (Shojaeizadeh et al. (20...)).
  5. **Adaptive and Interactive Learning Supports**
     - Research will focus on designing adaptive learning supports that respond to real-time eye-tracking data. For instance, varying the format and complexity of learning supports based on students' gaze patterns and problem-solving behaviors to enhance understanding and retention (Lee et al. (2020)).
  6. **Exploration of Cognitive Load and Task Demand**
     - Future research will delve deeper into understanding how eye-tracking can be used to measure cognitive load and task demand in educational contexts. This includes developing systems that can unobtrusively detect changes in cognitive effort and adapt instructional strategies accordingly (Shojaeizadeh et al. (20...)(Gulz et al. (2020)).
  7. **Teacher's Gaze and Classroom Dynamics**
     - Studies will also explore the role of teachers' gaze behaviors in the classroom. This research can inform teacher training programs by highlighting how teachers' eye movements influence student engagement and learning outcomes, thereby improving instructional practices (Maatta et al. (2021)).
  8. **Focus on Early Mathematics Education**
     - There is an emphasis on using eye-tracking to study early mathematical education, especially in understanding how young children perceive and interact with mathematical patterns and concepts. This can help develop more effective early childhood mathematics curricula and instructional strategies (Baumanns et al. (2024)).
- These trends indicate a significant shift towards more integrated, adaptive, and real-world eye-tracking applications in mathematics education, aiming to enhance teaching and learning processes through detailed insights into cognitive and perceptual mechanisms.

# Batch #05 (10 discussions)

Zhu et al. (2019).pdf | Zhang, Stylianides, & Stylianides (2023).pdf | T. Li et al. (2023).pdf | Schindler & Lilienthal (2019).pdf | R. Li et al. (2024).pdf | Norqvist et al. (2019).pdf

Lomos et al. (2023).pdf | Kosel et al. (2021).pdf | Haataja et al. (2021).pdf | Dröse et al. (2021).pdf

- The analysis of future trends in eye-tracking research in mathematics education based on the discussions in the provided papers highlights several key directions:
  1. **Enhanced Methodological Approaches**
     - Future research in eye-tracking should consider more dynamic and detailed metrics such as scanpaths and revisits rather than average net dwell time. This approach can better capture the processes of noticing and interpreting syntactic features in mathematical problems, as well as the construction of problem models (Haataja et al. (2021)) .
  2. **Integration with Other Research Methods**
     - Triangulating eye-tracking data with other methods, such as think-aloud protocols, recall interviews, or neuroscience techniques, can provide a more comprehensive understanding of students' cognitive processes. This integration can help overcome the inherent ambiguities in interpreting eye-tracking data alone (Haataja et al. (2021)).
  3. **Application to Diverse Mathematical Subdomains**
     - Eye-tracking research should be extended to various mathematical subdomains and age groups. Studies should explore the differences in eye-tracking patterns across different types of syntactic structures, such as active-passive constructions and comparatives, and apply these findings to different grades and mathematical content (Haataja et al. (2021)).
  4. **Development of Interpretation Tools**
     - Creating subdomain-specific interpretation tools for eye-tracking data can help educators and researchers make more accurate inferences. These tools can semi-automate the interpretation process by sequencing ET data and highlighting alternative interpretations, which could eventually become useful for teachers in real-time educational settings (Haataja et al. (2021)).
  5. **Focus on Visual Complexity and Cognitive Load**
     - Future studies should investigate the complexity of visual behavior and its relationship with cognitive load and judgment accuracy. For instance, considering metrics such as visual entropy can help understand how teachers' scanpaths influence their ability to assess student characteristics accurately (Haataja et al. (2021)).
  6. **Incorporation of Pupil Dilation Analysis**
     - Examining pupil dilation alongside gaze data can provide insights into students' cognitive load and engagement. This method can reveal how visual attention and cognitive effort vary during mathematical problem-solving (Haataja et al. (2021)).
  7. **Immediate Feedback and Interaction**
     - Using eye-tracking data to provide real-time feedback and support to students based on their visual attention can enhance learning outcomes. This approach can be particularly beneficial in online education platforms where immediate interaction and feedback are critical (Haataja et al. (2021)).
  8. **Cross-Contextual Studies**
     - Expanding eye-tracking studies to include different educational contexts, such as whole-class instructions, personal interactions, and cooperative learning environments, can provide a broader understanding of how gaze behavior influences learning and teaching dynamics (Haataja et al. (2021)).
- By addressing these trends, future eye-tracking research in mathematics education can provide deeper insights into the cognitive and interactive processes involved in learning and teaching, ultimately enhancing educational practices and outcomes.

