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ONLINE EYE-TRACKING: OBSERVING THE ATTENTION OF PRE-SERVICE CHEMISTRY TEACHER FROM NON-SCIENCE BACKGROUNDS IN SOLVING CHEMISTRY PROBLEMS

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ABSTRACT

Recent advances in online eye-tracking allow researchers to capture eye movements as visible markers of attentional processes. This study adopts a mixed-methods design using webcam-based eye tracking via the RealEye platform to profile the attentional patterns of pre-service chemistry teachers who completed non-science tracks in high school. Two participants from the Chemistry Education program at UIN Antasari Banjarmasin undertook a problem-solving task in chemistry; their eye movements were recorded and analyzed descriptively. In framing attention, we distinguish between overt orientation—shifts in gaze toward a target—and covert orientation—mental shifts of focus without corresponding eye movements. Findings indicate that both participants required a comparatively longer time to observe, read, and solve the given problems. These attentional profiles align with their problem-solving outcomes, which fell into the medium and low performance categories. The results suggest that a non-science secondary background may be associated with less efficient visual strategies when tackling chemistry tasks. Targeted instructional support—such as scaffolded practice with chemical representations and stepwise problem decomposition—may therefore be warranted in teacher-education curricula.

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INTRODUCTION

Understanding how students from non-science backgrounds approach and solve chemistry problems is critical to developing effective teaching strategies, particularly in classes that include such students [1]. Conventional methods of assessing learning often rely on self-reported data or limited behavioral observations, which may not fully capture the underlying cognitive processes [2].

Eye-tracking technology represents a valuable method for observing students' visual attention and eye movements. It offers deeper insights into the strategies employed during problem-solving and can even be used to assess students' metacognitive skills [3]. Eye tracking has been widely applied in various fields of research and, in recent years, has gained increasing attention in science education, particularly in chemistry, as demonstrated by multiple studies [4]–[10].

For instance, an eye-tracking study revealed that eye movement data could expose students' difficulties in using the periodic table to solve problems [11]. Moreover, eye tracking can serve as an effective tool in analyzing different levels of representation in chemistry education [12].

Eye tracking involves measuring where and for how long students focus their attention on specific elements of a task—such as equations, images, or texts. This method provides insights into cognitive load, reading comprehension, and decision-making processes [13]. By analyzing eye-tracking data, researchers—who are often educators—can identify patterns and pinpoint areas where students may struggle, thereby enabling targeted interventions to enhance learning outcomes. Furthermore, this technique facilitates the identification of factors influencing students' visual attention during problem-solving in chemistry.

One of the tools used to assess students' attention in solving chemistry problems is the eye tracker (also known as a gaze recorder). With recent advancements, eye trackers are now available in online formats, including webcam-based eye tracking. One such platform is **RealEye** (www.realeye.io), which enables marketers, educators, and UX designers to collect data on participants' visual behavior using standard desktops, laptops, or mobile devices [14]. According to the RealEye website, approximately 43 published studies have employed this platform as a research instrument.

This study aims to utilize online eye-tracking techniques to observe the visual attention of pre-service chemistry teachers from non-science backgrounds as they solve chemistry problems. The use of advanced eye-tracking software and hardware will enable researchers to collect detailed data on fixation durations, thereby providing a comprehensive profile of students' visual attention. This data may be used to develop more effective instructional materials and pedagogical strategies tailored to the unique challenges faced by non-science background pre-service teachers.

By leveraging the capabilities of eye-tracking technology, this study seeks to deepen our understanding of how students from diverse academic backgrounds engage with complex scientific content. Ultimately, the findings aim to contribute to the development of more inclusive and supportive educational environments. Furthermore, this research highlights the potential of webcam-based eye-tracking applications—particularly RealEye—as accessible tools for assessing student attention in educational settings.

METHODS

1. Research Methods

This study employed a mixed-methods approach using a sequential explanatory design. The first phase involved the collection and analysis of quantitative data, followed by a qualitative phase aimed at providing deeper insights into the quantitative findings.

2. Data Collection Technique

Data were collected using three main methods. First, online eye tracking was conducted using the RealEye platform (https://www.realeye.io/), which utilizes webcam technology to record participants' eye movements. Second, a chemistry problem-solving test was administered, comprising two main questions, each containing six sub-questions structured according to recognized problem-solving stages. Third, semi-structured interviews were conducted to investigate participants' reading strategies, focus of attention, and underlying reasons for observed attention patterns and durations. This qualitative data served to contextualize and deepen the interpretation of the eye-tracking results..

