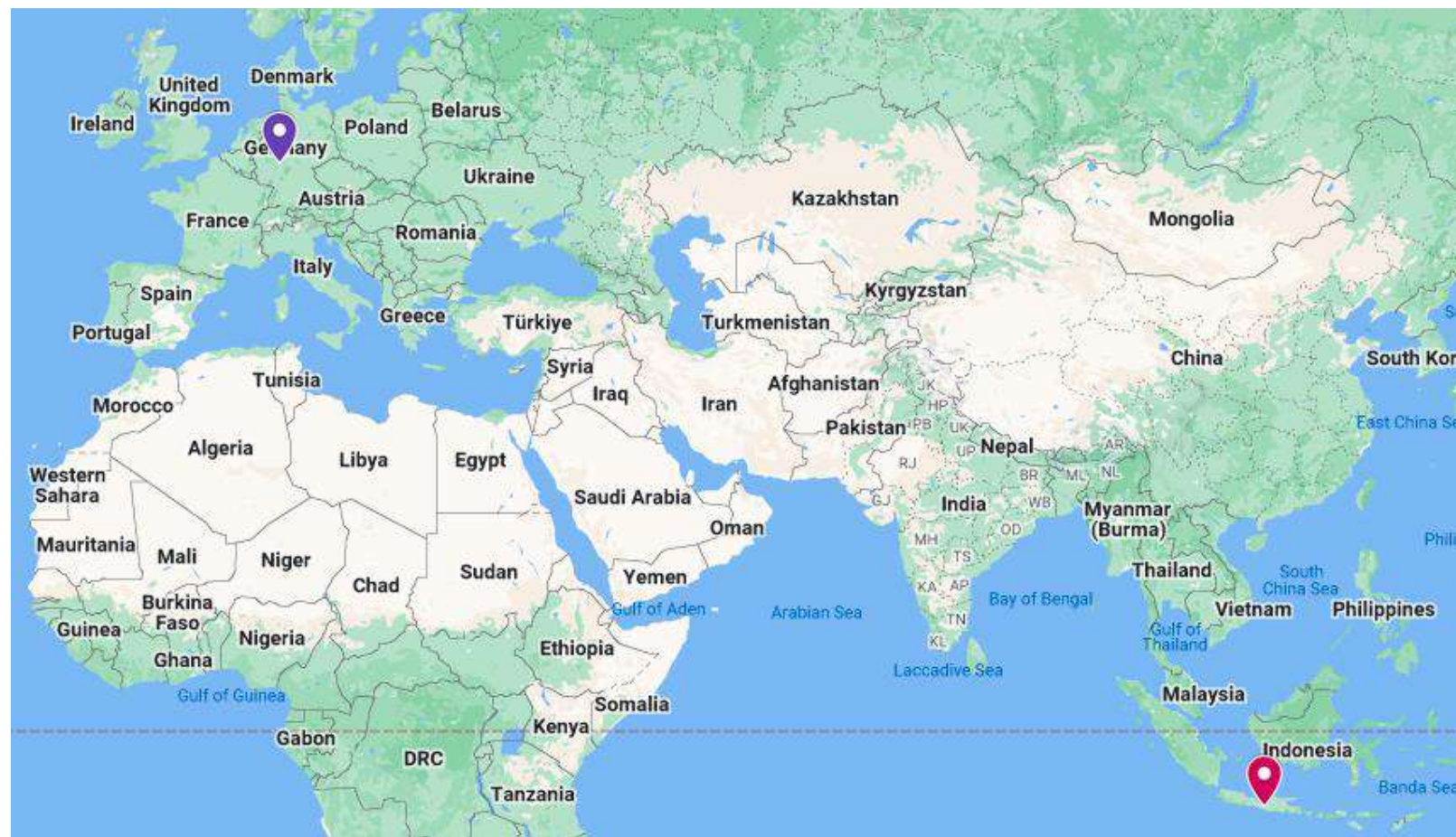


SELAMAT SIANG

Axel Langner, PhD Student





Eye-Tracking as a Feedback Tool in Education

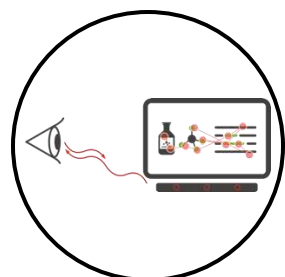


Axel Langner

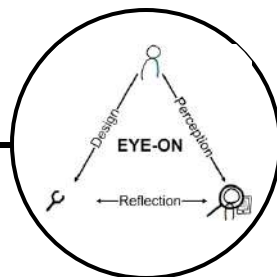


Nicole Graulich

AGENDA



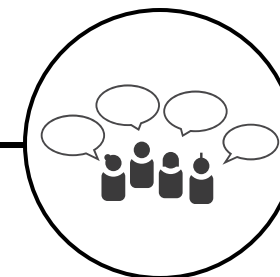
Eye-tracking



... as a feedback tool in
teacher education



... as a feedback tool in
chemistry education



Discussion

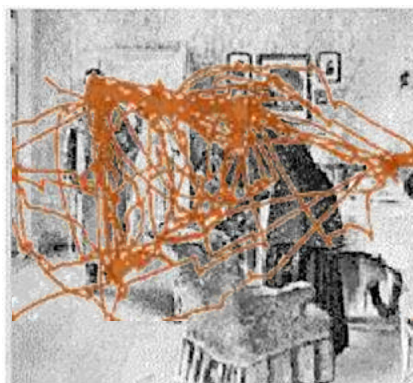
EYE MOVEMENTS



EYE MOVEMENTS



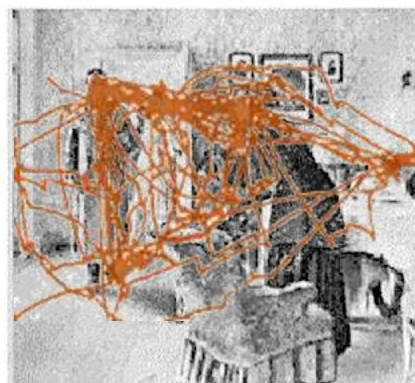
Examine the
picture



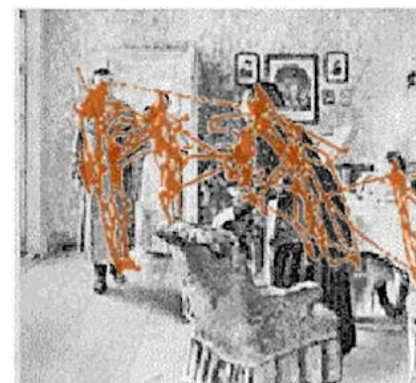
EYE MOVEMENTS



Examine the
picture



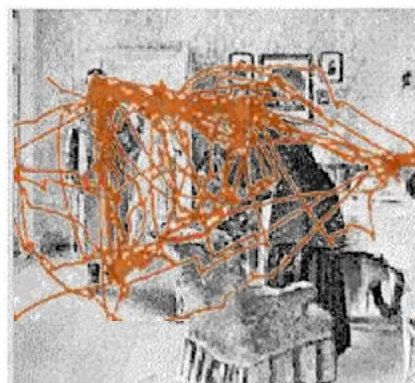
Remember
clothing



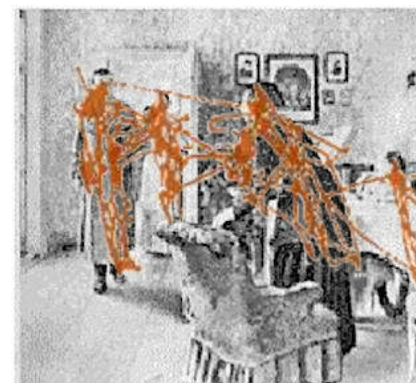
EYE MOVEMENTS



Examine the
picture



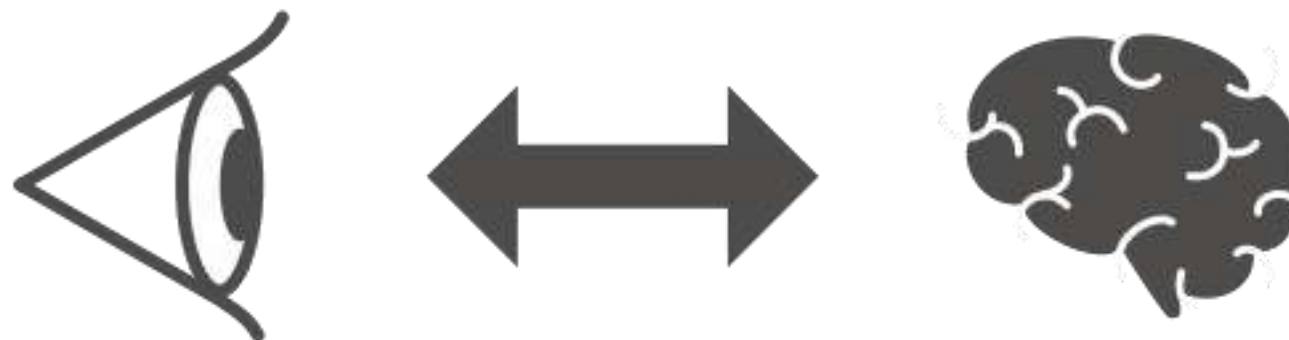
Remember
clothing



Estimate
economic level

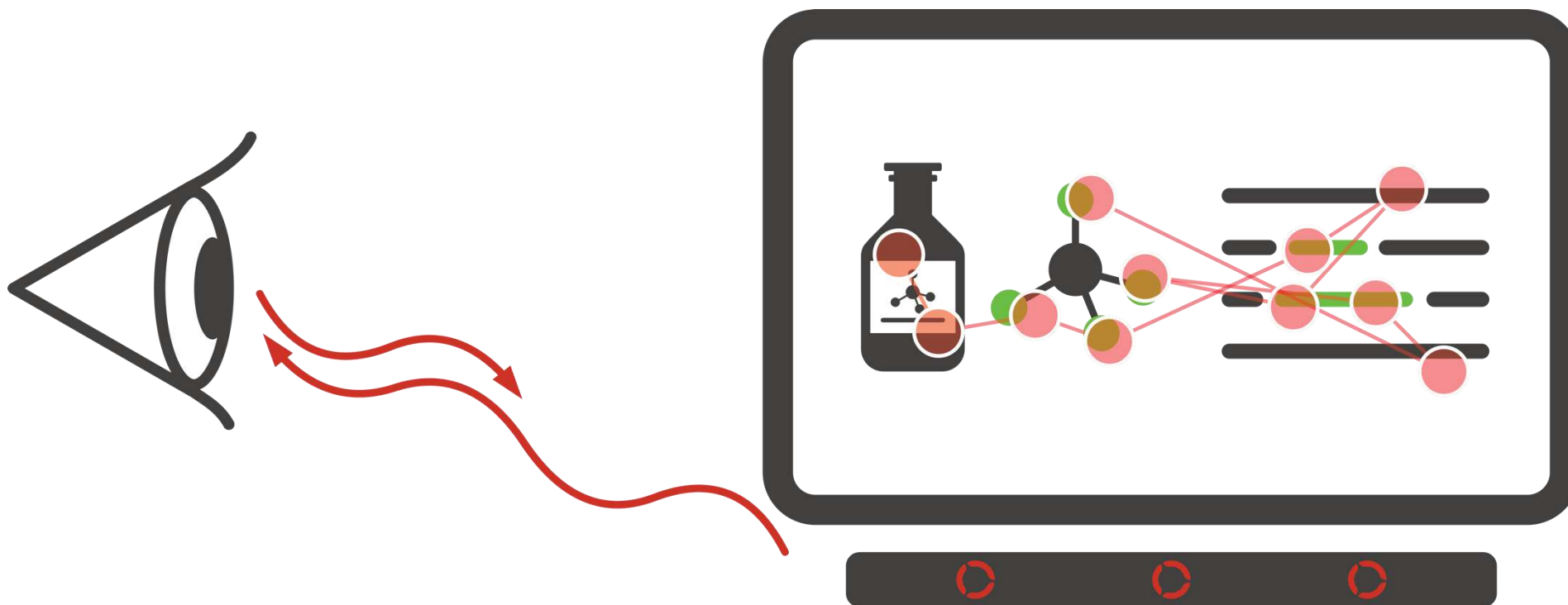


GAZE & COGNITION



Eye movements and cognitive processes are interconnected.