# Batch #06 (10 discussions)

Bartalis et al. (2023).pdf | X. Wang et al. (2022).pdf | Woollacott et al. (2023).pdf | Viktorsson et al. (2023).pdf | Simsek et al. (2020).pdf | Shvarts & Abrahamson (2023).p

Schreiter & Vogel (2023b).pdf | Ruf et al. (2022).pdf | H. Wu et al. (2024).pdf | Guarini et al. (2021).pdf

- Based on the detailed discussions in the provided papers, the following future trends in eye-tracking research in mathematics education can be derived:
  1. **Integration with Diagnostic Tools**
     - Future research is expected to further explore the potential of eye-tracking as a diagnostic tool in educational settings. Eye-tracking data can help identify students' conceptions and difficulties in understanding mathematical concepts, such as the differences between local and global views of data distributions (Schreiter & Vogel (2023…) (Bartalis et al. (2023)).
  2. **Application in Teacher Training and Practice**
     - Eye-tracking research is likely to be incorporated into teacher training programs. This can help educators understand how students engage with mathematical tasks and improve instructional designs to better guide students' learning processes. This trend points to the potential use of eye-tracking data to tailor instructional materials that address specific student difficulties (Schreiter & Vogel (2023…)) (Bartalis et al. (2023)).
  3. **Enhanced Problem-Solving Insights**
     - There will be a focus on understanding the relationship between eye-tracking measures and problem-solving performance. Eye-tracking can provide detailed insights into students' cognitive processes and difficulties during problem-solving, which can inform the development of more effective teaching strategies and educational tools (Simsek et al. (2020)).
  4. **Longitudinal and Cross-Grade Studies**
     - Future studies will likely adopt longitudinal and cross-grade designs to explore how eye-tracking metrics and mathematical understanding develop over time and across different educational levels. Such studies can provide a deeper understanding of the developmental trajectories of mathematical skills and the impact of various instructional interventions (Schreiter & Vogel (2023…)) (Simsek et al. (2020)).
  5. **Incorporation of Cognitive and Behavioral Metrics**
     - Research will continue to integrate eye-tracking data with other cognitive and behavioral metrics to provide a holistic view of student learning. This includes examining how eye-tracking data correlates with traditional measures of academic achievement and cognitive load, enhancing the predictive power of these tools for academic success (Simsek et al. (2020)) .
  6. **Customization and Personalization of Learning**
     - Eye-tracking technology will be used to create more personalized learning experiences. By understanding individual students' visual attention patterns and cognitive processes, educators can customize learning materials and instructional strategies to better meet the diverse needs of students (Schreiter & Vogel (2023…)).
  7. **Integration with Digital and Interactive Resources**
     - With the growing use of digital learning environments, future research will explore how eye-tracking can be integrated with interactive digital resources to enhance learning. This includes studying the impact of digital tools on students' engagement and understanding of mathematical concepts, as well as designing digital interfaces that optimize visual attention and cognitive load (Shvarts & Abrahamson (2…)).
- These trends suggest a significant evolution in the application of eye-tracking technology in mathematics education, focusing on improving diagnostic accuracy, instructional design, and personalized learning experiences.