3. Research Subjects

Two pre-service chemistry teachers with non-science backgrounds from the Chemistry Education Study Program at UIN Antasari Banjarmasin participated in a chemistry problem-solving task. The participants, currently in their 4th and 6th semesters, had completed both basic and advanced chemistry courses. Eye-tracking activities were conducted while they worked on the tasks to observe their visual attention patterns, which serve as indicators of cognitive engagement..

4. Eye Tracking Data Analysis

Eye movement data were analyzed descriptively to identify observation durations, primary focus areas, and visual efficiency during the problem-solving process. Following the quantitative analysis, a qualitative phase was conducted to further investigate participants' attention-related behaviors. The visual attention of pre-service chemistry teachers during problem solving was measured using an eye-tracking observation technique via the RealEye application.

The data collected included eye movement recordings in the form of gaze points, complete with fixation data and fixation plots. Additionally, CSV-format data were obtained, which included variables such as participant quality grade, item quality grade, test item display order, exposure number, fixation point coordinates (x and y), fixation start and end times (ms), fixation duration (ms), and saccade amplitude (percent). The observed behaviors included eye movements, gaze direction, and body posture [15]. Further factors influencing students' attention during problem solving were identified through interviews.

5. Sampling Selection Techniques

The study employed a purposive sampling technique. The participants were two female pre-service chemistry teachers enrolled in the Chemistry Education Study Program at UIN Antasari Banjarmasin. Both had non-science backgrounds in high school, specifically majoring in social studies, yet chose to pursue chemistry education at the university level. At the time of data collection, the participants were in their 4th and 6th semesters, respectively. Although they were at different stages in their academic program, both had completed basic and advanced chemistry courses. Based on this, the researcher assumed they possessed comparable foundational knowledge in chemistry. Additionally, their age difference was minimal, with only a one-year gap.

6. Research Instruments

The instruments used in the research were (1) an online research platform using webcam eye-tracking (RealEye); (2) computer devices; (3) chemistry problem-solving questions consisting of 2 main questions with 6 sub-questions each, arranged according to the problem-solving steps; (4) interview guidelines.

7. Research Procedures

Prior to data collection, several conditions were ensured to minimize potential disturbances or biased responses. These included verifying that participants were ready to take the test, were physically and mentally healthy (and had eaten breakfast beforehand), and were situated in a conducive environment. Additional measures included ensuring that room lighting was appropriate, no individuals were passing by during the session, and the positions of the computer screen, mouse, and keyboard were easily accessible. Participants' sitting posture, head position, and distance from the screen were also adjusted for comfort and aligned with the position established during the initial calibration of the RealEye eye-tracking webcam. During the data collection phase, participants completed chemistry problem-solving tasks while their attention was tracked using the RealEye platform. Eye movement data were recorded in the form of gaze points, fixation durations, and fixation counts. Following this, semi-structured interviews were conducted to qualitatively interpret and contextualize the quantitative data obtained from the eye-tracking analysis.

8. Data analysis

This study employed both quantitative and qualitative descriptive analyses [16]. The quantitative analysis focused on fixation duration data, as Areas of Interest (AOIs) were not defined during the experiment. As a result, the exported data from RealEye, in CSV format, consisted of fixation data across the entire display rather than specific AOIs. The number of fixations, or fixation count, was determined by counting the number of rows in the fixation dataset. This analysis was further supported by the participants' scores on the chemistry problem-solving tasks. The qualitative analysis involved interpreting eye movement recordings from RealEye, examining participants' problem-solving processes and written responses, and analyzing data obtained from interviews. These qualitative findings were integrated with the quantitative results to provide a more comprehensive understanding of participants' attention patterns during problem solving [16].

RESULT AND DISCUSSION

The research data regarding the visual attention of pre-service chemistry teachers with non-science backgrounds during chemistry problem solving are summarized in Table 1.

Table 1. Eye Tracking Fixation Data, Results and Chemistry Problem Solving Categories.