EYE-TRACKING



Eye-tracker

DATA COLLECTION

Screen-based

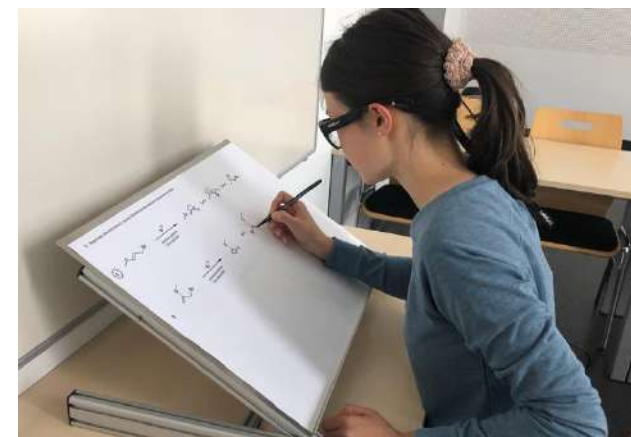


DATA COLLECTION

Screen-based

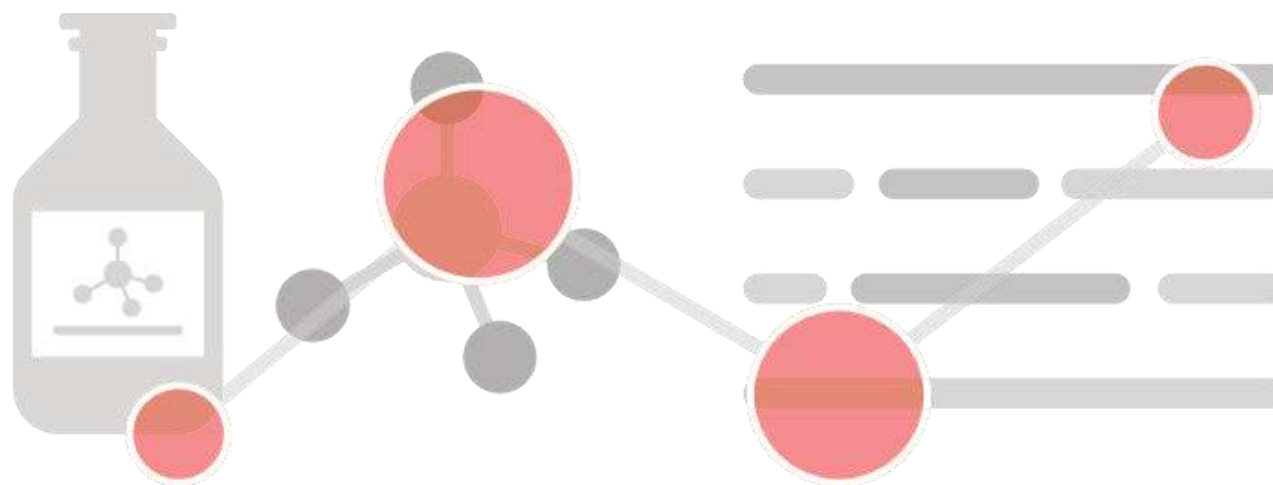


Mobile



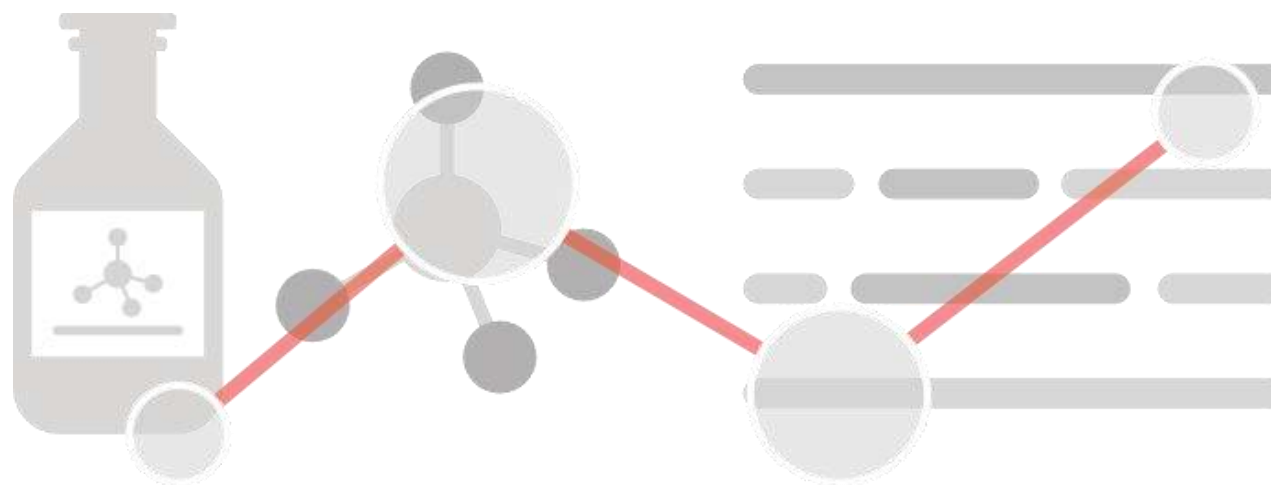
EYE-TRACKING

Fixations

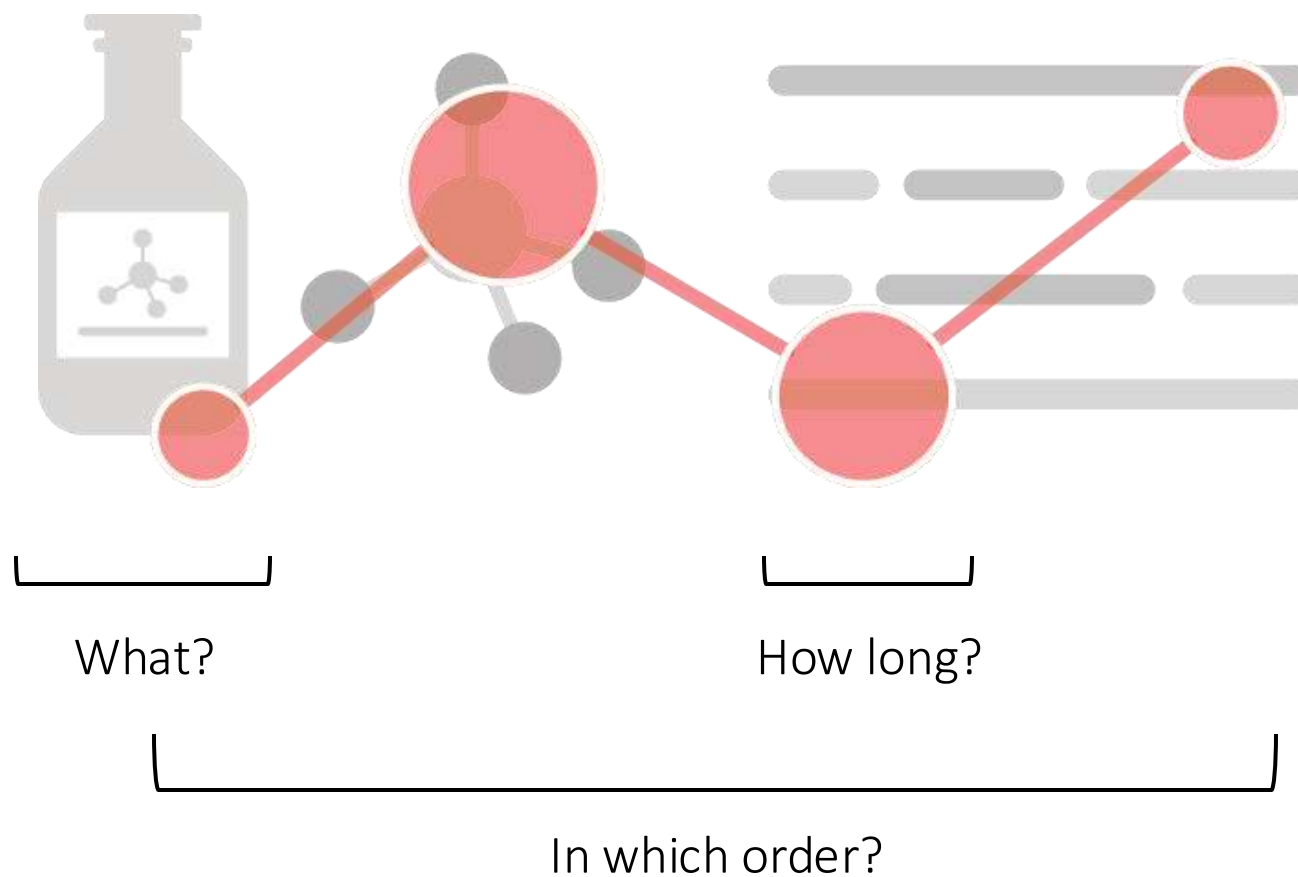


EYE-TRACKING

Saccades

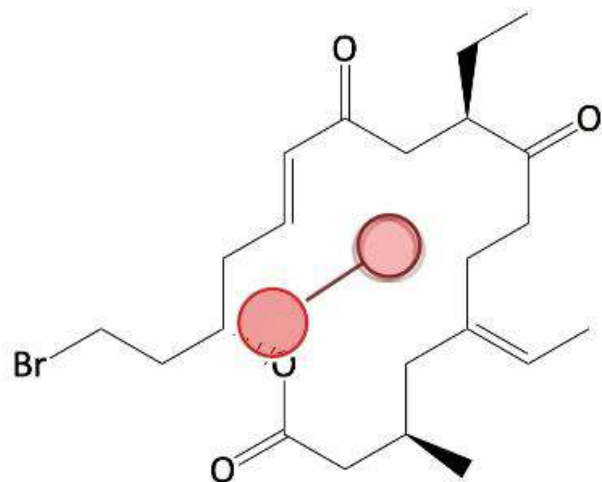


EYE-TRACKING

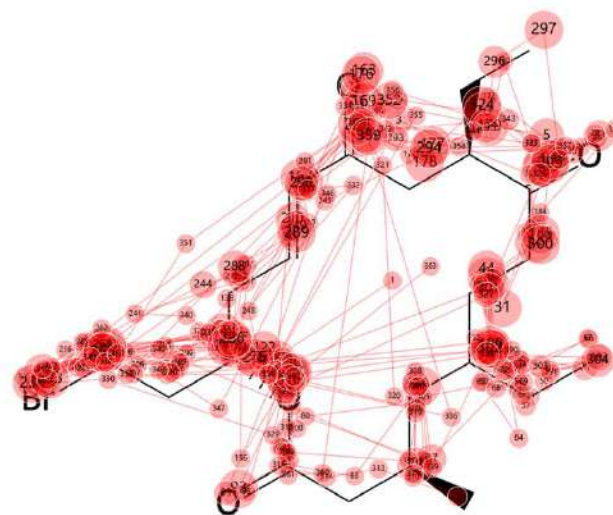


OUTPUT

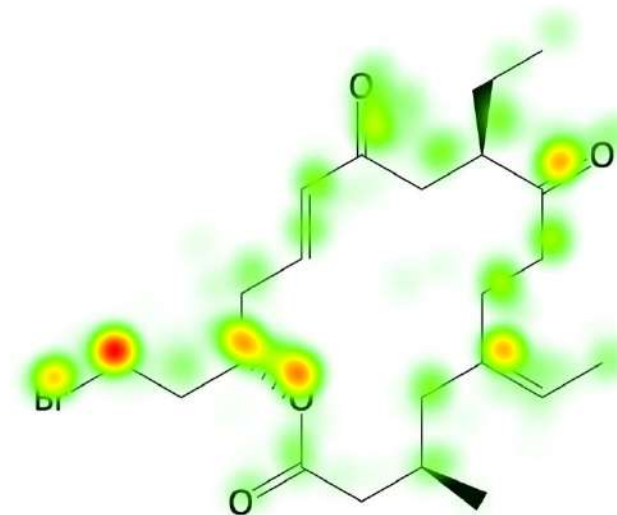
Task prompt: Identify electrophilic centers.



Replay

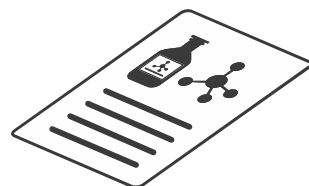


Gaze plot

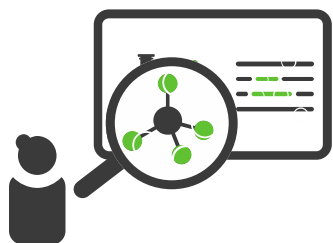


Heat map

METHODOLOGICAL TRIANGULATION



Questionnaires (e.g., surveys, reports, prior knowledge test, performance)



+



Verbal reports (e.g., think aloud)



Biometrics (e.g., electroencephalography, galvanic skin response)

Influence of the car brand



Perodua Nautica

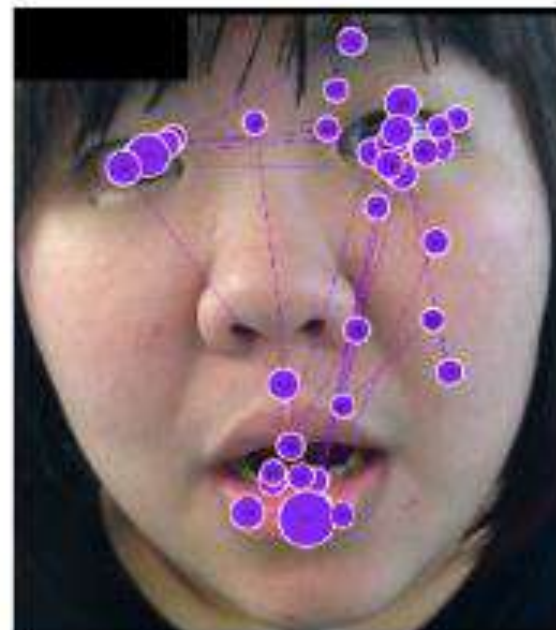


Toyota Rush

Facial emotion recognition

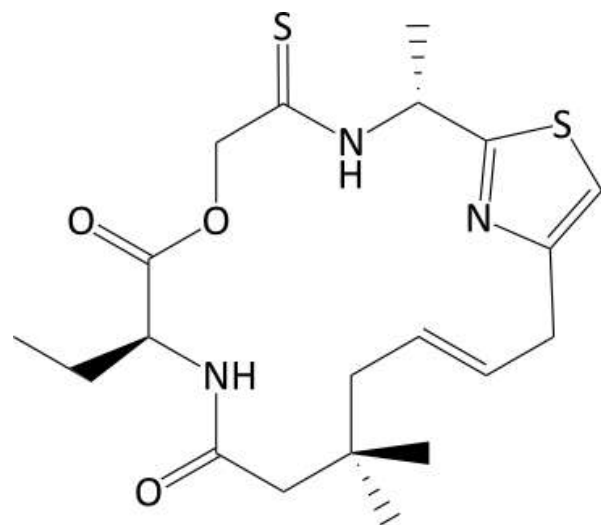


...with
autism spectrum disorder

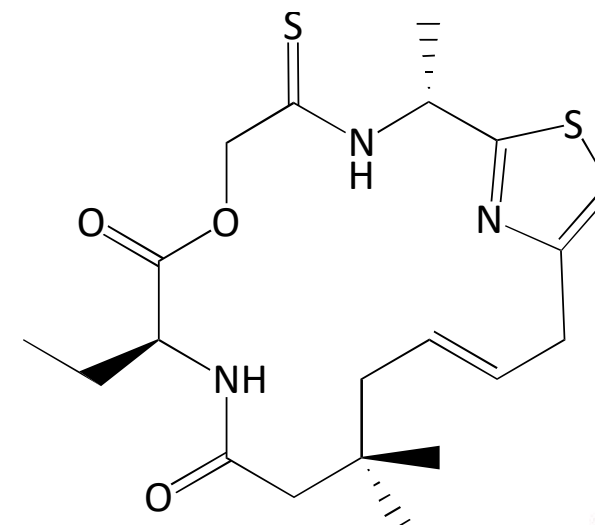


...without
autism spectrum disorder

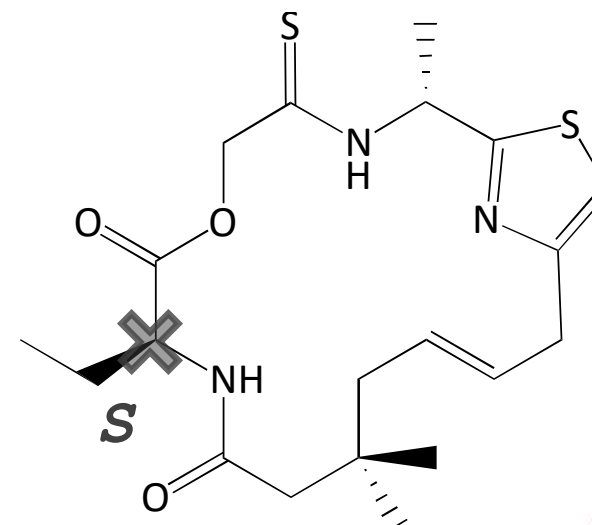
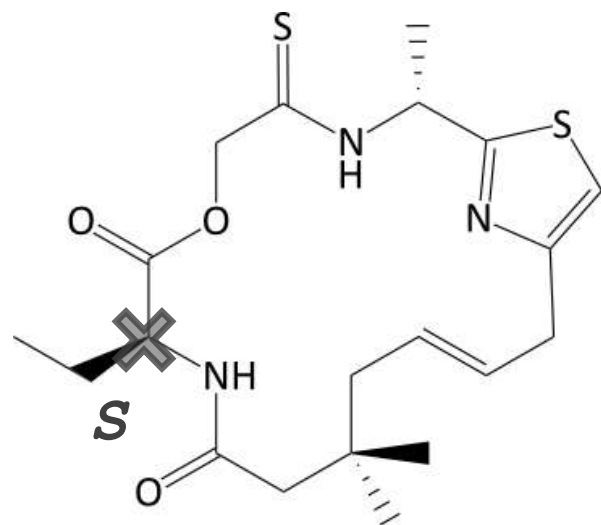
EDUCATION



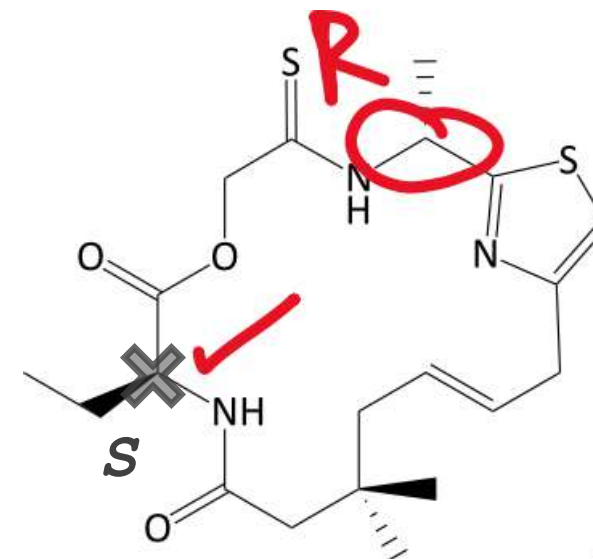
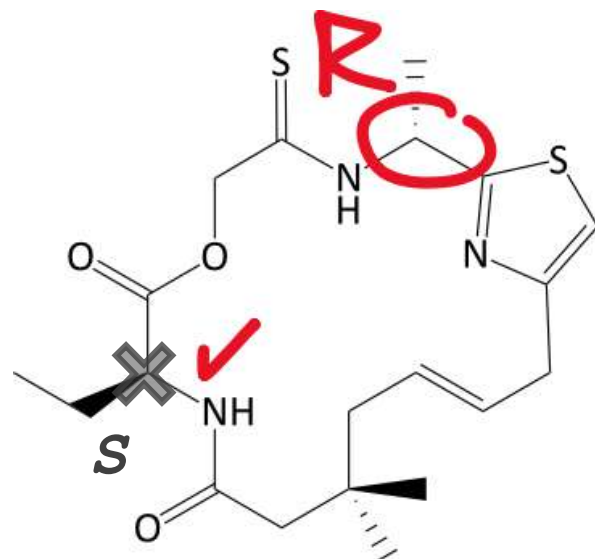
*Determine the configuration
of the asymmetric carbon
atoms (R/S configuration).*



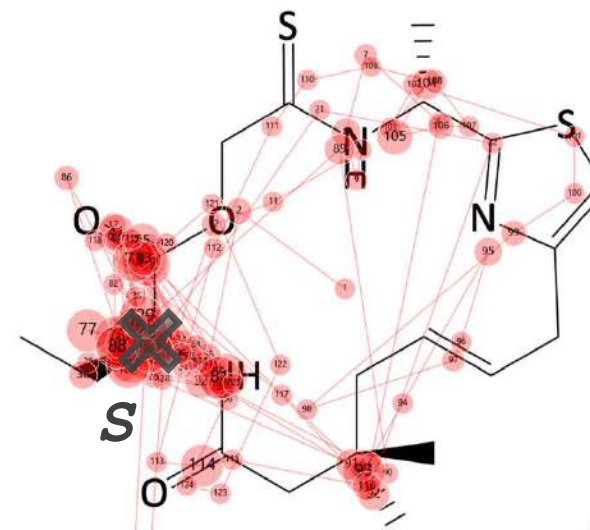
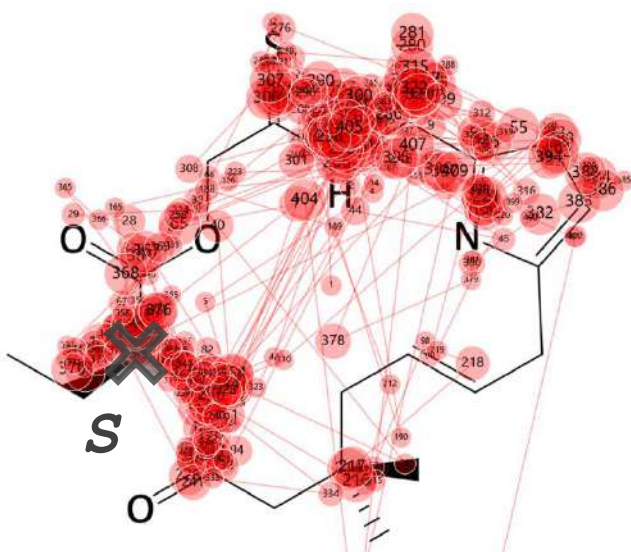
EDUCATION



EDUCATION



EDUCATION



ET IN CHEMISTRY EDUCATION RESEARCH

Diagnosis & Assessment

Problem-solving strategies

Expertise comparisons

Usage of representations

Evaluation of learning materials

Cognitive demand

Predictability

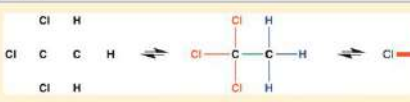
JOURNAL OF CHEMICAL EDUCATION

Forms versus Bonds: How Students Look at Spectra

John Cullipher and Hannah Sevan*

Department of Chemistry, University of Massachusetts, Boston, Boston, Massachusetts 02125, United States

Supporting Information



ABSTRACT: Students often face difficulties when presented with chemical structures and asked to relate these substances. Learning to relate structures to properties, both in predicting properties based on chemical structures and in inferring structure, is pivotal in students' education in chemistry. This troublesome problem is often referred to as structure-property relationships. While there is no shortage of literature on students' misconceptions, there is a lack of methodological studies that can directly and quantitatively reveal underlying assumptions about property relationships that constrain students' thinking. This study applied a "chemical thinking" lens to the structure-property relationships thinking. A combination of qualitative analysis using a think-aloud protocol and quantitative analysis of eye tracking data to probe students' reasoning when relating molecular structures to infrared spectral properties. Our initial findings offer partial validation of a newly developed eye-tracking data to expose reasoning patterns that appear to correspond to identifiable student groups.