## Batch #07 (10 discussions)

Spagnolo et al. (2021).pdf | Shvarts & Abrahamson (2019).p | Schindler, Schaffernicht, & Lilier | S. Kim et al. (2020).pdf | Own et al. (2022).pdf | Males & Setniker (2019).pdf

Boels, Garcia Moreno-Esteva, et al. | Boels & van Dooren (22023).pdf | Becker et al. (2023).pdf | Baumanns et al. (2022).pdf

- From the provided documents, several future trends in eye-tracking research in mathematics education can be derived. These trends highlight potential developments and directions for future studies in the field.
  1. **Integration with AI and Machine Learning**
     - **Trend**: There will be increased use of AI and machine learning algorithms to analyze eye-tracking data for identifying student strategies and performance patterns.
     - **Supporting Evidence**: Schindler et al. (2020-2021) discuss the use of Self-Organizing Maps (SOM) for clustering eye-tracking data to identify consistent student strategies. They suggest future work could involve other clustering algorithms and distance metrics to yield more consistent and informative clusters(Schindler, Schaffernicht …).
  2. **Development of Adaptive Educational Materials**
     - **Trend**: Eye-tracking research will contribute to the development of adaptive educational materials that can respond to individual student needs.
     - **Supporting Evidence**: Baumanns et al. (2022) indicate that eye-tracking can provide insights into students' pattern-recognition processes, which can inform the creation of teacher materials to support students adaptively and individually (Baumanns et al. (2022)).
  3. **Exploration of Cognitive Load and Attention**
     - **Trend**: Future research will focus on understanding cognitive load and attention distribution in mathematical problem solving, using eye-tracking to optimize instructional design.
     - **Supporting Evidence**: Kim et al. (2020) highlight the role of eye-tracking in understanding how students allocate their attention and manage cognitive load when solving complex mathematical problems, suggesting implications for educational software design (S. Kim et al. (2020)).
  4. **Use in Early Childhood Education**
     - Trend: Eye-tracking will be increasingly used in early childhood education to study and enhance young learners' engagement and learning processes.
     - Supporting Evidence: Own et al. (2022) demonstrate the potential of eye-tracking in evaluating tangible user interfaces (TUIs) for preschool mathematics education, suggesting further exploration of its use in early childhood education (Own et al. (2022)).
  5. **Investigation of Instructional Design Elements**
     - Trend: Research will delve deeper into how different textual and structural elements of mathematical tasks influence student attention and performance.
     - Supporting Evidence: Spagnolo et al. (2021) explored how the structural and textual elements of mathematical tasks capture students' attention and affect their performance, indicating that eye-tracking data can inform better task design (Spagnolo et al. (2021)).
  6. **Application in Teacher Education**
     - **Trend**: Eye-tracking research will be applied to teacher education to understand how preservice teachers interact with curriculum materials and to improve their instructional planning skills.
     - **Supporting Evidence**: Males & Setniker (2019) used eye-tracking to investigate how preservice teachers (PSTs) plan lessons using different curriculum materials, providing insights that can enhance teacher education programs (Males & Setniker (2019)).
- These trends reflect the diverse applications of eye-tracking in mathematics education, from early childhood to teacher education, and emphasize the role of technology in creating adaptive and effective learning environments.

## Batch #08 (9 discussions)

Simon & Schindler (2020-2021).pdf | Simon & Schindler (2022).pdf | Ranzato et al. (2020).pdf | Norqvist et al. (2023).pdf | Malone et al. (2020).pdf | J. Kim & Jo (2019).pdf

Casalvieri & Gambini (2022).pdf | Strohmaier et al. (2019).pdf | Simon et al. (2023).pdf