Data	Respondent 1			Respondent 2		
	Q1	Q2	Q1&2	Q1	Q2	Q1&2
Problem Solving Score	15	18	33	2	5	7
Problem Solving Values	36	43	**79**	5	12	**17**
Problem Solving Category			**Medium**			**Low**
Participant Quality Grade	**3**	**4**	**3.5**	**4**	**4**	**4**
Number of Fixation Duration (ms)	**994909**	**1066115**	**2061024**	**1398918**	**1527548**	**2926466**
Average Fixation Duration (ms)	**313.55468**	**281.89**	**296.34**	**326.85**	**344.04**	**335.6038991**
Fixation Count	3173	3782	6955	4280	4440	8720

The attention patterns of pre-service chemistry teachers with non-science backgrounds, as measured through online eye tracking, can be interpreted based on the data presented in Table 1, in conjunction with findings from related prior studies. The data include fixation metrics such as total and average fixation duration, fixation count, problem-solving scores, and participant quality grades. These indicators provide insight into participants' cognitive engagement and the effectiveness of their problem-solving strategies.

1. Problem-Solving Scores and Values

The problem-solving scores and values obtained by Respondent 1 for each question were consistently higher than those of Respondent 2. Similarly, when combining the results for both Question 1 and Question 2 (Q1 & Q2), Respondent 1 demonstrated significantly superior performance. This indicates that, individually, Respondent 1 possessed more effective problem-solving abilities than Respondent 2.

The findings suggest that Respondent 1 was better able to regulate cognitive strategies, such as identifying key information, applying relevant chemical concepts, and constructing step-by-step solutions. In contrast, Respondent 2 appeared to struggle from the initial stage of understanding the questions, which contributed to their lower scores and performance level. These results align with findings reported by [16], who observed that students employing systematic problem-solving strategies tended to achieve higher scores, even if their overall attention duration was not particularly high.

2. Problem-Solving Categories

Respondent 1's problem-solving ability falls within the medium category, while Respondent 2 is categorized as low. Respondent 1 demonstrated the ability to identify key information, apply relevant chemical concepts, and complete solution steps in a structured and systematic manner, indicating the use of scientific thinking strategies. In contrast, Respondent 2 appeared to have difficulty processing information, likely due to a limited understanding of chemical concepts.

The low score achieved by Respondent 2 suggests that extended task duration does not necessarily correlate with successful problem solving in the absence of appropriate conceptual understanding and strategic application. This is reflected in prolonged, yet repetitive, fixations on the same areas of the task interface [17].

3. Participant Quality Grade

The participant quality grades for Respondent 1 and Respondent 2 were 3.5 and 4.0, respectively, which fall under the "Good" category. These values indicate that the eye-tracking data collected from both participants are of sufficient quality for further analysis. The difference in their problem-solving performance, therefore, cannot be attributed to technical errors in data recording [18]. This finding is supported by research from [19], which emphasizes that while participant quality is a necessary technical prerequisite for valid eye-tracking data, it does not directly determine the success or outcome of the task.

4. Fixation Duration and Count

The data on fixation duration and fixation count suggest that both respondents devoted considerable time to observing, reading, understanding, and attempting to solve the chemistry problems. Typically, higher fixation durations and counts are associated with successful problem-solving, as they may reflect deeper cognitive processing. In most cases, this increase is not observed among individuals who fail to solve problems effectively [20].

Supporting this, Türkoğlu (2024) found that students who spent more time reading the questions and had a higher number of fixations in the initial comprehension phase tended to achieve higher problem-solving scores [16]. Similar conclusions were drawn by Sajka and Rosiek [21], and Dobias et al. [22], who stated that extended fixation duration and increased fixation counts generally contribute positively to problem-solving success.

However, the current study reveals a notable exception in the case of Respondent 2, who exhibited high fixation duration and count but scored only 17, placing her in the low problem-solving category. This discrepancy suggests that increased visual attention alone does not guarantee successful problem resolution. As highlighted by Chettaoui et al. [19], integrating eye-tracking data with additional learning traces and behavioral attributes is necessary to improve the accuracy of predicting student learning outcomes, particularly in complex cognitive tasks such as problem solving.

In describing the attention patterns of pre-service chemistry teachers from non-science backgrounds, this study integrates quantitative data (e.g., fixation duration and count) with qualitative data from RealEye gaze point recordings and participant interviews. While previous studies have used fixation duration as an indicator of cognition and attention [23], relying solely on these metrics may be inadequate, especially in studies involving complex tasks [23]. The eye-tracking visualizations recorded during the problem-solving tasks for Questions 1 and 2 for each respondent are presented in Figure 1 and Figure 2.