KEYWORDS: First-Year Undergraduate/General, Second-Year Undergraduate, Upper-Division Undergraduate, Graduate Education/Research, Chemical Education Research, Spectroscopy

FEATURE: Chemical Education Research

JOC The Journal of Organic Chemistry

Developing Expertise in ¹H NMR Spectral Interpretation

Megan C. Connor, Benjamin H. Glass, Solaira A. Finkenshaedt-Quinn,

Cite This: *J. Org. Chem.* 2021, 86, 1385–1395

ABSTRACT: Advancements in organic chemistry depend upon chemists' ability to interpret NMR spectra, though research demonstrates that cultivating such proficiency requires years of graduate-level study. The organic chemistry community thus needs insight into how this expertise develops to expedite learning among its newest members. This study investigated undergraduate and doctoral chemistry students' understanding and information processing during the interpretation of ¹H NMR spectra and complementary IR spectra. Eighteen undergraduate and seven doctoral chemistry students evaluated the outcome of a series of syntheses using spectra corresponding to the products. Eye movements were measured to identify differences in cognitive processes between undergraduate and doctoral participants, and interviews were conducted to elucidate the chemical assumptions that guided participants' reasoning. Results suggest five areas of understanding are necessary for interpreting spectra, and progress in understanding corresponds to increasing knowledge of experimental and implicit chemical variables. Undergraduate participants exhibited uninformative bidirectional processing of all information, whereas doctoral participants exhibit relevant information. These findings imply the community can support novices' development.

JOURNAL OF CHEMICAL EDUCATION

Beyond ball-and-stick: Students' processing of novel STEM visualizations

Scott R. Hinze^{a,b,*}, David N. Rapp^{a,b}, Vickie M. Williamson^c, Mary Jane Shultz^d, Ghislain Deslongchamps^e, Kenneth C. Williamson^f

ABSTRACT: Students are frequently presented with novel visualizations introducing abstract concepts normally inaccessible to the naked eye. Despite being unfamiliar, students do employ the visualizations to solve problems. Domain experts exhibit more when using complex visualizations, but less is known about how and why students use them. This project examined students' moment-by-moment data visualizations. In a laboratory experiment, introductory-level organic chemistry students used ball-and-stick and novel electrostatic potential (ESP) representations while solving movement patterns, verbal explanations, and individual differences and initially relied on familiar representations, particularly for difficult questions.

JOURNAL OF CHEMICAL EDUCATION

Use of Simulations and Screencasts to Increase Student Understanding of Energy Concepts in Bonding

Jessica R. VandenPlas^a, Deborah G. Herrington, Alec D. Shrode, and Ryan D. Svedeed

ABSTRACT: The growing popularity of flipped, blended, and online learning, combined with the need to support a student population with increasingly diverse backgrounds, has led to the development and use of online materials to support students' learning of chemistry outside of a face-to-face classroom. Chemistry simulations provide opportunities to make such materials more interactive. However, it is important to understand how to best employ them to support students' independent learning outside of the classroom. The larger Chemistry project aims to determine how resources and simulations can be used to best support the development of students' conceptual understanding of core chemistry concepts in such environments. This paper focuses specifically on the concepts of force and energy as they pertain to bonding and intermolecular interactions. It describes the investigations of students' use of class use of a PNET simulation that illustrates force and energy changes that occur when two atoms come together or are separated. In an introduction to bonding, students completed one question in one of three different treatment conditions: (1) exploring the simulation directly using guided scaffolding an experienced researcher using the same simulation, or (3) watching an "intuitive screencast" expert-narrated screencast plus additional information related to the formation and breaking of bonds in a computer-based learning environment. All treatments resulted in similar learning gains, indicating greater gains than others. Further, findings indicate that the enhanced screencast was better received by students than the other two treatments. Finally, using eye tracking to compare student use of the screencast to the simulation to the screencast using the same simulation, the data suggest that the screencast may not be as effective as the simulation in supporting student learning. It may serve to make the assignment more engaging if students are required to engage in more work through the initial questions.

JOURNAL OF CHEMICAL EDUCATION

Looking into the Black Box: Using Gaze and Pupil Probe How Cognitive Load Changes with Mental

Jessica M. Karch^{a,*}, Josibel C. Garcia Valles, and Hannah Sevan^a

ABSTRACT: When characterizing students' item-solving strategies, methods such as interviews and think-aloud protocols are often used. However, these measures provide limited information about sub- or preconscious signals and cognitive processes that also affect students' item-solving strategies and abilities. A growing number of researchers in chemical education research have begun to address this gap by using physiological measurements to assess cognitive load (e.g., heart rate and EEG) and to look at item-solving strategies (e.g., via eye tracking). One physiological measure of cognitive load that has been well-documented in psychology literature is pupil dilation. In this study, two streams of eye-tracking data (gaze combined to reveal information about what mental tasks general chemistry students were engaged in) and how those mental tasks elicited a (pupillometric) response. We found that, for complex multiple-choice tasks, pupil dilation during solving the item. For a more straightforward true/false task, there was a marked difference in who correctly answered the question and those who incorrectly answered it. Those who correctly answered the question showed more pupil dilation than those who incorrectly answered it. This result is consistent with the literature on cognitive load. Our results are consistent with previously published literature about CCI items.

RedFame

LewisSpace: an Exploratory Study with a Machine Learning Model

Ramla Ghali^a, Sébastien Ouellet^b, Claude Frossier^c

ABSTRACT: The use of educational games as a tool for providing learners with a playful and educational support is a topic that has attracted much interest in the scientific community. In this paper, we present an educational game that we developed to teach chemistry lessons, namely LewisSpace, a 3D environment known as LewisSpace and aimed at balancing between playfulness and educational content to increase engagement and motivation while learning. The game contains multiple missions aimed at constructing Lewis diagram molecules which are organized in an ascending order of difficulty. The game is designed to provide students with a playful and educational support. The game is designed to provide students with a playful and educational support. The game is designed to provide students with a playful and educational support.

JOURNAL OF CHEMICAL EDUCATION

Eye tracking student strategies for solving stoichiometry problems involving particulate nature of matter diagrams

John Y. Baluyut^a / Thomas A. Holme^a

ABSTRACT: Reaction mechanisms commonly used in organic chemistry are a great challenge for students in terms of understanding the representation and inferring the appropriate chemical concepts, particularly designed case comparisons are seldom used. While these tasks place great demands on students' problem-solving capabilities, it is unknown how learners allocate their attention on the complex and information-rich representations. Understanding students' visual decoding behavior when dealing with case comparisons could provide valuable insights into supporting students' problem-solving process. In this exploratory study, we employed eye-tracking methodology to observe beginning and advanced undergraduate chemistry students when working through case-comparison tasks. By establishing a novel eye-tracking measure, the fixation/transition ratio, distinct viewing behaviors could be observed. Results indicate significant differences between both student groups. Advanced students are overall faster in their decision-making and transition more frequently indicating a higher salience for chemically relevant features. Further, they show a significant increase in representation on students' visual behavior. Implications for designing case comparisons and supporting students' learning are discussed.

JOURNAL OF CHEMICAL EDUCATION

Decoding Case Comparisons in Organic Chemistry: Eye Tracking Student Visual Behavior

Marc Rodemer, John Eklund, Nicole Graulich^a, and Sascha Bernholt^b

ABSTRACT: Reaction mechanisms commonly used in organic chemistry are a great challenge for students in terms of understanding the representation and inferring the appropriate chemical concepts, particularly designed case comparisons are seldom used. While these tasks place great demands on students' problem-solving capabilities, it is unknown how learners allocate their attention on the complex and information-rich representations. Understanding students' visual decoding behavior when dealing with case comparisons could provide valuable insights into supporting students' problem-solving process. In this exploratory study, we employed eye-tracking methodology to observe beginning and advanced undergraduate chemistry students when working through case-comparison tasks. By establishing a novel eye-tracking measure, the fixation/transition ratio, distinct viewing behaviors could be observed. Results indicate significant differences between both student groups. Advanced students are overall faster in their decision-making and transition more frequently indicating a higher salience for chemically relevant features. Further, they show a significant increase in representation on students' visual behavior. Implications for designing case comparisons and supporting students' learning are discussed.

JOURNAL OF CHEMICAL EDUCATION

Identifying Student Use of Ball-and-Stick Images versus Electrostatic Potential Map Images via Eye Tracking

Vickie M. Williamson^{a,*}, Mary Hegarty^b, Ghislain Deslongchamps^c, Kenneth C. Williamson, III^d, and Mary Jane Shultz^e

ABSTRACT: This pilot study examined students' use of ball-and-stick images versus electrostatic potential maps when asked questions about electron density, positive charge, proton attack, and hydride attack with six different molecules (two alcohols, two carboxylic acids, and two hydrocarboxylic acids). Students' viewing of these three visual images was measured by monitoring eye fixations of the students while they read and answered questions. Results showed that students spent significantly more time with the ball-and-stick images when asked questions about proton or hydride attack, but equal time on the images when asked about electron density or positive charge. When comparing accuracy and time spent on the images, students who spent more time on the ball-and-stick images when asked about positive charge were less likely to be correct, while those who spent more time on the electrostatic potential maps were more likely to be correct. The paper serves to introduce readers to eye-tracker data and calls for replication with a larger subject pool and for the inclusion of eye tracking as a chemical education research tool.

JOURNAL OF CHEMICAL EDUCATION

Setting Up Chemistry Demonstrations According to the Left-Right Principle: An Eye-Movement-Pattern-Based Analysis

Andreas Nehring^{a,*} and Sebastian Busch^b

ABSTRACT: Although demonstrations play a central role in teaching and learning chemistry, the effects of such principles have rarely been subject to systematic empirical studies. According to the left-to-right principle, the left side of the first step of a reaction in the upper left part of the setup and then place the following apparatus in the right part. From an experimental eye-tracking study on students' visual attention that was published in the *Journal of Chemical Education*, we analyzed eye-tracking in order to find out whether eye-movements are influenced in a manner that generally appears significantly more often within the data time, right-to-left patterns. Although the left-to-right rule does not seem to systematically indicate more left-to-right patterns, it is associated with a decrease of right-to-left patterns. Accordingly, a right-to-left setup seems to add more eye-movements that do not follow the logic of the demonstration. We discuss these findings with regard to their importance for education and new perspectives on future chemistry demonstrations.

JOURNAL OF CHEMICAL EDUCATION

Eye-Tracking Study of Complexity in Gas Law

Hui Tang^{a,*} and Norbert Pienta^b

ABSTRACT: This study, part of a series investigating students' use of online tools, hardware and software to explore the effects of problem difficulty and cognitive load on students' problem-solving performance. Eye movements are indices of cognitive eye-tracking data typically used to analyze fixations on the visual representations. Such information is not usually available from traditional classroom settings. In this study, we used eye-tracking to investigate students' problem-solving performance. Eye movements are indices of cognitive eye-tracking data typically used to analyze fixations on the visual representations. Such information is not usually available from traditional classroom settings. In this study, we used eye-tracking to investigate students' problem-solving performance.

RedFame

LewisSpace: an Exploratory Study with a Machine Learning Model

Ramla Ghali^a, Sébastien Ouellet^b, Claude Frossier^c

ABSTRACT: The use of educational games as a tool for providing learners with a playful and educational support is a topic that has attracted much interest in the scientific community. In this paper, we present an educational game that we developed to teach chemistry lessons, namely LewisSpace, a 3D environment known as LewisSpace and aimed at balancing between playfulness and educational content to increase engagement and motivation while learning. The game contains multiple missions aimed at constructing Lewis diagram molecules which are organized in an ascending order of difficulty. The game is designed to provide students with a playful and educational support. The game is designed to provide students with a playful and educational support. The game is designed to provide students with a playful and educational support.

ET IN CHEMISTRY EDUCATION RESEARCH

Diagnosis & Assessment

Problem-solving strategies

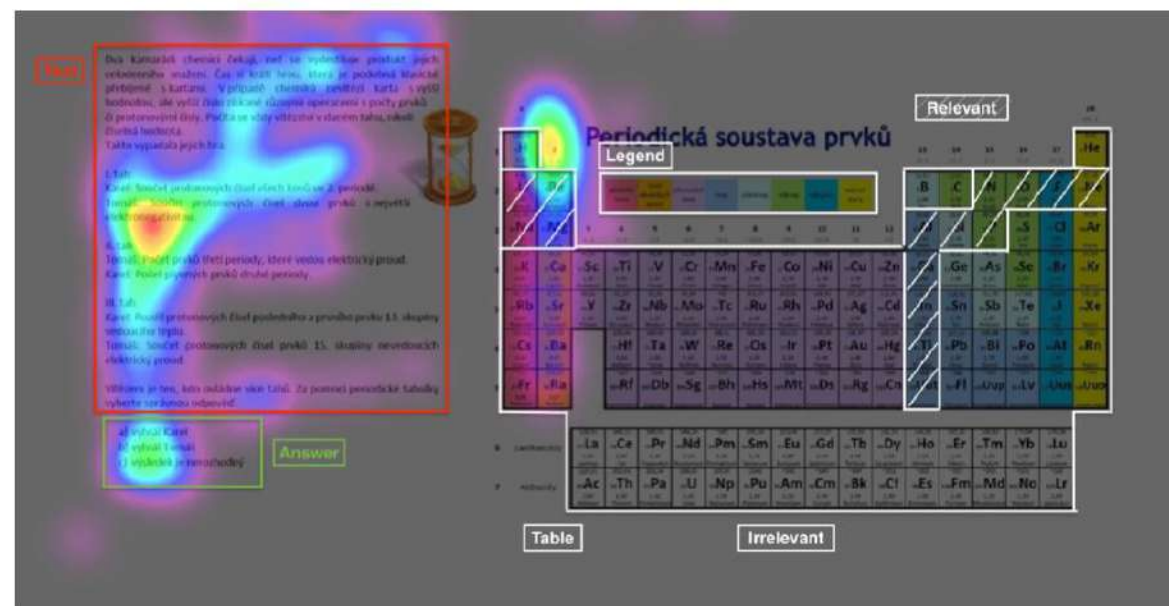
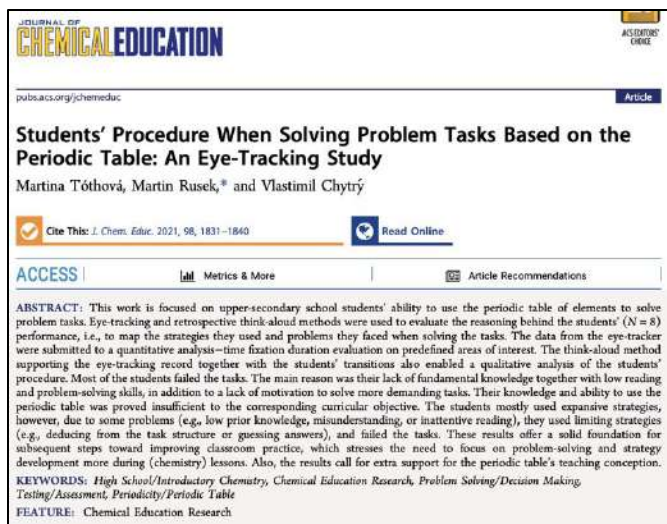
Expertise comparisons

Usage of representations

Evaluation of learning materials

Cognitive demand

Predictability



Pupils scantily used the periodic table
and often memorized or guessed.