- From the provided documents, several future trends in eye-tracking (ET) research in mathematics education can be identified:
  1. **Integration with AI for Enhanced Data Analysis**
     - Future research is likely to increasingly integrate AI technologies with ET to analyze gaze patterns. AI can help cluster data and identify patterns that might not be immediately visible to human researchers, providing more detailed insights into students' strategies. For example, Simon et al. (2023) utilized AI to analyze gaze heatmaps, finding significant differences in strategy use between students with and without mathematical difficulties (MD) (Simon & Schindler (2020…).
  2. **Focus on Peripheral Vision and Broader Visual Field**
     - Since traditional ET captures foveal data, future research may expand to include peripheral vision to better understand the full scope of visual processing during mathematical tasks. Simon & Schindler (2020-2021) suggest that peripheral vision plays a significant role in tasks like number line estimation, which is not fully captured by current ET technology (Simon & Schindler (2020…).
  3. **Enhanced Understanding of Strategy Differences**
     - Future studies are expected to delve deeper into understanding the differences in strategies between students with and without MD, particularly in tasks that involve complex visual processing. Simon & Schindler (2022) noted differences in how these groups use counting and direct strategies on number lines, indicating that more advanced tasks might reveal further distinctions (Simon & Schindler (2020…).
  4. **Application of ET in Diverse Mathematical Contexts**
     - Expanding the use of ET to different types of mathematical problems beyond traditional tasks, such as word problems (WPs) and dynamic tasks, could provide a more comprehensive understanding of student learning processes. Strohmaier et al. (2019) highlight the potential for using ET in various contexts, including complex mathematical texts and real-world applications (Strohmaier et al. (2019)).
  5. **Combining ET with Other Research Methods**
     - Future research might increasingly combine ET with other qualitative methods, such as think-aloud protocols and stimulated recall interviews, to triangulate data and provide a richer understanding of cognitive processes. This approach is suggested by the need to resolve contradictions between ET and other methods like think-aloud (TA) protocols (Simon & Schindler (2020…)(Norqvist et al. (2023)).
  6. **Quantification and Analysis of Human Attention**
     - ET's ability to objectively measure attention provides valuable insights into how students engage with mathematical tasks. Future studies could leverage this strength to better understand and quantify students' reasoning and attention during problem-solving (Norqvist et al. (2023)).
  7. **Development of Mobile and Less Invasive ET Technologies**
     - The advancement of mobile ET glasses and other less invasive technologies will likely enable more naturalistic studies of student behavior in classroom settings. This will help researchers understand how students interact with both digital and paper-based materials in real-world learning environments (Strohmaier et al. (2019)).
- These trends suggest a future where ET research in mathematics education becomes more integrated with advanced technologies, provides deeper insights into student cognitive processes, and expands its applicability to a variety of educational contexts.

## Batch #09 (10 discussions)

Schreiter et al. (2021).pdf | Schreiter & Vogel (2023a).pdf | Schindler, Schaffernicht, & Lilier | Peake et al. (2020).pdf | Nazareth et al. (2019).pdf | Morris et al. (2022).pdf

Liang & She (2023).pdf | Haataja, Toivanen, et al. (2019).pdf | Abt et al. (2023).pdf | Stahnke & Friesen (2023).pdf