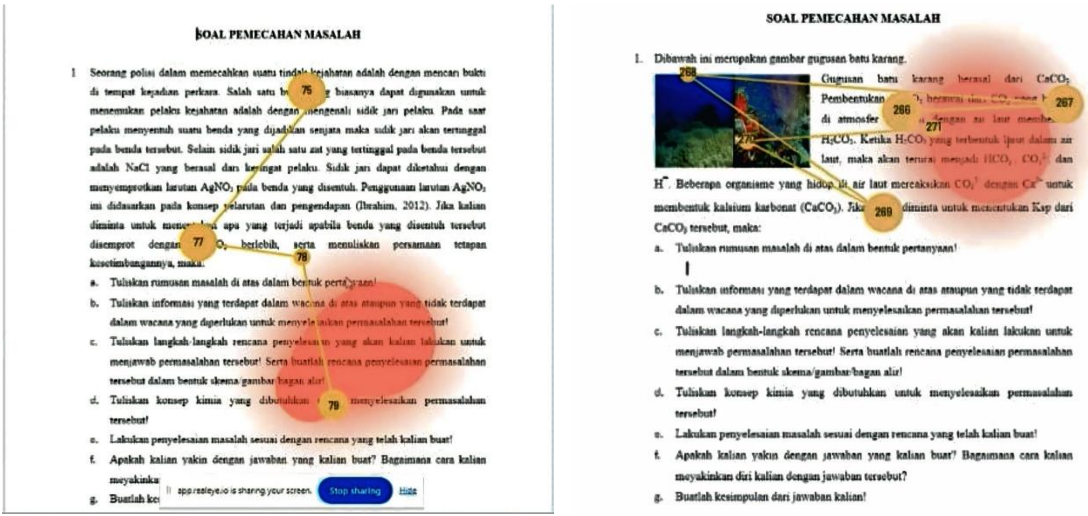

Figure 1. Eye tracking recording in gazepoint form for respondent 1 during chemistry problem solving (Q1: left and Q2: right).

In Figure 1, Respondent 1's visual attention is primarily concentrated on the narrative of the question before shifting to the sub-questions. Interview responses indicate that this participant began problem solving by identifying the core problem within the narrative—specifically, recognizing given data—before proceeding to solve the task. Afterward, the respondent re-evaluated the answer to ensure the correct concept was applied. While Respondent 1 chose not to revise the answer to Question 1 due to uncertainty about the material, she expressed greater confidence in answering Question 2, citing greater familiarity with the topic.

In Figure 2, Respondent 2's visual attention is seen to focus longer on the sub-questions rather than the main narrative and appears to be fixated on a single point. Despite stating in the interview that the problem-solving strategy involved first reading the narrative thoroughly, Respondent 2 admitted to spending too much time on one question, which limited the time available for the remaining items. This task was her first experience with such problem-solving questions, and she felt it was necessary to fully understand the narrative. Additionally, she noted that operating the computer while connected to the online eye-tracking platform (RealEye) required keyboard familiarity to prevent frequent recalibration caused by shifts in posture and gaze. She acknowledged the need to enhance both conceptual understanding and familiarity with the problem format, as well as the necessity of more supporting data to complete the tasks effectively.

Based on the observations from Figures 1 and 2, it can be concluded that Respondent 1 employed a more efficient and structured visual strategy for solving chemistry problems. This is evident from the eye-tracking data, which shows: (1) an initial focus on the narrative, enhancing comprehension; (2) a logical transition from the narrative to sub-problems; and (3) a more flexible and distributed attention pattern in Question 2, where the material was more familiar. The combined analysis of gaze points, problem-solving scores, and interview responses supports the conclusion that visual attention efficiency significantly impacts problem-solving performance. This contrast between Respondents 1 and 2 illustrates that, despite having similar non-science backgrounds, differences in cognitive strategy and visual behavior can lead to markedly different outcomes.