ET IN CHEMISTRY EDUCATION RESEARCH

Diagnosis & Assessment

Problem-solving strategies

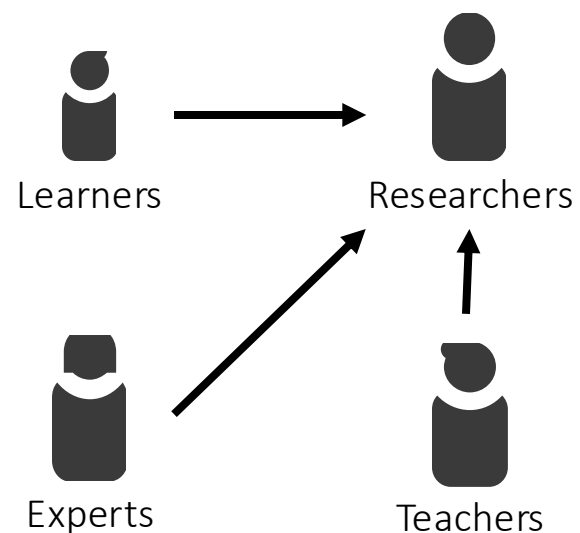
Expertise comparisons

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ET IN CHEMISTRY EDUCATION RESEARCH

Diagnosis & Assessment

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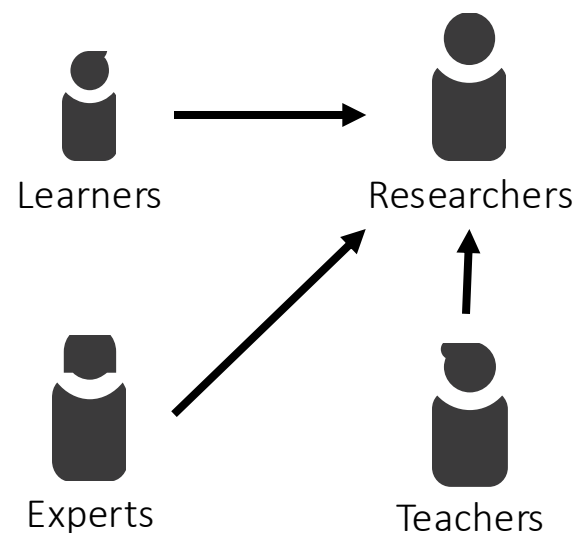
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ET IN CHEMISTRY EDUCATION RESEARCH

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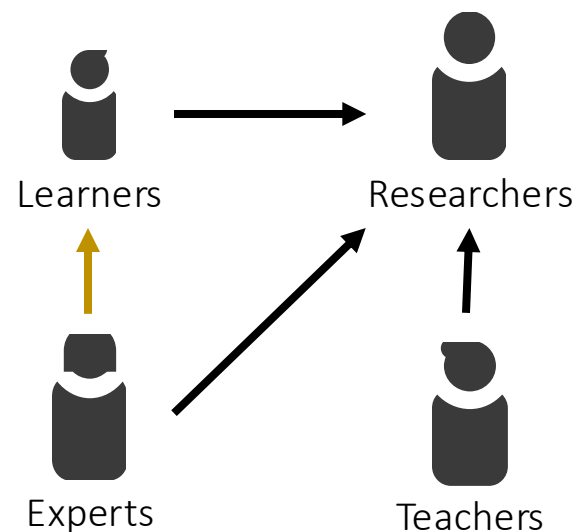
Evaluation of learning materials

Cognitive demand

Predictability

Learning

Eye movement modeling examples



ET IN CHEMISTRY EDUCATION RESEARCH

Diagnosis & Assessment

Problem-solving strategies

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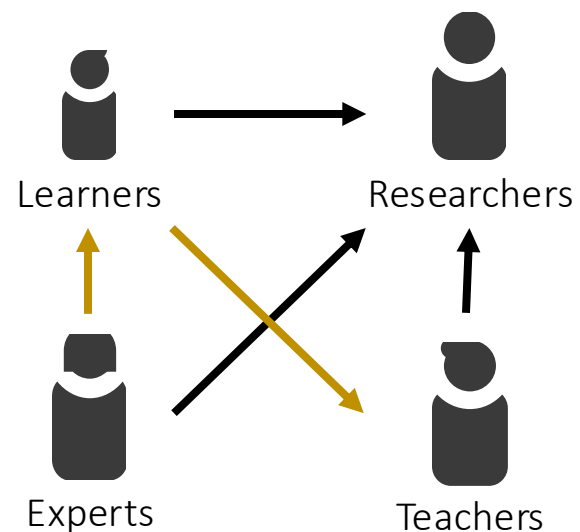
Cognitive demand

Predictability

Learning

Eye movement modeling examples

Teaching expertise development



ET IN CHEMISTRY EDUCATION RESEARCH

Diagnosis & Assessment

Problem-solving strategies

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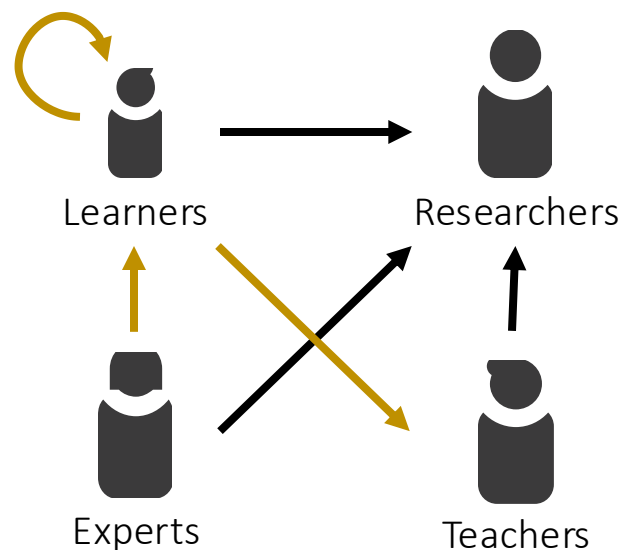
Predictability

Learning

Eye movement modeling examples

Teaching expertise development

Scientific expertise development



Diagnosis & Assessment

Problem-solving strategies

Expertise comparisons

Usage of representations

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Cognitive demand

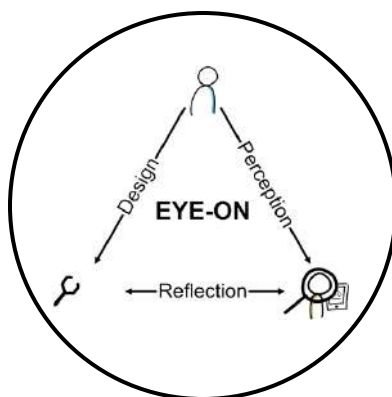
Predictability

Learning

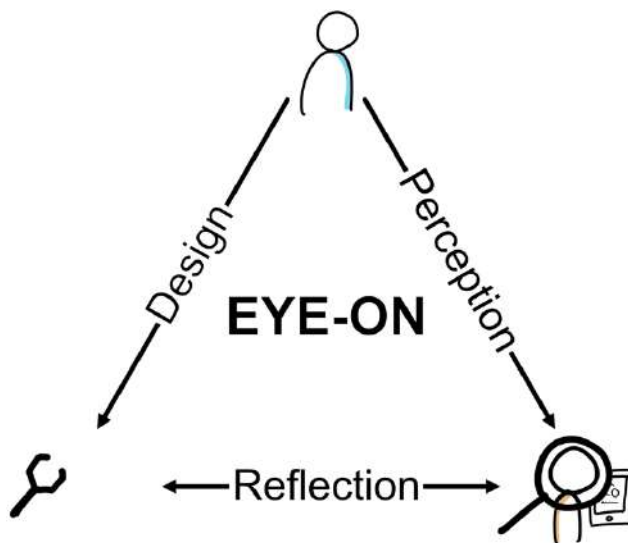
Eye movement modeling examples

Teaching expertise development

Scientific expertise development

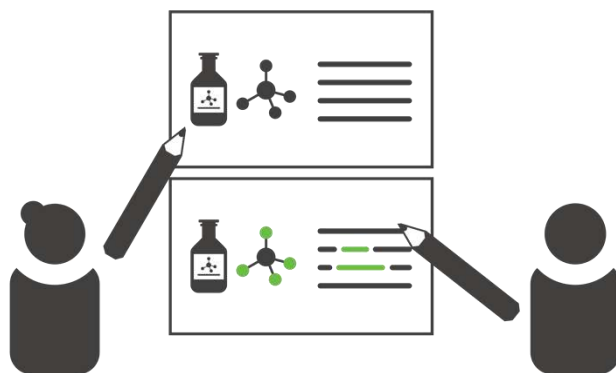


Designing multimedia learning materials & investigating the perceptual process of the learner



OUR GOAL

Supporting



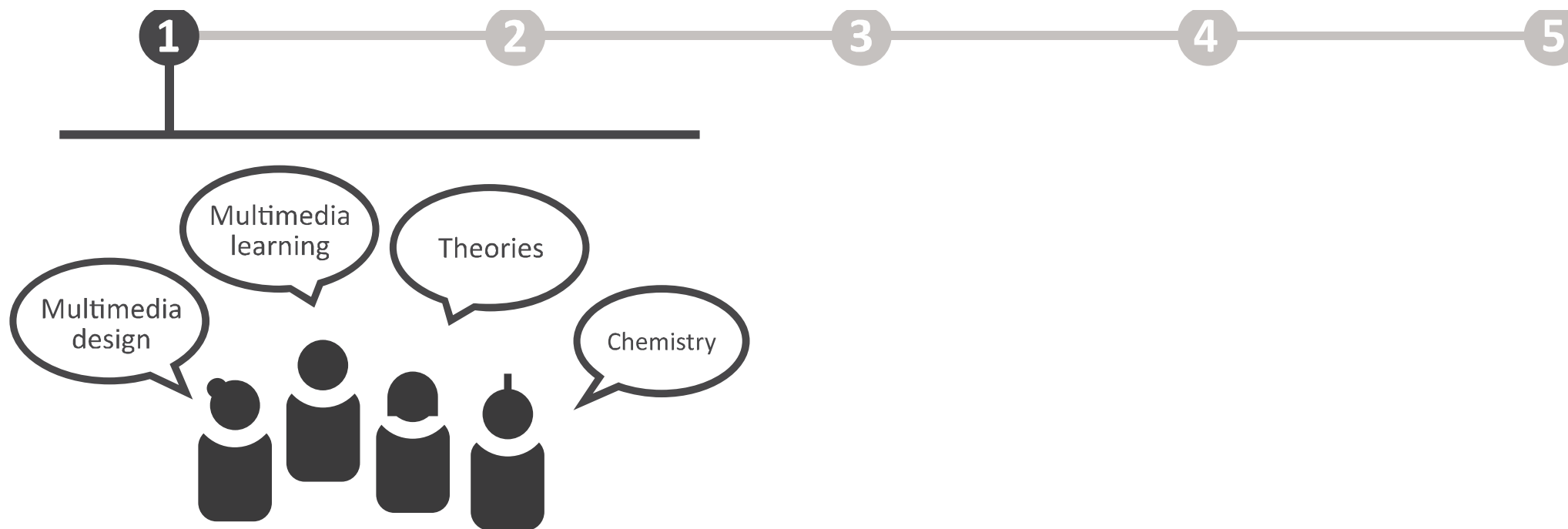
learning material design

by

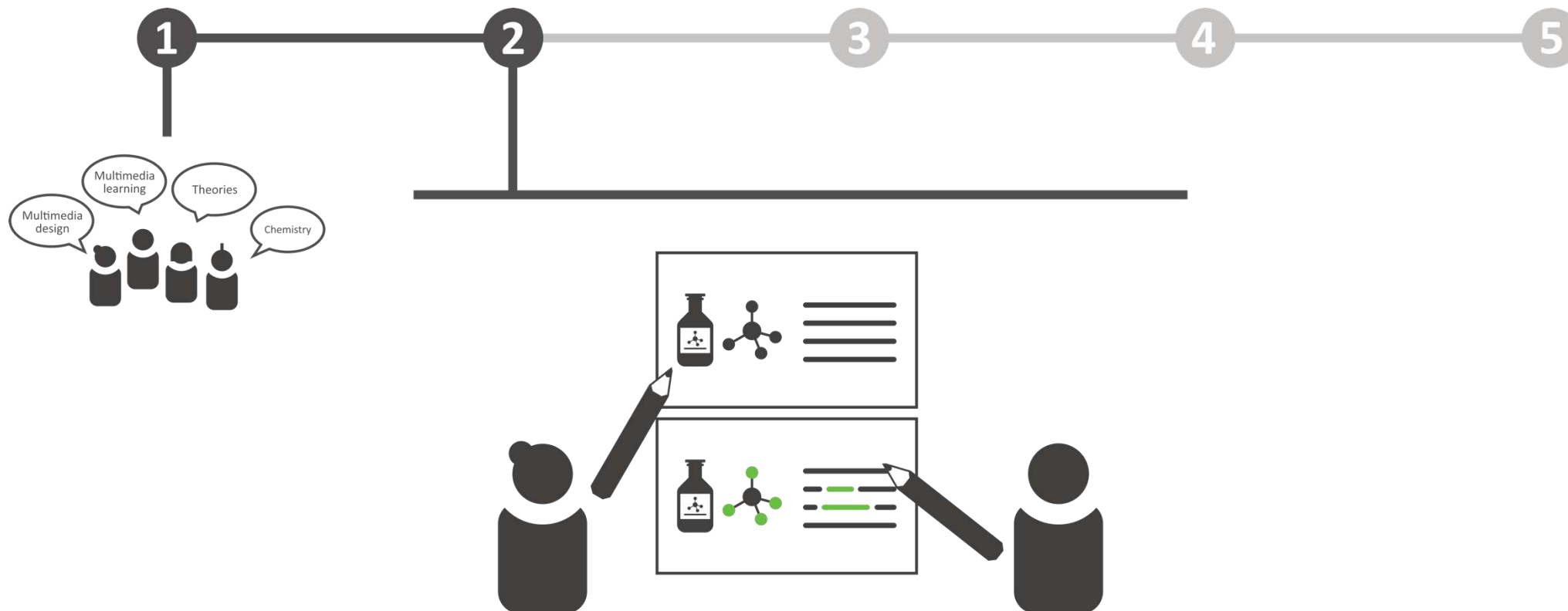


offering insight into learners' visual behavior.