- Based on the provided excerpts from the papers, here are the future trends in eye-tracking research in mathematics education:
  1. **Development of Coding Schemes for Qualitative Analysis**
     - Future research will likely focus on creating detailed coding schemes for eye-tracking data. These schemes will help systematically identify areas of interest and typical patterns of transitions, facilitating both qualitative and quantitative analyses. This approach can help in understanding students' problem-solving processes and cognitive profiles when dealing with mathematical tasks such as comparing data distributions using box plots (Abt et al. (2023)).
  2. **Integration of AI and Eye-Tracking for Identifying Learning Differences**
     - The combination of eye-tracking and AI for pattern recognition is expected to advance. This integration will help in identifying group differences in gaze patterns, which can indicate different strategy uses among students. Future research will aim to determine a set of tasks that can reliably classify students' learning needs, which can then be used to provide targeted support (Schindler, Schaffernicht ...).
  3. **Focus on Instructional Design in Teacher Education**
     - Eye-tracking research will continue to explore how specific knowledge about difficulty-generating task characteristics influences teachers' diagnostic judgments. Future studies will likely investigate how teachers' understanding of both mathematical and instructional task characteristics can be enhanced through eye-tracking data, ultimately aiming to improve teacher training programs (Schreiter et al. (2021)).
  4. **Investigating Teacher-Student Nonverbal Communication**
     - Future studies will delve deeper into the role of teacher-student eye contact during instructional scaffolding. This research will help in understanding how visual attention is directed and how it influences students' learning processes. There will be a focus on comparing gaze behaviors across different teachers and students to uncover general patterns in nonverbal interaction during mathematics lessons (Haataja, Toivanen, et a...).
  5. **Understanding the Cognitive Processes Involved in Numerical Comparison**
     - Eye-tracking will be used to further investigate the cognitive processes underlying numerical comparison tasks. Future research will aim to distinguish between bottom-up perceptual processes and top-down decision-making processes by analyzing the duration of first fixations. This understanding can help refine numerical cognition theories and educational practices (Peake et al. (2020)).
  6. **Eye-Tracking as a Diagnostic Tool in Statistical Education**
     - The potential of eye-tracking as a diagnostic tool to detect students' conceptions and difficulties in statistical thinking will be explored further. Future research will examine how students perceive and process local and global distributional features in data visualizations. This will help in designing instructional strategies that guide students towards a more global understanding of data, which is crucial for effective statistical reasoning(Schreiter & Vogel (2023...).
- These trends highlight the expanding role of eye-tracking technology in providing detailed insights into the learning processes in mathematics education, ultimately aiming to improve instructional methods and educational outcomes.

## Batch #10 (10 discussions)

Thomaneck et al. (2022).pdf
Pouta et al. (2021).pdf
Pitta-Pantazi et al. (2024).pdf
Huh et al. (2019).pdf
Heyd-Metzuyanim et al. (2023).pdf
Gomez & Huron (2020).pdf
De Mooij et al. (2020).pdf
Da Silva Soares et al. (2022).pdf
Becker et al. (2022).pdf
Baumanns et al. (2023).pdf

- From the discussion sections of the provided papers, several future trends in eye-tracking research in mathematics education can be derived:
  1. **Integration with Artificial Intelligence (AI)**
     - Future research may involve integrating AI to analyze eye-tracking data, which can significantly enhance the automation and accuracy of interpreting students' strategies and thinking processes. Machine learning, both supervised and unsupervised, can facilitate the analysis of large datasets and support qualitative analyses (Pitta-Pantazi et al. (2…)).
  2. **Personalized Learning Environments**
     - Eye-tracking data can be used to create adaptive learning environments that respond in real-time to students' needs. By analyzing gaze data, intelligent tutoring systems can identify when a student is struggling and provide immediate, tailored assistance to prevent errors and enhance learning outcomes (Becker et al. (2022)).
  3. **Early Identification of At-risk Students**
     - Eye-tracking can help in the early identification of students who are at risk of developing mathematical difficulties. By examining how students approach and solve tasks, educators can detect patterns that indicate potential learning issues and intervene early (Pitta-Pantazi et al. (2…)).
  4. **Combination with Other Methodologies**
     - Combining eye-tracking with other research methodologies, such as discourse analysis, can offer a more comprehensive understanding of both social and cognitive aspects of learning. This mixed-method approach can help in studying the effectiveness of group problem-solving and the role of non-verbal communication in learning (Thomaneck et al. (2022)) (Heyd-Metzuyanim et al. …).
  5. **Professional Development for Teachers**
     - Applying eye-tracking technology in teacher training can enhance teachers' professional vision by focusing on students' thinking processes rather than just their actions. This can lead to more effective noticing and interpretation skills, which are crucial for providing appropriate instructional support (Pouta et al. (2021)).
  6. **Real-time Data Processing and Predictive Analytics**
     - Future research should focus on developing real-time data processing capabilities to enable predictive analytics based on eye-tracking data. This will allow for immediate feedback and support during the learning process, improving student engagement and performance (Becker et al. (2022)).
  7. **Expanded Research on Cognitive Load**
     - Further investigations into how eye-tracking can measure cognitive load dynamically during the learning process can provide deeper insights into how different tasks and prior knowledge levels affect students. This can help in designing more effective instructional materials and learning environments (Huh et al. (2019)) (Pouta et al. (2021)).
  8. **Exploring Developmental Differences**
     - Future studies might examine how eye-tracking data varies across different age groups and abilities, helping to understand how developmental differences impact mathematical learning and strategy use (Pitta-Pantazi et al. (2…)).
- By addressing these trends, future research can leverage eye-tracking technology to enhance educational practices, provide personalized learning experiences, and support teachers in fostering better learning outcomes for students in mathematics education.