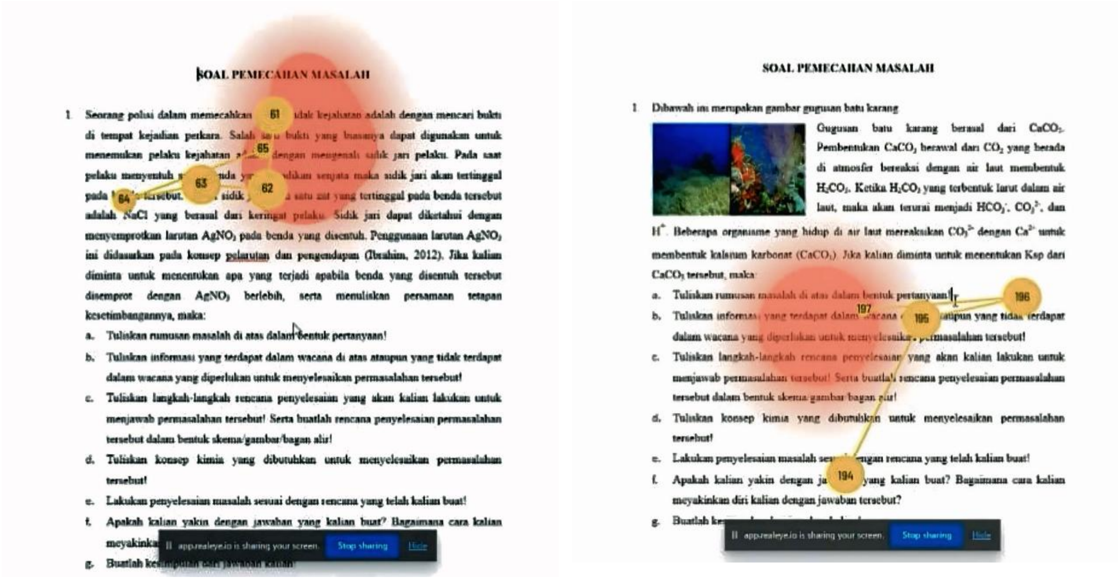

Figure 2. Eye tracking recording in gazepoint form for respondent 2 during chemistry problem solving (Q1: left and Q2: right).

The findings of this study suggest that while the visual attention of pre-service chemistry teachers during problem solving can be described through eye-tracking data—specifically fixation duration, fixation count, and gaze point recordings collected via the RealEye platform—this information should not be interpreted in isolation. Several additional factors can influence attention and fixation duration during problem-solving tasks, including problem complexity [20], problem elements [24], cognitive load, individual skill level, confusion and interest in the task, and affective processes [23].

Moreover, the study highlights that pre-service chemistry teachers from non-science backgrounds encounter several significant challenges in solving chemistry problems. These challenges include misconceptions and alternative conceptions [25], the inherent complexity of chemical content [26], limited or absent foundational knowledge [25], difficulties with attention and focus [27], as well as negative perceptions and concerns related to chemistry materials [26].

By gaining insight into both the visual attention patterns and the specific challenges faced by pre-service chemistry teachers with non-science backgrounds, educators can design more effective instructional strategies. These strategies should aim to support conceptual understanding, reduce cognitive load, and enhance engagement—ultimately improving the problem-solving abilities of this student population in chemistry learning contexts.

CONCLUSION

Based on the findings of this study, it can be concluded that pre-service chemistry teachers in the Chemistry Education Study Program at UIN Antasari Banjarmasin with non-science backgrounds during high school tend to require more time when observing, reading, and solving chemistry problems. This tendency is evident from the recorded fixation duration and fixation count for each participant. Both respondents demonstrated sustained visual attention on the narrative and sub-questions of the problems, as captured through the RealEye eye-tracking data. However, despite the intensity of their visual engagement, both expressed uncertainty about the accuracy of their answers during interviews. This lack of confidence was attributed to limited conceptual knowledge and the challenges of working with the RealEye platform, which was unfamiliar to them. These self-assessments were consistent with their performance scores, which fell into the medium and low categories. In response to these findings and the identified limitations, it is recommended that future research examine differences in problem-solving performance and attention patterns between pre-service chemistry teachers from science and non-science backgrounds. Such comparisons may provide a clearer understanding of how background knowledge influences visual strategies in chemistry problem solving. Additionally, the use of other online eye-tracking platforms beyond RealEye could be considered to expand the range of available tools and potentially enhance data accuracy. It is also suggested that future studies define Areas of Interest (AOIs) more precisely within the problem-solving tasks to enable the collection of more detailed and focused attention data across each stage of the problem-solving process.