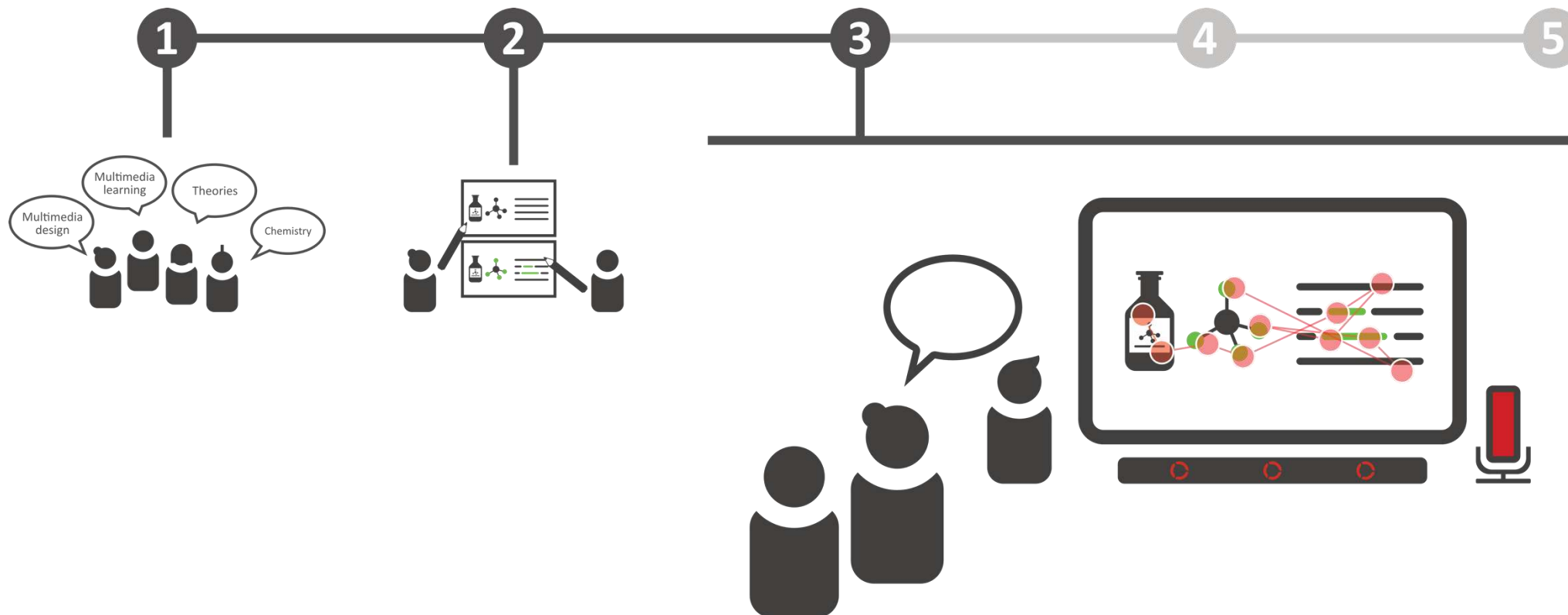
COURSE DESIGN



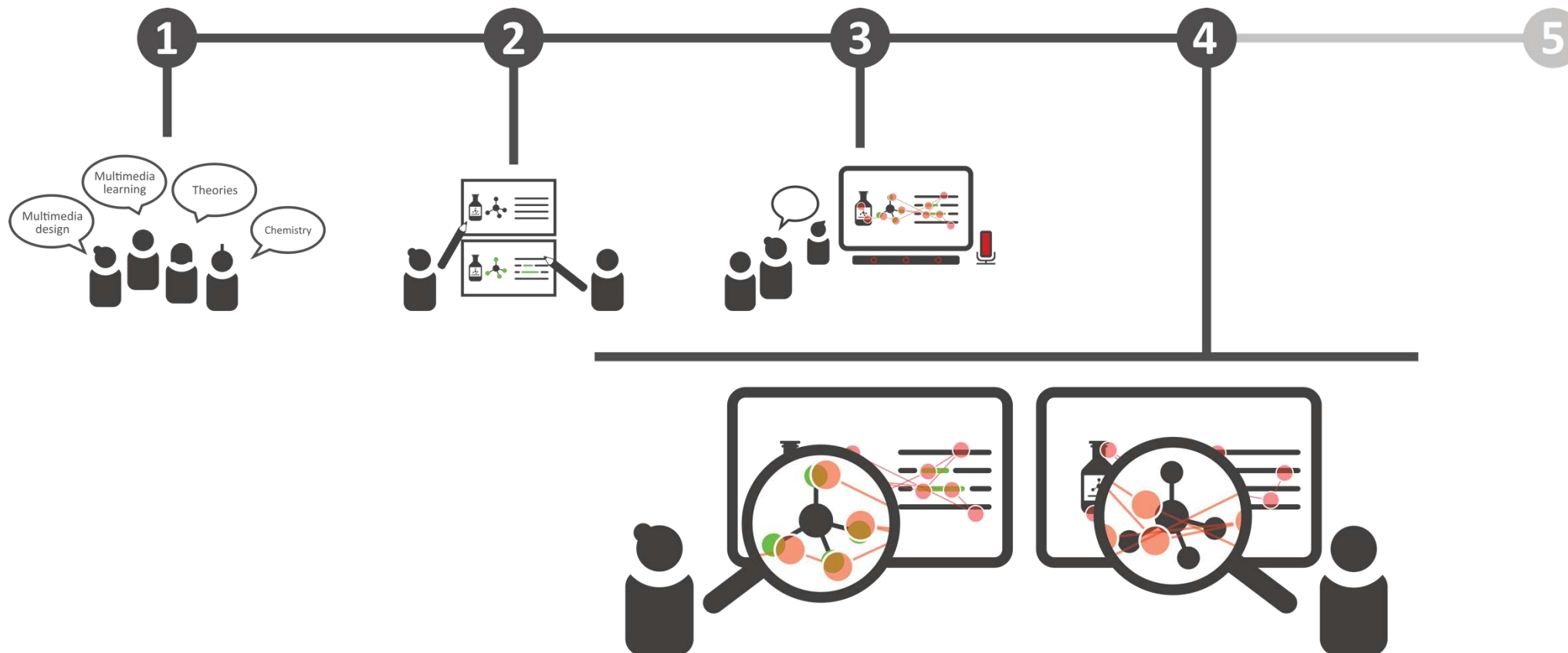
COURSE DESIGN



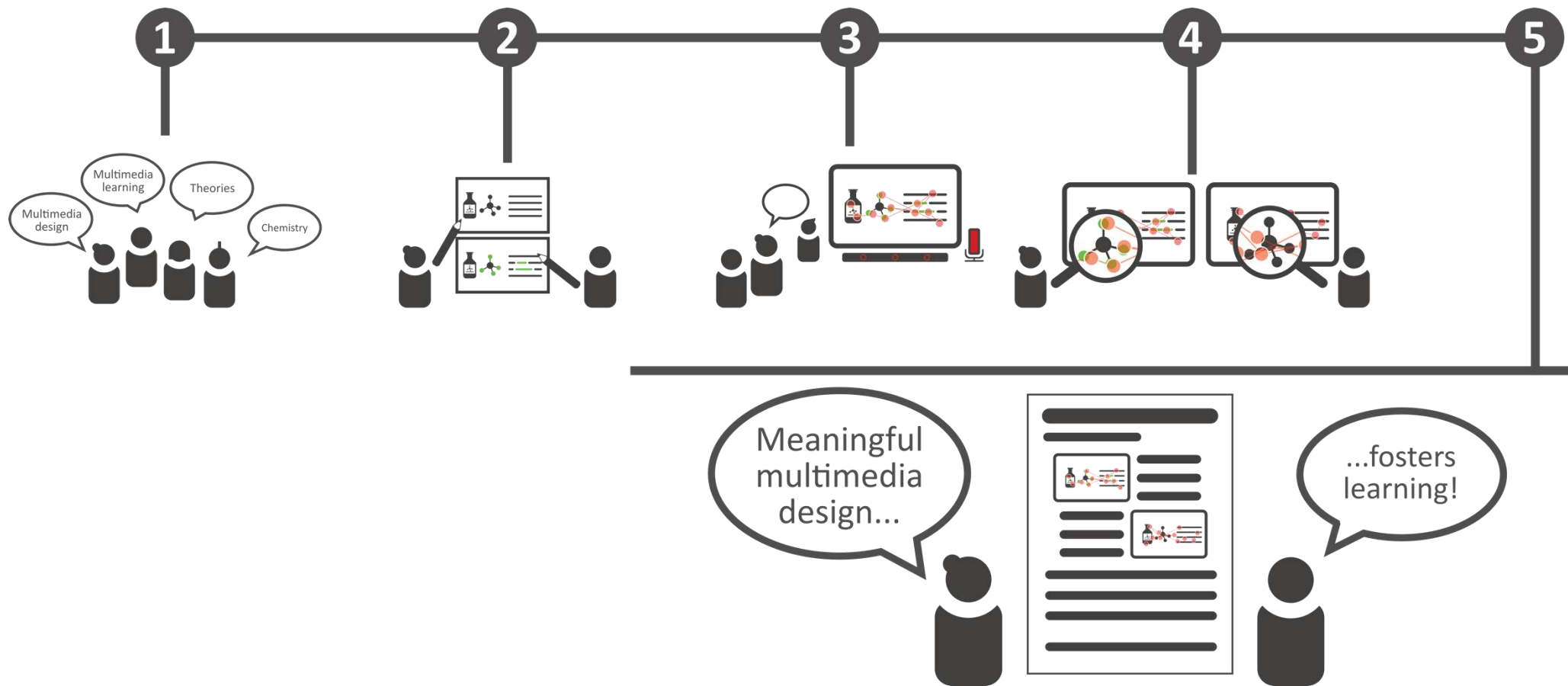
COURSE DESIGN



COURSE DESIGN



COURSE DESIGN



COURSE DESIGN

Chemistry Education 3 e-Learning
Justus-Liebig-University Giessen, Germany

Signaling

Supporting the information selection process

Data collection

Design

The study was conducted with chemistry teacher trainees in their second semester using a between-subject design. A Total Pro X3-120 screen-based eye tracker was used. All students had a similar level of knowledge and were able to choose the pace of the task individually. The tasks were executed exclusively on a computer. The data were analyzed post-hoc. The visualization started with a warm-up task to become familiar with the procedure, then participants answered several tasks successively. After each task the subjective (intrinsic) and extraneous cognitive load (ICL and ECL) was determined (following [1]).

To solve the task, participants had to identify the degree of substitution of adjacent C atoms of the hydroxy group. To simplify the selection, the hydroxy groups and the corresponding terms were highlighted for the positive design group (Fig. 1). This signaling is meant to reduce the cognitive load of the participants (Fig. 1).

Research Questions

- Does signaling facilitate the information selection process?
- Does supporting the information selection process lead to a subjectively better understanding of the task?

Analysis

Selection of functional groups

To test whether signaling has an influence on selection, the time participants needed to find the corresponding hydroxy groups in the molecule after reading the terms "primary" and "secondary" was measured.

The time participant Post1 needed to find the primary and secondary hydroxy groups was reduced in comparison to Neg1 (Fig. 2.1). Additionally, Neg1 needed the key terms "primary" and "secondary" less frequently than Post1. This observation, as well as the longer time of fixation of the negative task design group (Fig. 4.2), supports the assumption that relevant aspects of the task are more difficult to identify without the signaling (Fig. 2.2).

Backtracking

By signaling certain aspects of the task is meant to be more easily understandable. If a specific content is not understood completely, the participant may take another look at it for better understanding, so called backtracking (cf. [9], [10]).

Participant Neg1 had to look more often at the task than Post1. Additionally, Neg1 needed the key terms "primary" and "secondary" less frequently than Post1. This observation, as well as the longer time of fixation of the negative task design group (Fig. 4.2), supports the assumption that relevant aspects of the task are more difficult to identify without the signaling (Fig. 2.2).

Disturbances

The actual group of the starting material is not relevant and therefore provides a distraction. Apart from the non-relevant groups in the molecule, all not directly relevant text passages are considered to be disturbances. For the positive task design group relevant parts were highlighted.

Frequent visits of a certain element imply high informational content of this element for the participant (7). Consequently, the actual group had a higher informational value for Neg1 than it had for Post1. By highlighting the hydroxy groups, participant Post1 was able to select these more easily than Neg1 (Fig. 4.1).

The term "ac-catalyst" in the task passage probably has led the attention of the participants of the negative task design group to the actual group since it resembles the nomenclature of sugar anomers. This assumption is based upon the increased focus on this part of the test (Fig. 4.2).

Conclusion

Due to the small number of participants it is difficult to formulate a final conclusion, however, it seems that signaling has helped the participants to select relevant information. The relative time of fixation of the text and in particular of the distracting information in image and text is higher within the group without signaling. In addition, the positive task design group solved similar results as the comparison group but needed less process time as well as having a subjectively lower ICL and ECL. The significantly reduced backtracking indicates a better and better understanding of the task while needing less resting time.

The more the better?

How the usage of the coherence principle supports the success of learning material – an eye-tracking study.

Justus-Liebig-University Giessen, Germany
Institute of Chemistry Education
This poster was designed in the course
"Chemistry Education 3: e-Learning".

James Smith
Mary Johnson

Theory

When editing learning materials various design principles could be adapted, which potentially reduce the cognitive load of the instructional design (Extraneous Cognitive Load). One of those principles is the coherence principle. This principle demands that only information, which serves the understanding of the task, are presented in the design of the task. Irrelevant details can be distracting and lead the attention of the learner away from relevant information. [18]

Research Question

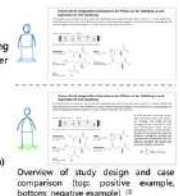
Are relevant information rarer looked at when not applying the coherence principle? Do the participants have difficulties solving the task due to impairment of integration and selection processes?

Study Design and Case Comparison

- Study design: between subject design
- Case comparison: design principle applied (positive example) or not applied (negative example)

Methods

- Data collection via eye-tracking
- Hardware: Tobii Pro eye-tracker X3-120
- Software: Tobii Pro Lab
- Recording eye movements
- Fixations as moments of seeing [9]
- Audio recording (methodological triangulation)



Data analysis

- Defining Areas of Interest (AOI)
- Using various metrics (qualitative description of the duration [9] and percentage of fixation duration of an AOI of the total fixation time [9])
- Evaluation of task solving success (scoring)



References

- [1] Johnson, M. (2012) The Cambridge handbook of multimedia learning. Cambridge University Press (2). [2] Smith, J. (2012) [3] [4] [5] [6] [7] [8] [9] [10] [11] [12] [13] [14] [15] [16] [17] [18] [19] [20] [21] [22] [23] [24] [25] [26] [27] [28] [29] [30] [31] [32] [33] [34] [35] [36] [37] [38] [39] [40] [41] [42] [43] [44] [45] [46] [47] [48] [49] [50] [51] [52] [53] [54] [55] [56] [57] [58] [59] [60] [61] [62] [63] [64] [65] [66] [67] [68] [69] [70] [71] [72] [73] [74] [75] [76] [77] [78] [79] [80] [81] [82] [83] [84] [85] [86] [87] [88] [89] [90] [91] [92] [93] [94] [95] [96] [97] [98] [99] [100]

Results of quantitative analysis

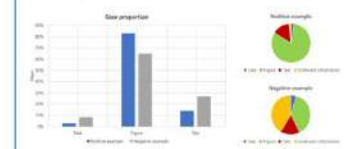
- Positive example: focus of fixations on electric charge of the amino acids as well as the poles of the filter paper
- Negative example: focus of fixations on irrelevant text and the term "isoelectric point (pI)" (cf. heatmaps)



Heatmaps: Comparison of distribution of visual attention between positive (left) and negative (right) example (coherence principle)

Results of quantitative analysis

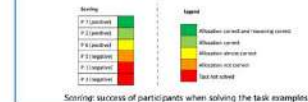
- Focus on the figure in the negative example is rarer than in the positive example (cf. bar chart)
- Shift of attention to irrelevant information in the negative example (cf. pie chart)



Pie charts: relative fixation duration (percentage of fixation duration of an AOI of the total fixation time) without taking irrelevant information into account (left) and when taking irrelevant information into account (right)

Scoring

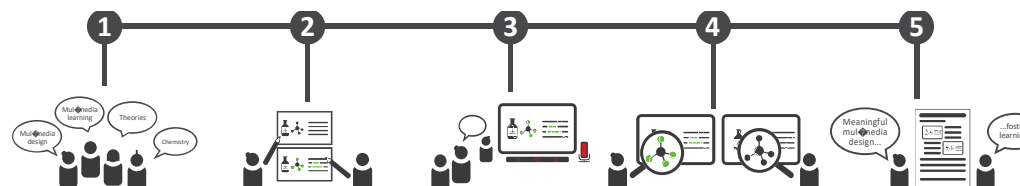
- More successful task solving in positive examples



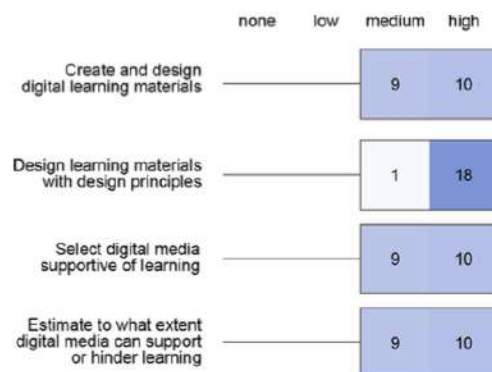
Conclusion

- Analyzing the data showed: electric charge of molecules in negative example less focused and AOI "Figure" viewed shorter.
- Negative example correlated with less success in solving the task (cf. Scoring), which indicates difficulties in integration and selection processes.
- Non-use of the coherence principle can lead to less focusing on relevant information as well as difficulties in solving the task. Therefore, using the coherence principle when designing learning material can be classified as reasonable.

TEACHING EXPERTISE DEVELOPMENT



The course **increased** student teachers...



...skills to **create, select, and design** learning material.

constructs	median	z	p^{a}	r^b
Attitude (pre)	3.00			
Attitude (post)	3.28	2.11	0.035	0.48
Subjective norm expectations (pre)	2.75			
Subjective norm expectations (post)	3.00	2.67	0.008	0.61
Self-efficacy expectations (pre)	2.14			
Self-efficacy expectations (post)	2.57	2.44	0.015	0.56

^aSignificance level of 0.05 and confidence interval of 95%. ^bCalculated as indicated by Rosenthal.⁸⁵

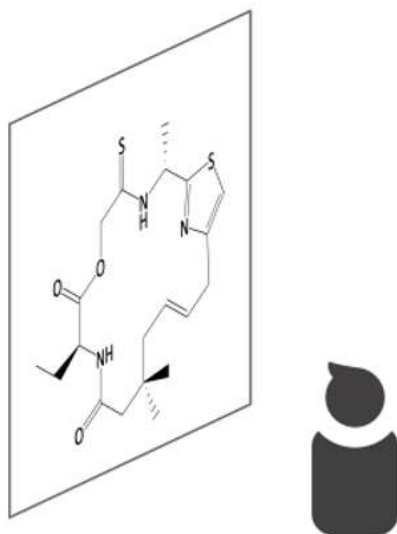
...**attitude and self-efficacy** toward digital media use in teaching.

An eye-gaze-augmented retrospective in Organic Chemistry

iGaze
eye-gaze-augmented retrospective

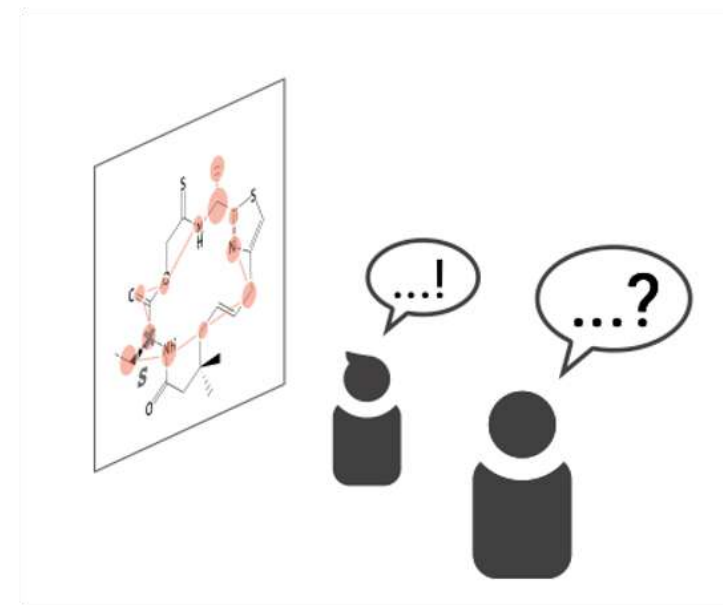
OUR GOAL

Supporting



students' problem-solving

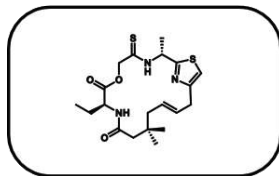
with



an eye-gaze-augmented retrospective.