## Batch #11 (7 discussions)

Zhang, Song, et al. (2023).pdf    Stahnke & Blömeke (2021).pdf    Schindler, Bader at al. (2019).pdf    Schindler & Lilienthal (2020).pdf    J. Wang et al. (2020).pdf    Chvátal et al. (2023).pdf

Chaudhuri et al. (2022).pdf

- Based on the detailed analysis of the provided documents, here are the future trends in eye-tracking research in mathematics education:
  1. **Integration of Haptic and Eye-Tracking Technologies**
     - Future research will investigate the combination of haptic didactic aids and eye movement tracking glasses. This approach aims to explore how students interact with real geometric objects, providing deeper insights into their cognitive processes when solving geometry problems (Chvátal et al. (2023)).
  2. **Focus on Metacognitive Strategies**
     - There is a recognized need to delve deeper into students' metacognitive strategies. Future studies will likely explore how students plan, monitor, and evaluate their problem-solving processes using eye-tracking to capture these cognitive activities in real-time (Chvátal et al. (2023)).
  3. **Application in Teacher Training**
     - Eye-tracking research will continue to influence teacher training programs. By understanding where teachers focus their attention, training can be tailored to improve classroom management and instructional strategies, ultimately enhancing teaching efficacy and student support (Stahnke & Blömeke (2021)).
  4. **Examination of Classroom-Related and Teacher-Related Factors**
     - Future research will likely investigate how various contextual factors, such as classroom environment and teacher characteristics (e.g., age, experience, stress levels), influence teachers' visual focus of attention. This will help in understanding the complexities of classroom dynamics and teacher-student interactions (Stahnke & Blömeke (2021)).
  5. **Enhanced Analysis Techniques**
     - The development of automated analysis techniques for eye-tracking data is anticipated. This would allow more efficient and comprehensive analysis of students' problem-solving strategies and could lead to the creation of adaptive learning tools that respond to individual student needs (Zhang, Song, et al. (20...).
  6. **Exploration of Cognitive Load and Attention**
     - Future studies will explore the relationship between cognitive load and visual attention in mathematical problem-solving. Understanding how time constraints and task complexity affect students' cognitive load can inform the design of more effective educational interventions (Chvátal et al. (2023)).
  7. **Subject-Specific Variations**
     - Differentiating the impact of eye-tracking across various subjects (e.g., math versus literacy) will be an area of interest. This can reveal potential subject-specific strategies in teachers' visual focus and individual student support (Stahnke & Blömeke (2021)).
  8. **Use of EEG and FMRI**
     - Combining eye-tracking with other neuroimaging techniques like EEG and FMRI is expected to provide a more comprehensive understanding of the cognitive processes involved in problem-posing and solving. This interdisciplinary approach can offer insights into the neural underpinnings of mathematical cognition (Zhang, Song, et al. (20...).
  9. **Longitudinal Studies**
     - Conducting longitudinal studies to observe how teachers' visual focus of attention evolves over an academic year can provide insights into the development of teaching practices and their impact on student learning outcomes (Stahnke & Blömeke (2021)).
- These trends highlight the evolving nature of eye-tracking research in mathematics education, focusing on technological integration, cognitive strategy analysis, teacher training, and interdisciplinary approaches to better understand and support mathematical learning.