REFERENCES

[1] E. Susilawati, I. Hamidah, N. Rustaman, and W. Liliawati, “Problem Solving Learning in Science Education: A Systematic Literature Review,” *Jurnal Penelitian Pendidikan IPA*, vol. 10, no. 8, Art. no. 8, Aug. 2024, doi: 10.29303/jppipa.v10i8.5033.

[2] D. Keller and J. Hermanns, “Development of a self-test for undergraduate chemistry students: how do students solve tasks on basic content knowledge?,” *Chemistry Teaching International*, vol. 6, no. 1, pp. 65–75, Mar. 2024, doi: 10.1515/cti-2023-0068.

[3] K. Muna and M. Bahit, “Eye-tracking and metacognitive skills: A review on the use of eye-tracking for measuring students’ metacognitive skills in chemistry learning,” *Journal of Physics: Conference Series – The 1st International Conference on Mathematics, Science and Computer Education*, vol. 1422, no. 1, p. 012033, Jan. 2020, doi: 10.1088/1742-6596/1422/1/012033.

[4] O. R. Anderson, B. C. Love, and M.-J. Tsai, “Neuroscience Perspectives for Science and Mathematics Learning

in Technology-Enhanced Learning Environments," *International Journal of Science and Mathematics Education*, vol. 12, no. 3, pp. 467–474, Jun. 2014, doi: 10.1007/s10763-014-9540-2.

[5] Y.-C. Chen and F.-Y. Yang, "Probing The Relationship Between Process Of Spatial Problems Solving And Science Learning: An Eye Tracking Approach," *International Journal of Science and Mathematics Education*, vol. 12, no. 3, pp. 579–603, Jun. 2014, doi: 10.1007/s10763-013-9504-y.

[6] K. L. Havanki and J. R. VandenPlas, "Eye Tracking Methodology for Chemistry Education Research," in *ACS Symposium Series*, D. M. Bunce and R. S. Cole, Eds., Washington, DC: American Chemical Society, 2014, vol. 1166, pp. 191–218, doi: 10.1021/bk-2014-1166.ch011.

[7] M.-L. Lai et al., "A review of using eye-tracking technology in exploring learning from 2000 to 2012," *Educational Research Review*, vol. 10, pp. 90–115, Dec. 2013, doi: 10.1016/j.edurev.2013.10.001.

[8] J. Peterson, Z. Pardos, M. Rau, A. Swigart, C. Gerber, and J. McKinsey, "Understanding Student Success in Chemistry Using Gaze Tracking and Pupillometry," in *Artificial Intelligence in Education*, C. Conati, N. Heffernan, A. Mitrovic, and M. F. Verdejo, Eds., Cham: Springer International Publishing, 2015, pp. 358–366, doi: 10.1007/978-3-319-19773-9_36.

[9] V. M. Williamson, M. Hegarty, G. Deslongchamps, K. C. I. Williamson, and M. J. Shultz, "Identifying Student Use of Ball-and-Stick Images versus Electrostatic Potential Map Images via Eye Tracking," *Journal of Chemical Education*, vol. 90, no. 2, pp. 159–164, Feb. 2013, doi: 10.1021/ed200259j.

[10] M.-H. Yen and F.-Y. Yang, "Methodology and Application of Eye-Tracking Techniques in Science Education," in *Science Education Research and Practices in Taiwan: Challenges and Opportunities*, M.-H. Chiu, Ed., Singapore: Springer, 2016, pp. 249–277, doi: 10.1007/978-981-287-472-6_13.

[11] M. Tóthová, M. Rusek, and V. Chytrý, "Students' Procedure When Solving Problem Tasks Based on the Periodic Table: An Eye-Tracking Study," *Journal of Chemical Education*, vol. 98, no. 6, pp. 1831–1840, Jun. 2021, doi: 10.1021/acs.jchemed.1c00167.

[12] S. W. Locatelli, L. S. de Oliveira, R. da S. S. Junior, and J. R. Sato, "Perspectives of the Eye-Tracking Application to Understand Access to Representational Levels in Chemistry," *Journal of Science Education and Technology*, 2024, doi: 10.1007/s10956-024-10123-x.

[13] A. P. Sidhawara, S. Wibirama, and D. J. Suroso, "Kajian Eye-Tracking Pengaruh Gender Terhadap Proses Kognitif dalam Pembelajaran Multimedia," *Jurnal Teknik Elektro dan Teknologi Informasi*, vol. 12, 2023. *doi: 10.22146/jnteti.v12i2.5145.*

[14] M. Pietrzak, F. Żarnowiec, and D. Sromek, "RealEye Webcam Eye-Tracking for Computers (Technology White Paper)," RealEye sp. z o.o., White Paper 1, v. 2.0.0, Aug. 2024, www.realeye.io.