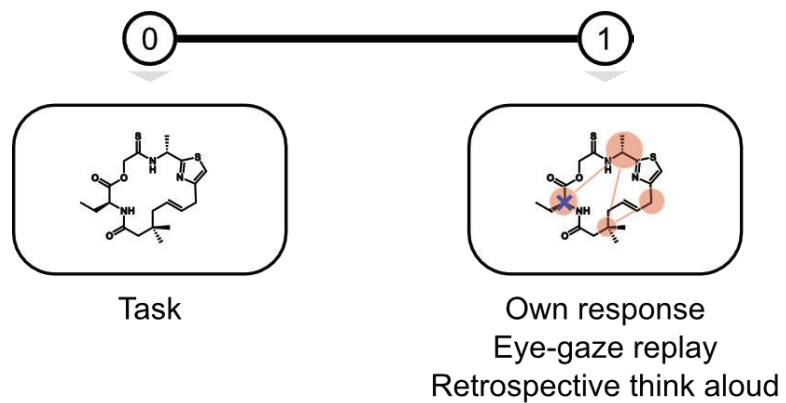
STUDY DESIGN

0

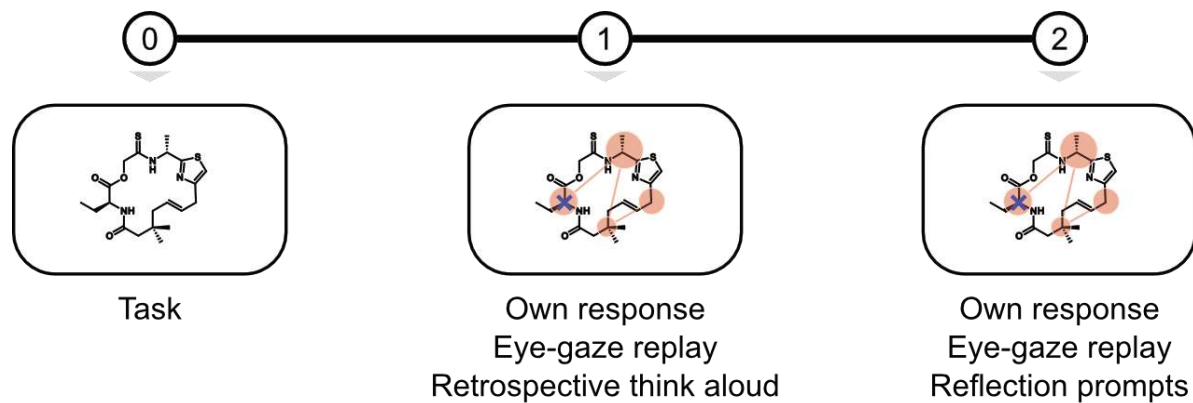


Task

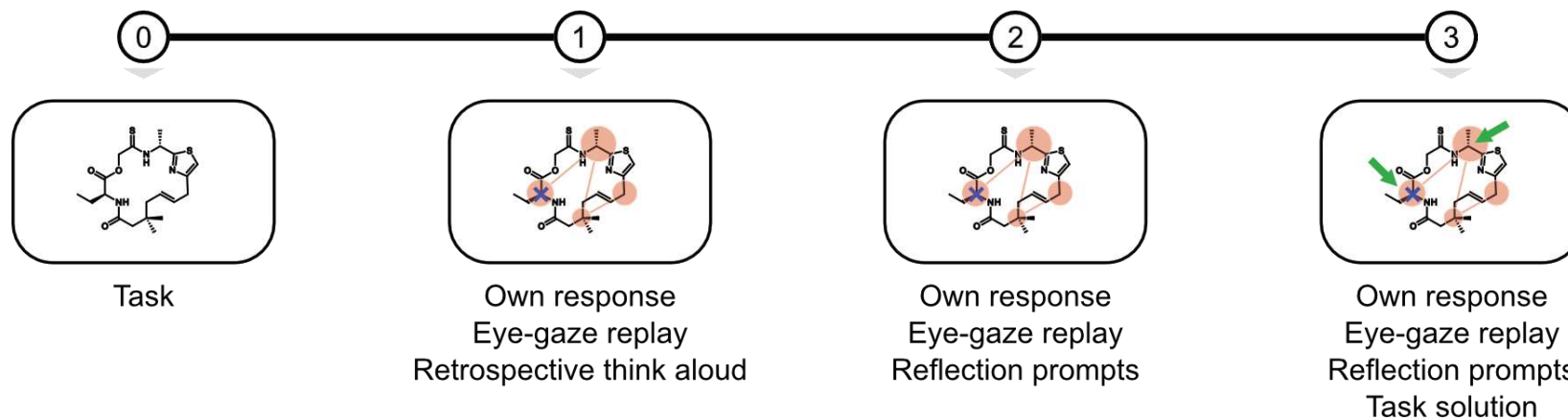
STUDY DESIGN



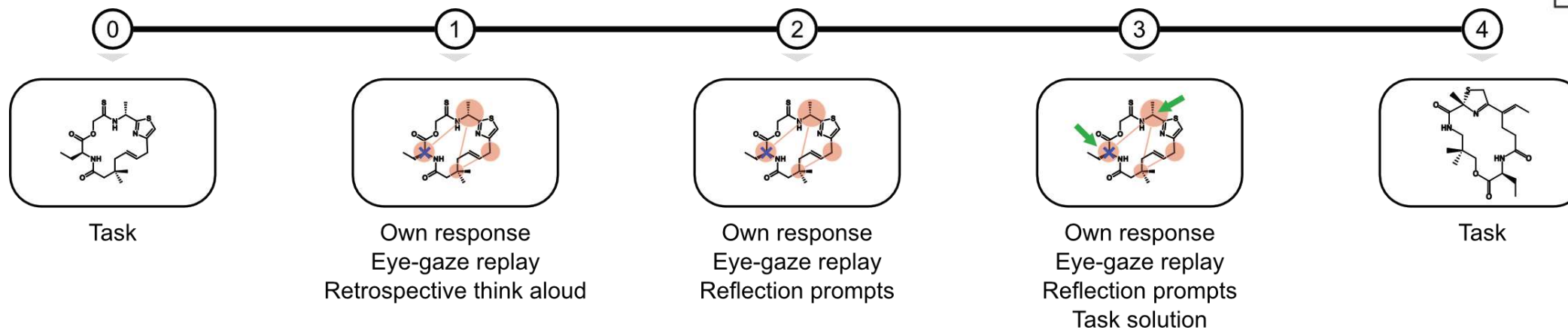
STUDY DESIGN



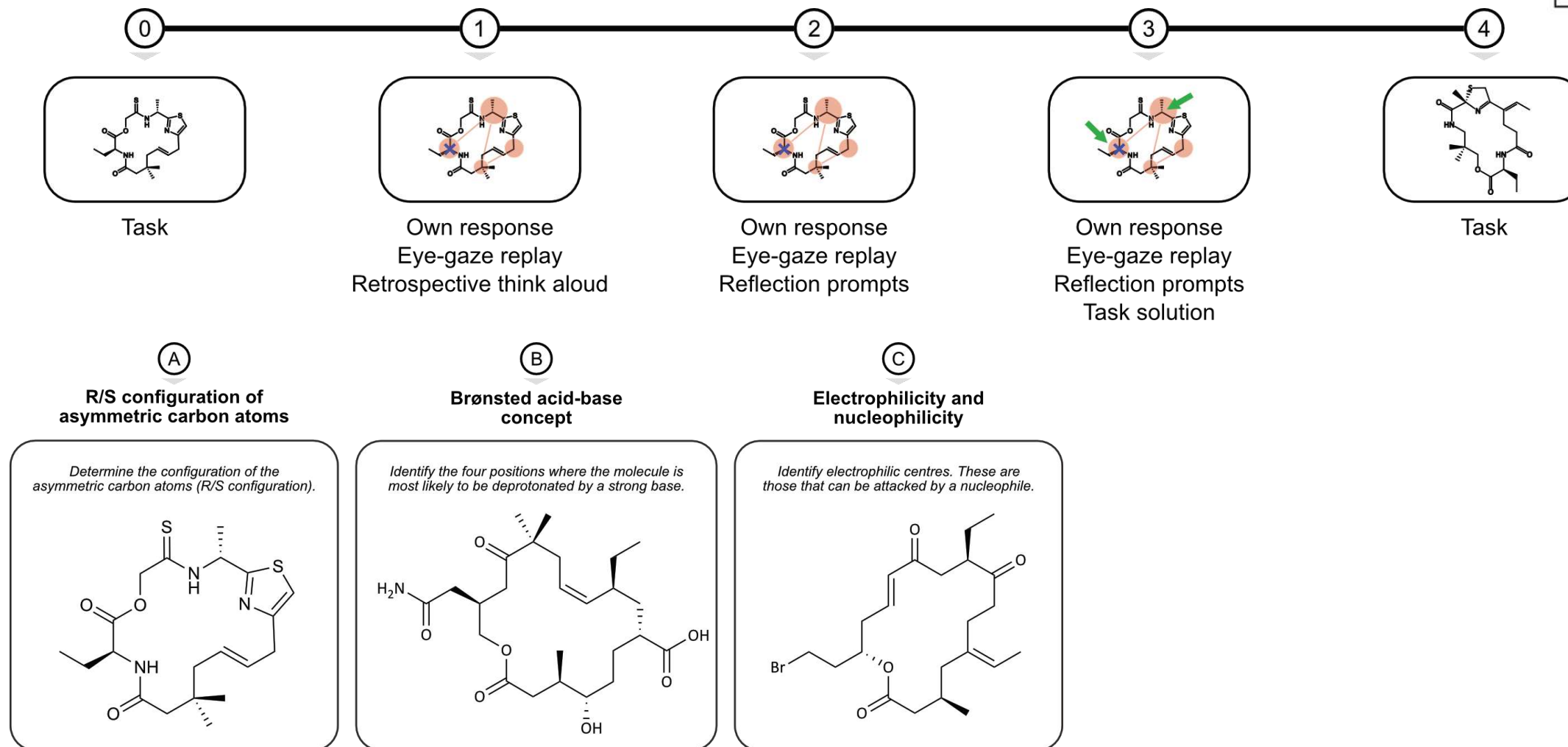
STUDY DESIGN



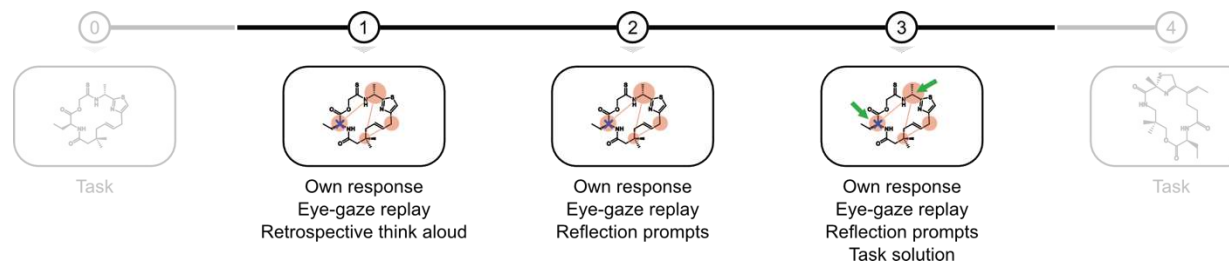
STUDY DESIGN



STUDY DESIGN



SCIENTIFIC EXPERTISE DEVELOPMENT



B Identify the four positions where the molecule is most likely to be deprotonated by a strong base.

Nitrogen of the carboxamide

1 Anna: "So, I started with the amine because it has protons. It was all about protons. But I discarded that idea. [...] Because ammonia itself is a base. Therefore, it's less likely to be deprotonated. That's why I discarded it." [...]

2 Anna: "As I don't have any new information or know if I am right or wrong, for now, I wouldn't change my strategy." [...]

3 Anna: "Oh, it's an amide, not an amine! I'm such a fool. So, I had previously discarded it because an amine is a base. And bases don't give up their protons." [...]

Anna: "I should have looked more closely."

Anna: "But I think that even with an amide, I might not have considered it being deprotonated." [...]

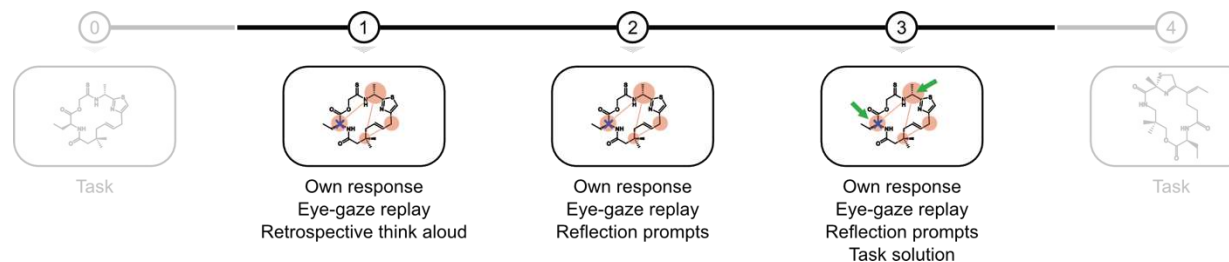
Anna: "But thinking about it now, if I have an amide, so there's a carboxyl group. And if I deprotonate that, then I have a free pair of electrons. It can flip from nitrogen to carbon and then from carbon to oxygen. And negative charges are always well placed on oxygen. Then it's clear that it gets deprotonated. Unlike an amine, which wouldn't really want to do that, as it lacks stabilisation."

Anna: "At the beginning, I quickly scanned the molecule. It was like a filter step, where I really only looked at places with protons."

Anna: "So, I saw it [carboxamide] like an amine." [...]

Anna: "As of now, I would move from the proton and take a closer look at the neighbouring bond."

SCIENTIFIC EXPERTISE DEVELOPMENT



Elaborated reflection

(B) Identify the four positions where the molecule is most likely to be deprotonated by a strong base.

Nitrogen of the carboxamide

1 Anna: "So, I started with the amine because it has protons. It was all about protons. But I discarded that idea. [...] Because ammonia itself is a base. Therefore, it's less likely to be deprotonated. That's why I discarded it." [...]

2 Anna: "As I don't have any new information or know if I am right or wrong, for now, I wouldn't change my strategy." [...]

3 Anna: "Oh, it's an amide, not an amine! I'm such a fool. So, I had previously discarded it because an amine is a base. And bases don't give up their protons." [...]

A Anna: "I should have looked more closely."

I Anna: "But I think that even with an amide, I might not have considered it being deprotonated." [...]

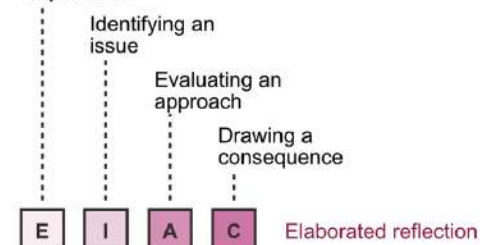
A Anna: "But thinking about it now, if I have an amide, so there's a carboxyl group. And if I deprotonate that, then I have a free pair of electrons. It can flip from nitrogen to carbon and then from carbon to oxygen. And negative charges are always well placed on oxygen. Then it's clear that it gets deprotonated. Unlike an amine, which wouldn't really want to do that, as it lacks stabilisation."

E Anna: "At the beginning, I quickly scanned the molecule. It was like a filter step, where I really only looked at places with protons."

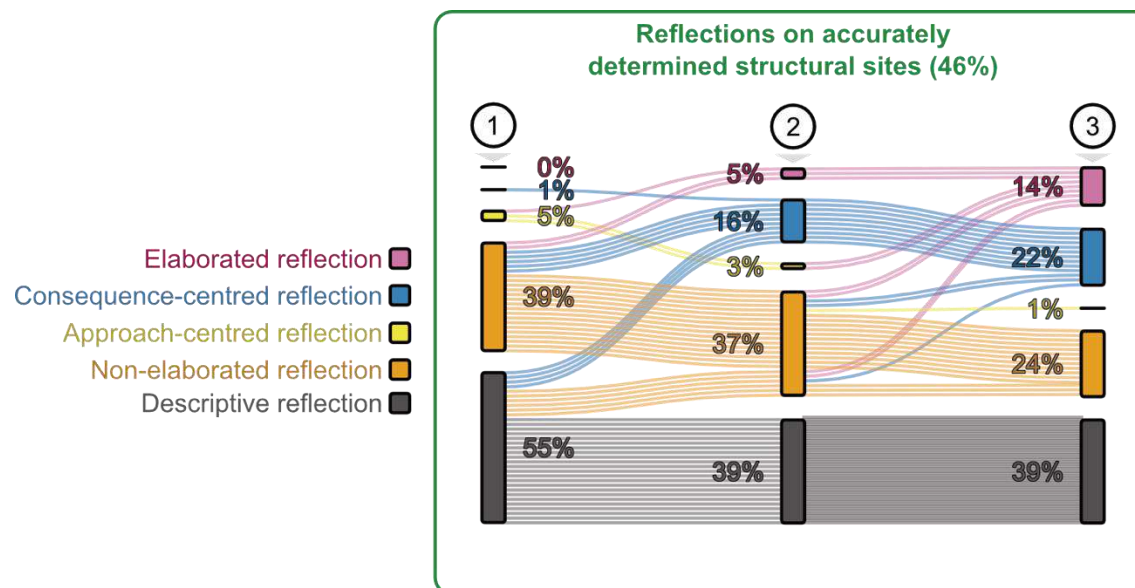
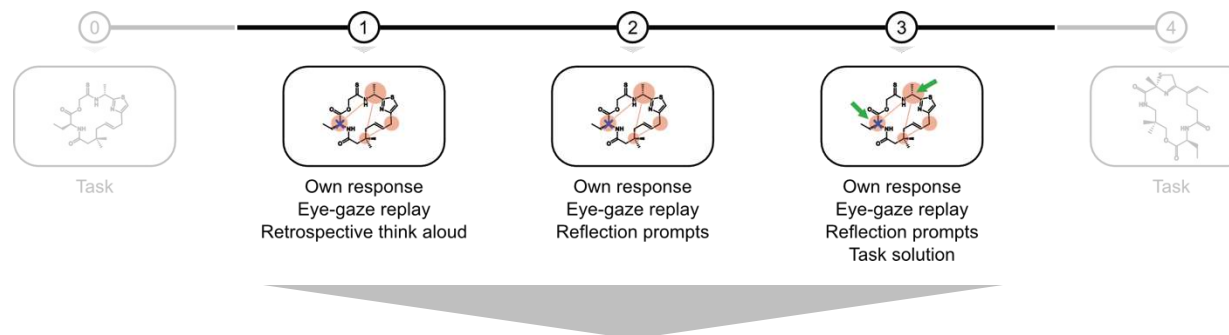
I Anna: "So, I saw it [carboxamide] like an amine." [...]

C Anna: "As of now, I would move from the proton and take a closer look at the neighbouring bond."