## Batch #12 (7 discussions)

Schindler & Lilienthal (2022).pdf
J. Wang et al. (2019).pdf
Hachaj et al. (2021).pdf
Garcia Moreno-Esteva & Hai
Dyrvold & Bergvall (2023b).pdf
Throndsen et al. (2022).pdf
Simon et al. (2021).pdf

- From the discussion in the provided papers, several future trends in eye-tracking research in mathematics education can be derived. Here are some of the expected developments in the field:
  1. **Integration of Eye-Tracking with Other Usability Evaluation Methods**
     - Future research is likely to combine eye-tracking data with traditional usability testing methods to provide a more comprehensive understanding of user interactions and cognitive processes. Eye-tracking metrics such as number of fixations, average fixation duration, and saccade amplitude can offer additional insights that complement standard usability measures, revealing deeper usability issues and informing interface design improvements (Simon et al. (2021)).
  2. **Dynamic and Interactive Digital Teaching Materials**
     - There is a growing interest in incorporating dynamic and interactive elements in digital teaching materials to enhance student engagement and persistence. Studies indicate that students spend more time and attention on dynamic resources compared to static text, suggesting that these elements can make mathematical concepts more accessible and support deeper learning (Simon et al. (2021)).
  3. **Longitudinal Studies on Cognitive Effort and Problem Difficulty**
     - Future research might focus on longitudinal studies to better understand the stability of mathematics anxiety (MA) and its impact on cognitive effort over time. This approach could help in identifying how problem difficulty influences cognitive effort across different educational stages and how these factors interact with MA (Simon et al. (2021)).
  4. **Application of Eye-Tracking in Collaborative Learning**
     - The use of eye-tracking in studying collaborative creative processes in mathematics education is expected to grow. This includes exploring how students work together on mathematical problem-solving tasks and how their visual attention and cognitive processes are distributed and coordinated in a collaborative setting (Simon et al. (2021)).
  5. **Investigating Eye-Tracking Metrics in Various Geometric Identification Tasks**
     - There is potential for further research to apply eye-tracking to the identification of different geometric shapes beyond triangles. Such studies can help in understanding the visual strategies students use and how these strategies are influenced by the attributes of the shapes being identified (Simon et al. (2021)).
  6. **Advanced Data Analysis Techniques for Eye-Tracking Data**
     - The development of more sophisticated data analysis techniques, such as scanning signatures, can help synthesize complex eye-movement behaviors in a quantitative and intuitive manner. These techniques can provide detailed insights into how students interact with visual information and navigate problem-solving tasks (Simon et al. (2021)).
- By exploring these trends, future research can enhance our understanding of how students learn mathematics and how educational tools and methods can be optimized to support this learning process.

# Identification of Trend Categories

## ChatGPT-Response

Based on the analysis of the 12 discussions, several future trends in eye-tracking research in mathematics education emerge. These trends reflect recurring themes and directions highlighted across multiple discussions. Here are the synthesized future trends, their frequencies, and respective references:

**1. Integration with Other Data Sources**

**Frequency: 5 References**

- Integration of eye-tracking with learning traces and behavior attributes to enhance predictive accuracy (Türkoğlu & Yalçınalp (2024))
- Integration with real-time learning systems and digital scaffolding (C. J. Wu et al. (2021))
- Integration with other biometric measurements like heart rate and electrodermal activity (Sharma et al. (2022))
- Multimodal data integration, combining eye-tracking with behavioral logs, video recordings, and verbal reports (Gulz et al. (2020), Lee et al. (2020), Baumanns et al. (2024))
- Triangulation with other research methods such as think-aloud protocols and neuroscience techniques (Haataja et al. (2021))