[15] A. A. Taim, S. Tiatri, and J. T. Beng, "Gazerecorder: Mengamati Atensi Pada Siswa Sekolah Menengah Atas Menggunakan Eye Tracker," *Jurnal Muara Ilmu Sosial, Humaniora dan Seni*, vol. 6, no. 2, Art. no. 2, 2022, doi: 10.24912/jmishumsen.v6i2.13558. 2022.

[16] H. Türkoğlu and S. Yalçınalp, "Investigating problem-solving behaviours of university students through an eye-tracking system using GeoGebra in geometry: A case study," *Education and Information Technologies*, Feb. 2024, doi: 10.1007/s10639-024-12452-1.

[17] M. Andrzejewska et al., "Eye-tracking verification of the strategy used to analyse algorithms expressed in a flowchart and pseudocode," *Interactive Learning Environments*, Nov. 2016.

[Online]. Available: https://www.tandfonline.com/doi/full/10.1080/10494820.2015.1073746. *(Accessed: Jul. 22, 2025.)*

[18] "Participant Quality Stats Explained | Knowledge Base | RealEye.io," Participant Quality Stats Explained. [Online]. Available: https://support.realeye.io/participant-quality-stats-explained/. *(Accessed: Sep. 11, 2024)*

[19] N. Chettaoui, A. Atia, and M. S. Bouhlel, "Student Perfor.mance Prediction with Eye-Gaze Data in Embodied Educational Context," *Education and Information Technologies*, vol. 28, no. 1, pp. 833–855, Jan. 2023, doi: 10.1007/s10639-022-11163-9.

[20] G. Knoblich, S. Ohlsson, and G. E. Raney, "An eye movement study of insight problem solving," *Memory & Cognition*, vol. 29, no. 7, pp. 1000–1009, Oct. 2001, doi: 10.3758/BF03195762.

[21] M. Sajka and R. Rosiek, "Solving a problem by students with different mathematical abilities: A comparative study using eye-tracking," in *CERME 9 – Ninth Congress of the European Society for Research in Mathematics Education*, K. Krainer and N. Vondrová, Eds., Prague, Czech Republic: Charles University in Prague, Faculty of Education and ERME, Feb. 2015, pp. 1752–1758. [Online]. Available: https://hal.science/hal-01288030. *(Accessed: Sep. 11, 2024).*

[22] M. Dobias, J. Dolezal, V. Chytrý, A. Klesalová, P. Kozelka, and J. Černohous, "Determining a strategy for problem solving based on eye movements," *Ad Alta Journal of Interdisciplinary Research*, vol. 7, pp. 26–27, Sep. 2017.

[23] S. Negi and R. Mitra, "Fixation duration and the learning process: an eye tracking study with subtitled videos," *Journal of Eye Movement Research*, vol. 13, no. 6, p. doi: 10.16910/jemr.13.6.1.

[24] Á. Bartalis, I. Péntek, and I. Zsoldos-Marchiș, "A Pilot Study on Investigating Primary School Students' Eye Movements While Solving Compare Word Problems," *Open Education Studies*, vol. 5, no. 1, p. 20220207, Nov. 2023, doi: 10.1515/edu-2022-0207.

[25] I. I. Salame, A. Montero, and D. Eschweiler, "Examining some of the students' challenges and alternative conceptions in learning about acid-base titrations," *International Journal of Chemistry Education Research*, vol. 6, no. 1, pp. 1–10, Apr. 2022, doi: 10.20885/ijcer.vol6.iss1.art1.

[26] N. P. Timilsena, K. B. Maharjan, and K. M. Devkota, "Teachers' and students' experiences in chemistry learning difficulties," *Journal of Positive School Psychology*, vol. 6, no. 10, pp. 2856–2867, 2022.

[27] Webmaster, "Eye-Tracking for Diverse and Advanced Learning Techniques in Chemistry Education," *Innovative Learning Center*. [Online]. Available: https://ilearningcenter.education/eye-tracking-for-diverse-learning-advanced-learning-techniques-in-chemistry-education/. *(Accessed: Sep. 11, 2024).*