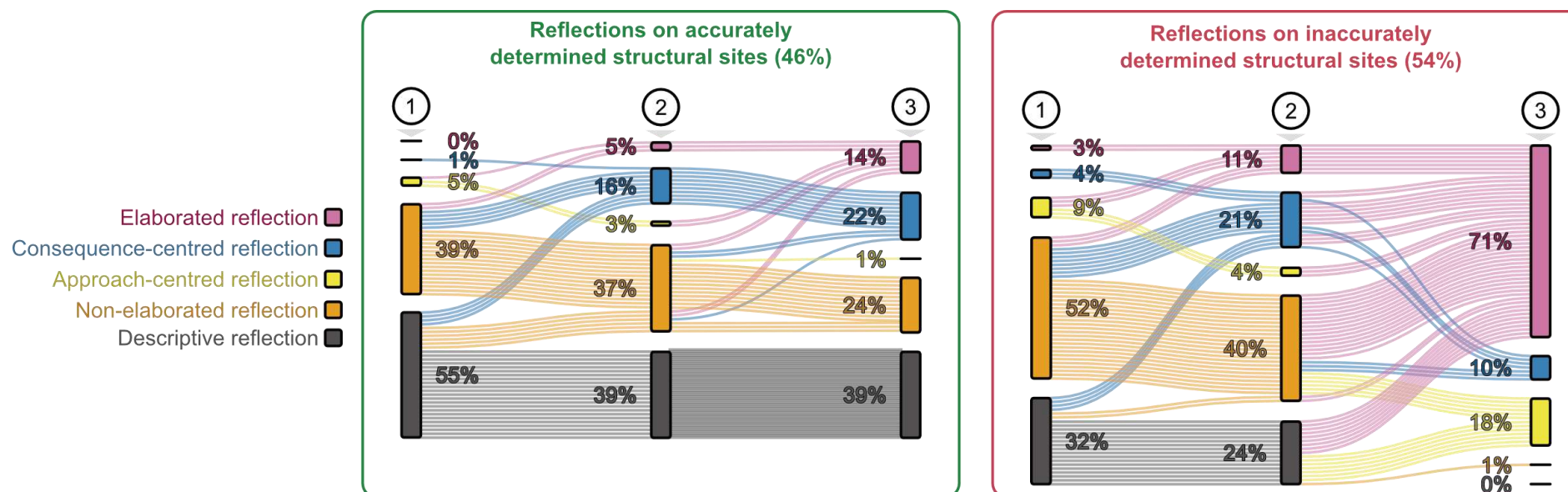
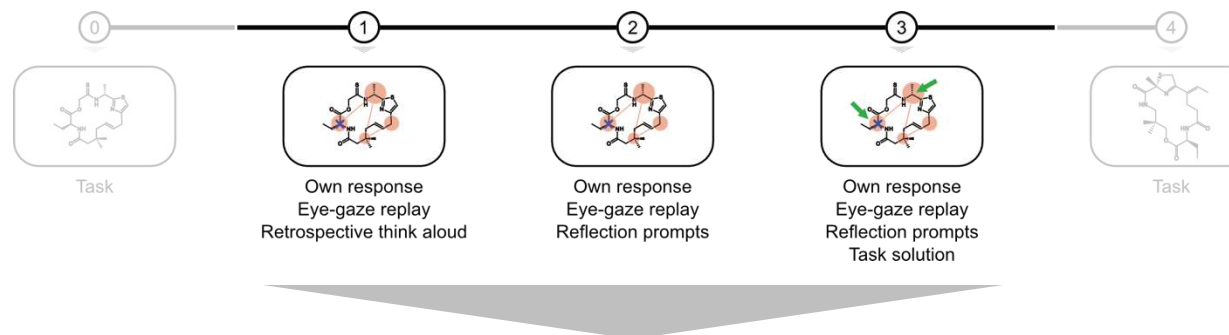
Describing the experience



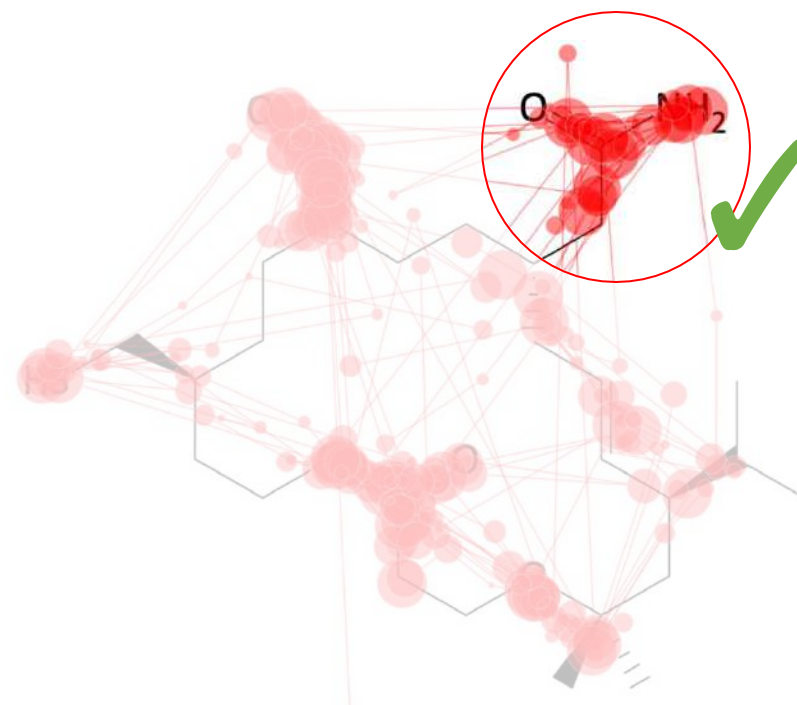
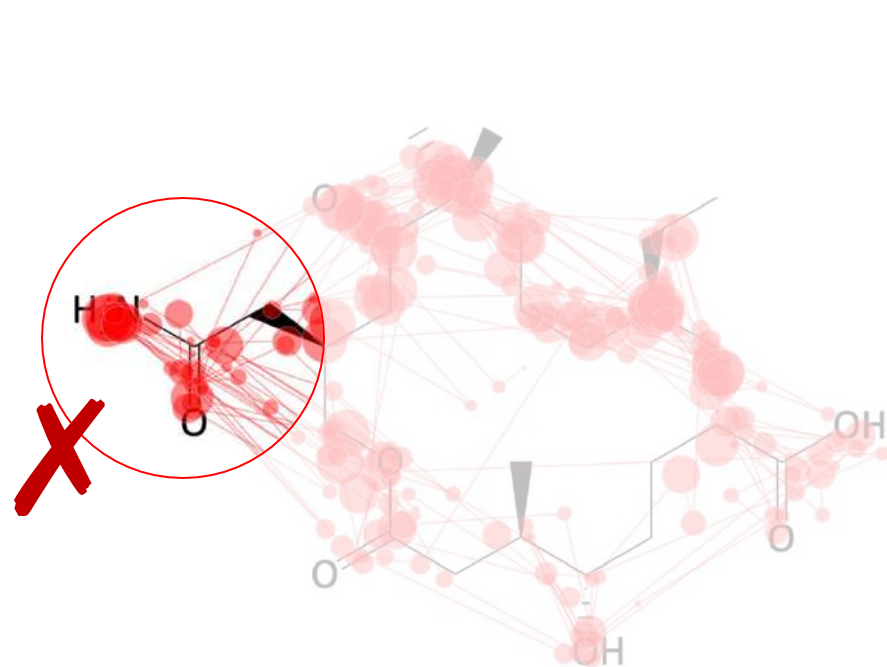
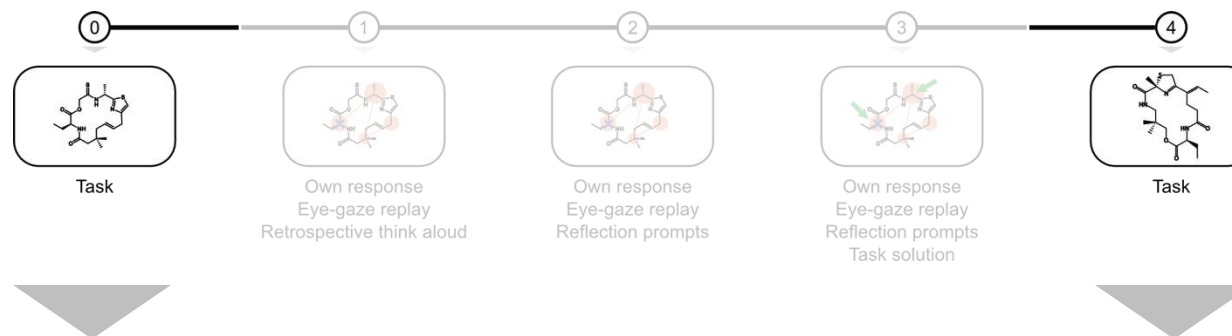
SCIENTIFIC EXPERTISE DEVELOPMENT



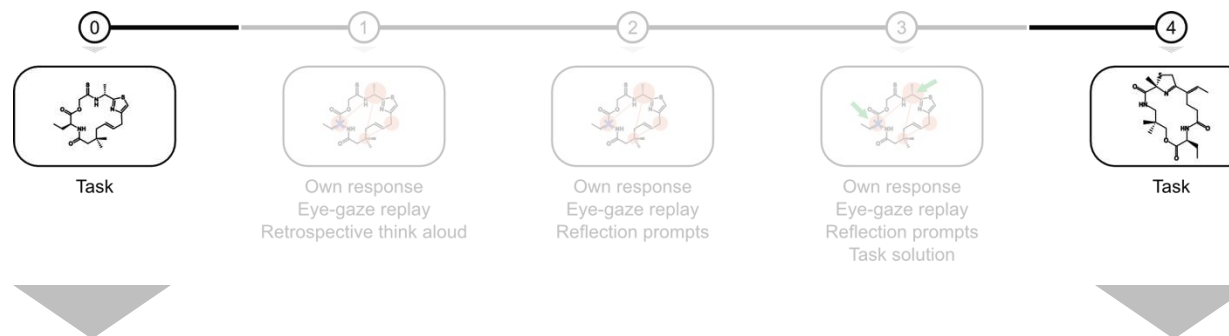
SCIENTIFIC EXPERTISE DEVELOPMENT



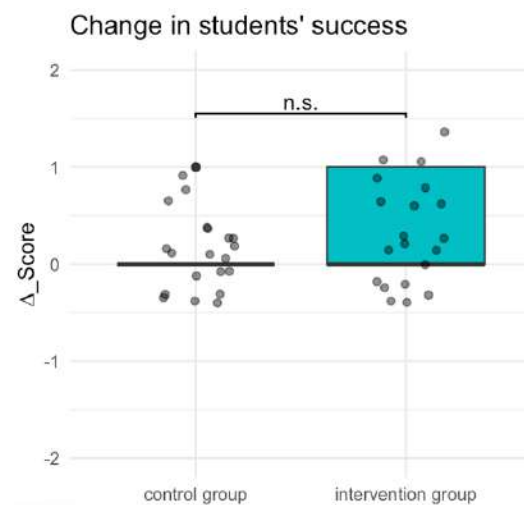
SCIENTIFIC EXPERTISE DEVELOPMENT



SCIENTIFIC EXPERTISE DEVELOPMENT

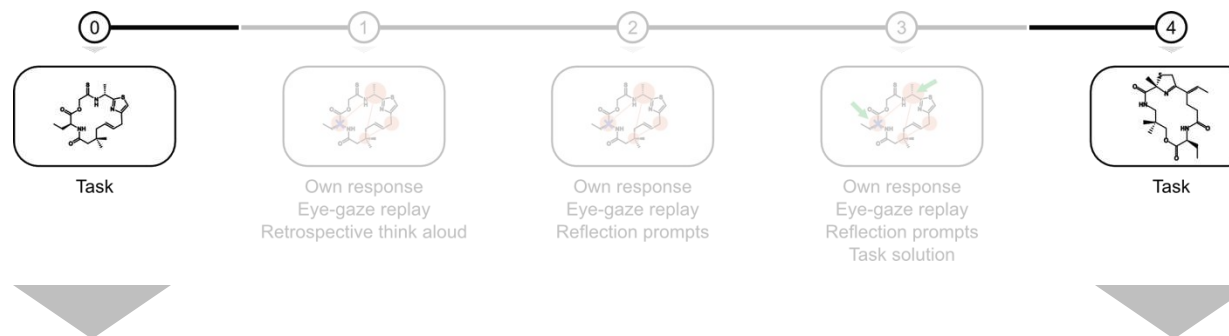


The eye-gaze-augmented retrospective...

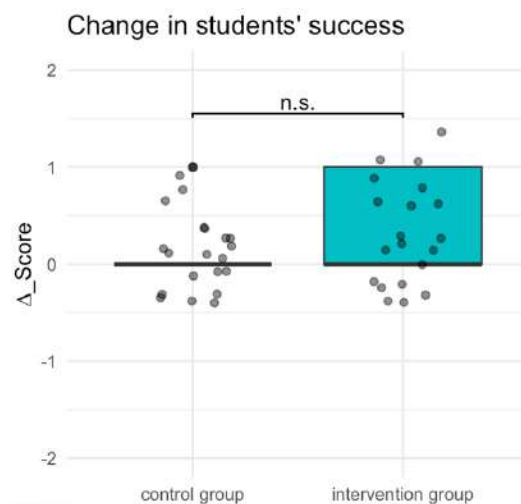


...did **not** influence
students' success.

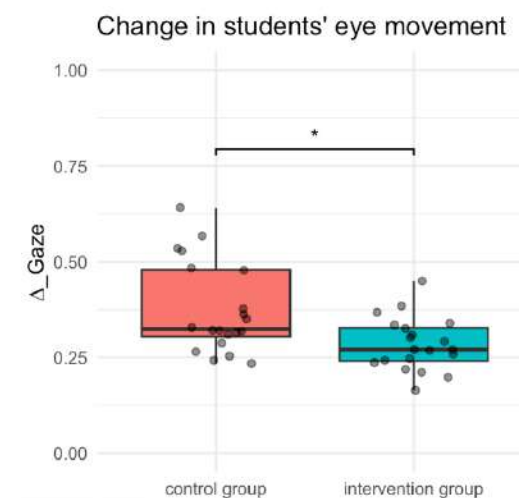
SCIENTIFIC EXPERTISE DEVELOPMENT



The eye-gaze-augmented retrospective...

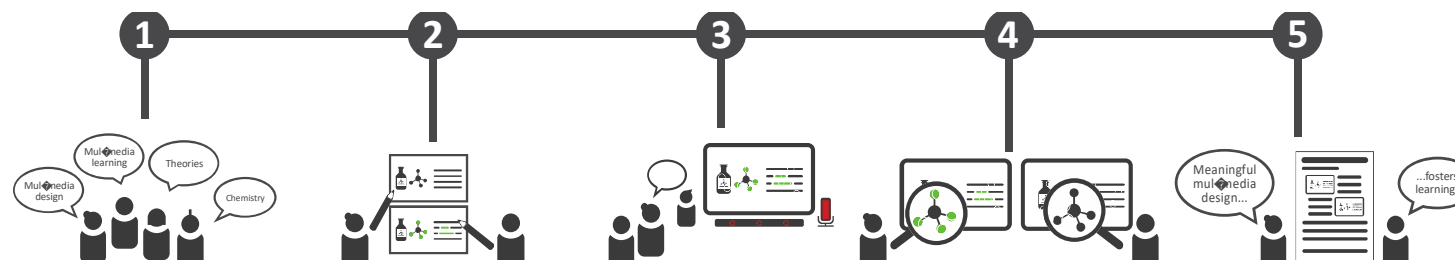


...did **not** influence
students' success.

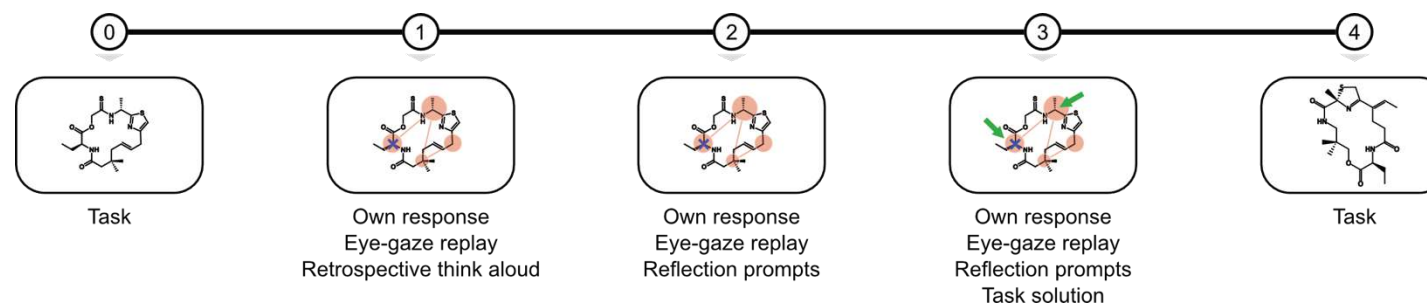


...stimulated
more **consistent**
eye-movements.

CONCLUSION



Eye-tracking isn't just a diagnostic tool; it can also serve as a **feedback tool**.



THANK YOU!