**2. Focus on Cognitive Load and Learning Performance**

**Frequency: 4 References**

- Relationship between cognitive load and learning performance, strategies to manage cognitive load (Sharma et al. (2022))
- Cognitive load and instructional design (Skrabanova et al. (2020))
- Cognitive load and visual complexity, examining pupil dilation (Haataja et al. (2021))
- Cognitive load dynamics during the learning process (Huh et al. (2019), Pouta et al. (2021))

**3. Personalized and Adaptive Learning**

**Frequency: 4 References**

- Personalized learning through AI and adaptive systems (Gulz et al. (2020))
- Customized learning materials based on individual visual attention patterns (Schreiter & Vogel (2023))
- Real-time adaptation and immediate feedback in online platforms (Haataja et al. (2021))
- Adaptive educational materials informed by eye-tracking data (Baumanns et al. (2022))

**4. Advanced Data Analysis Techniques**

**Frequency: 4 References**

- Advanced data analysis techniques like clustering and epistemic network analysis (Schindler et al. (2022), Schintzler et al. (2020))
- Machine learning analysis of eye-tracking data (Boels, Lyford, et al. (…))
- Automated analysis techniques for eye-tracking data (Zhang, Song, et al. (20…))
- Use of AI for enhanced data analysis (Simon & Schindler (2020…))

**5. Teacher Gaze and Instructional Practices**

**Frequency: 4 References**

- Investigating teacher gaze patterns and scaffolding interactions (Haataja, Garcia Moreno-…) (Schintzler et al. (2020))
- Teacher training programs utilizing eye-tracking (Stahnke & Blömeke (2021))
- Eye-tracking in teacher education to enhance professional vision (Pouta et al. (2021))
- Examining classroom-related and teacher-related factors (Stahnke & Blömeke (2021))

**6. Early Identification and Intervention**

**Frequency: 3 References**

- Early identification of at-risk students through eye-tracking (Pitta-Pantazi et al. (2…))
- Eye-tracking as a diagnostic tool in educational settings (Schreiter & Vogel (2023…), Bartalis et al. (2023))
- Identifying learning differences and providing targeted support (Schindler, Schaffernicht …)

**7. Collaboration and Joint Attention**

**Frequency: 3 References**

- Focus on collaborative problem-solving and joint attention (Salminen et al. (2021))
- Eye-tracking in collaborative learning settings (Simon et al. (2021))
- Use of visual cues to support joint attention in group tasks (Salminen et al. (2021))

**8. Ecological Validity and Real-World Applications**

**Frequency: 3 References**

- Conducting eye-tracking studies in naturalistic settings like classrooms (Gulz et al. (2020))
- Use of mobile eye-tracking technologies in authentic classroom settings (Haataja, Garcia Moreno-…)
- Increasing ecological validity of eye-tracking research (Gulz et al. (2020))

**9. Exploration of Metacognitive Processes**

**Frequency: 3 References**

- Investigating metacognitive strategies using eye-tracking (Kang et al. (2023))
- Focus on metacognitive processes in problem-solving (Chvátal et al. (2023))
- Combining eye-tracking with ERP techniques to study metacognitive processes (Kang et al. (2023))

**10. Cross-Disciplinary Applications**

**Frequency: 2 References**

- Applying eye-tracking research to other subjects like biology, physics, economics, and geography (Boels, Lyford, et al. (…))
- Differentiating impact across various subjects (Stahnke & Blömeke (2021))

By synthesizing these trends, the landscape of future eye-tracking research in mathematics education reveals a strong emphasis on integrating advanced technologies and methods, enhancing personalized learning and instructional practices, and applying eye-tracking in diverse and real-world educational contexts.

# Manual Merging and Polishing of the Trend Categories

See text in the main body of the paper.

## Grouping and Visualization of the Trend Categories