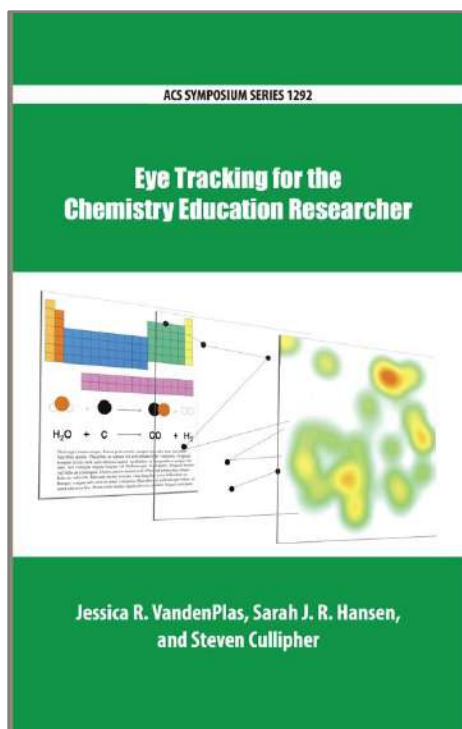
Do you have questions?

What are your thoughts?

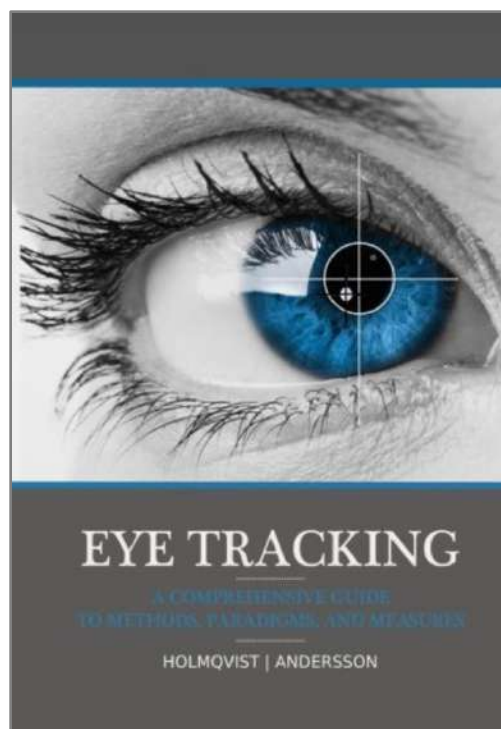
What should (chemistry education)
eye-tracking research focus on?

ADDITIONAL SLIDES

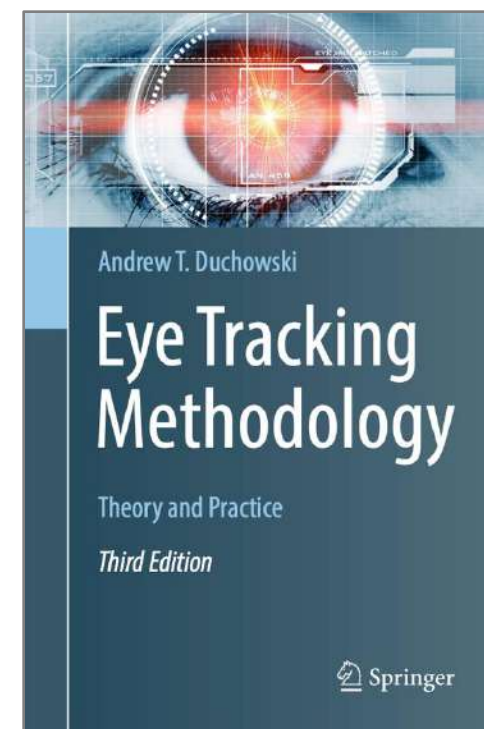
LITERATURE RECOMMENDATIONS



Eye-Tracking for Chemistry
Education Researcher



Eye-Tracking Guide



Eye-Tracking Guide

DATA COLLECTION

Screen-based

VR-Eye-Tracking

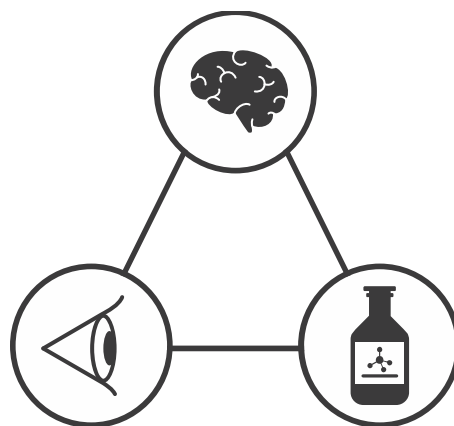
Mobile



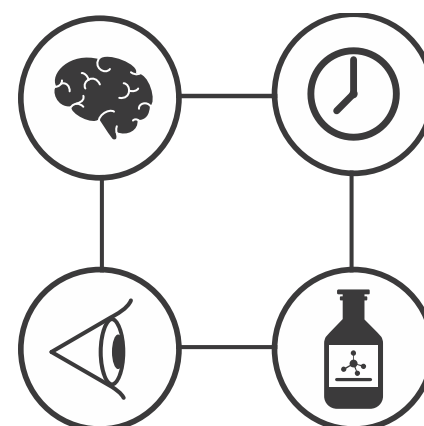
ASSUMPTIONS



Relevant information in
gaze center



Immediacy
assumption



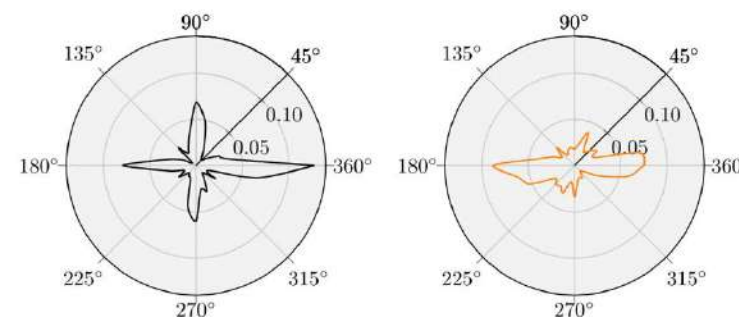
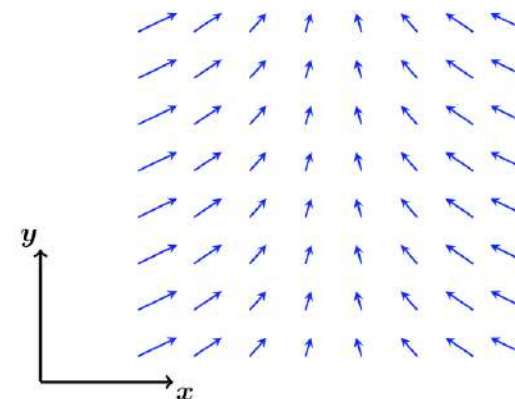
Eye-mind
assumption



Covert & overt attention
directed to the same stimulus

VISUAL BEHAVIOR... IN VECTOR FIELD PLOTS

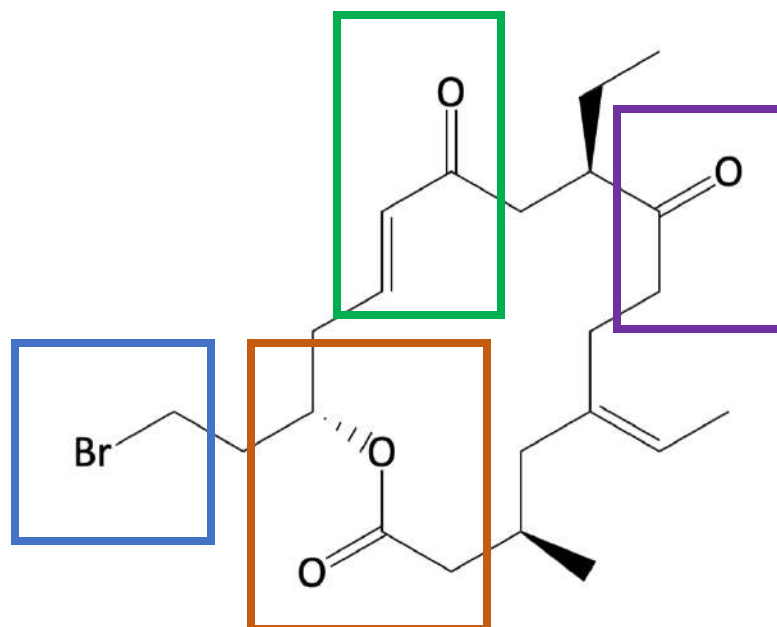
Interpret the divergence of this vector field.



best performer

worst performer

DATA ANALYSIS



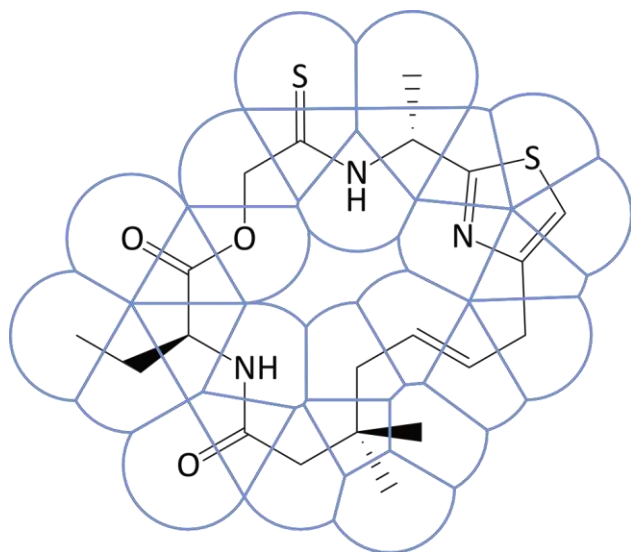
Areas of Interest (AOI)

Number of fixations
Fixation duration
Gaze proportion
Gaze path
Transition
Revisits
Time to first revisit
First five fixations
Time to first fixation
Time of first visit
Dwell time
Saccade angle
Pupil dilation
Blinks
...

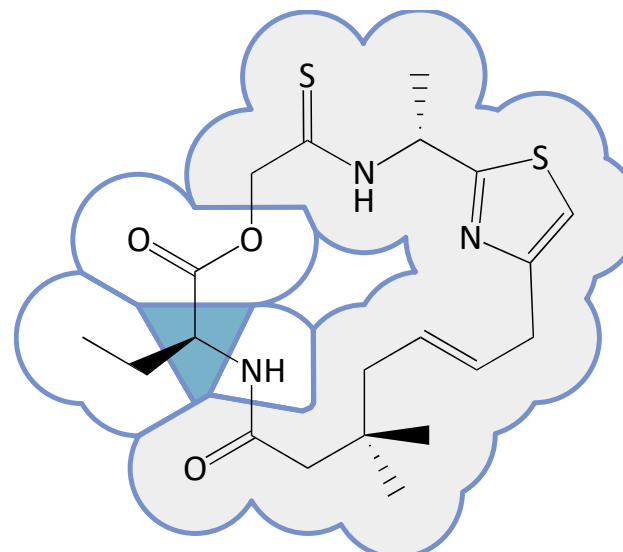
Metrics

DATA PREPARATION

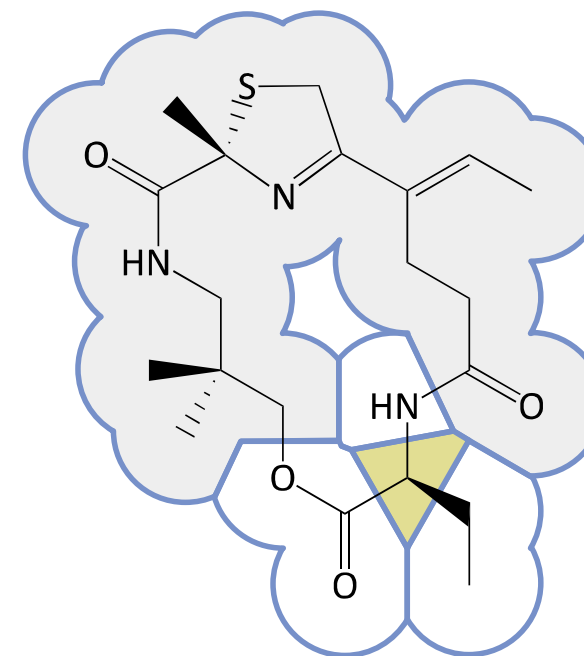
Defining Areas of interest (AOIs)



Limited-radius
Voronoi tessellation



Task 1



Task 2

DATA INTERPRETATION

Fixation duration: Attention (Desjarlais 2017)
Information processing (Clinton 2017)
Difficulty (Holmqvist *et al.* 2011)
Organisation process (Alemdag & Cagiltay 2018)
Cognitive load (Tang & Pienta 2012)
Comprehension process (Cullipher *et al.* 2018)
Task complexity (Cullipher *et al.* 2018)
Expertise level (Baluyut & Holme 2019)
Layout evaluation (Gegenfurtner 2011)
Distractors (Duchowski 2002)
Interest (Desjarlais 2017)
...

Transitions: Visual attention distribution (Richter & Scheiter 2019)
Information processing (Desjarlais 2017)
Working memory capacity (Holmqvist *et al.* 2011)
Integration process (Alemdag & Cagiltay 2018)
Chunking (Holmqvist *et al.* 2011)
Comprehension process (Scheiter & Eitel 2017)
Effort of information integration (Mason *et al.* 2013)
prior knowledge (Scheiter & Eitel 2017)
Expertise level (Topczewski *et al.* 2017)
Transfer performance (Scheiter & Eitel 2017)
Success (Krebs *et al.* 2019)
Layout evaluation (Holmqvist *et al.* 2011)
Importance of information (Holmqvist *et al.* 2011)
task complexity (Holmqvist *et al.* 2011)
...

ET IN CHEMISTRY EDUCATION RESEARCH

Diagnosis & Assessment

Problem-solving strategies

Expertise comparisons

Usage of representations

Evaluation of learning materials

Cognitive demand

Predictability

Journal of Chemical Education
pubs.acs.org/jchemeduc

Decoding Case Comparisons in Organic Chemistry: Eye-Tracking Students' Visual Behavior
Marc Rodemer, Julia Eddhard, Nicole Graulich,* and Sascha Bernholt*

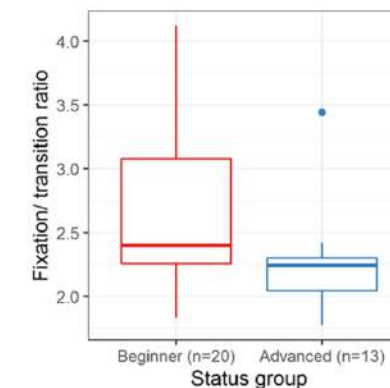
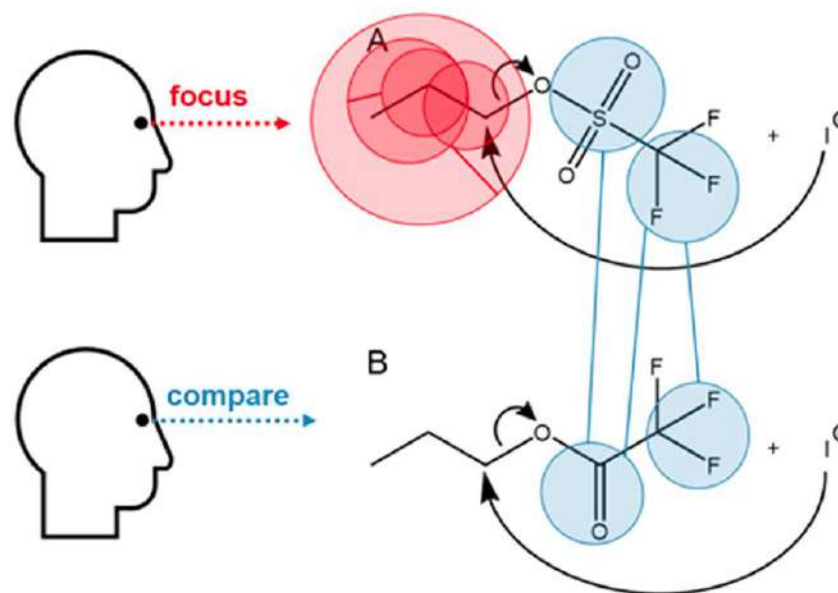
Cite This: *J. Chem. Educ.* 2020, 97, 3530–3539 | Read Online

ACCESS | Metrics & More | Article Recommendations | Supporting Information

ABSTRACT: Reaction mechanisms commonly used in organic chemistry are a great challenge for students in terms of understanding the representation and inferring the appropriate chemical concepts. In order to support the process of identifying and selecting chemical concepts, purposefully designed case comparisons are widely used. While these tasks place great demands on students' problem-solving capabilities, it is unknown how learners distribute their attention on the complex and information-rich representations. Understanding students' visual decoding behavior when dealing with case comparisons could provide valuable insights into supporting students' problem-solving process. In this exploratory study, we employed eye-tracking methodology to observe beginner and advanced undergraduate chemistry students when working through case comparison tasks. By establishing a novel eye-tracking measure, the fixation/transition ratio, distinct viewing behaviors could be observed. Results indicate significant differences between both status groups. Advanced students are overall faster in their decision-making and transition more frequently between the representations, indicating a higher selectivity for chemically relevant entities. Further, the results show a significant impact of the visual complexity of a representation on students' visual behavior. Implications for designing case comparisons and supporting students' decoding process are discussed.

KEYWORDS: Second-Year Undergraduate, Organic Chemistry, Analogies/Transfer, Problem Solving/Decision Making, Mechanisms of Reactions, Nucleophilic Substitution, Chemical Education Research

FEATURE: Chemical Education Research



Beginner students exhibit more focused behavior.

Diagnosis & Assessment

Problem-solving strategies

Expertise comparisons

Usage of representations

Evaluation of learning materials

Cognitive demand

Predictability

JOURNAL OF CHEMICAL EDUCATION Article
pubs.acs.org/jchemeduc

Atoms versus Bonds: How Students Look at Spectra

Steven Cullipher and Hannah Sevian*

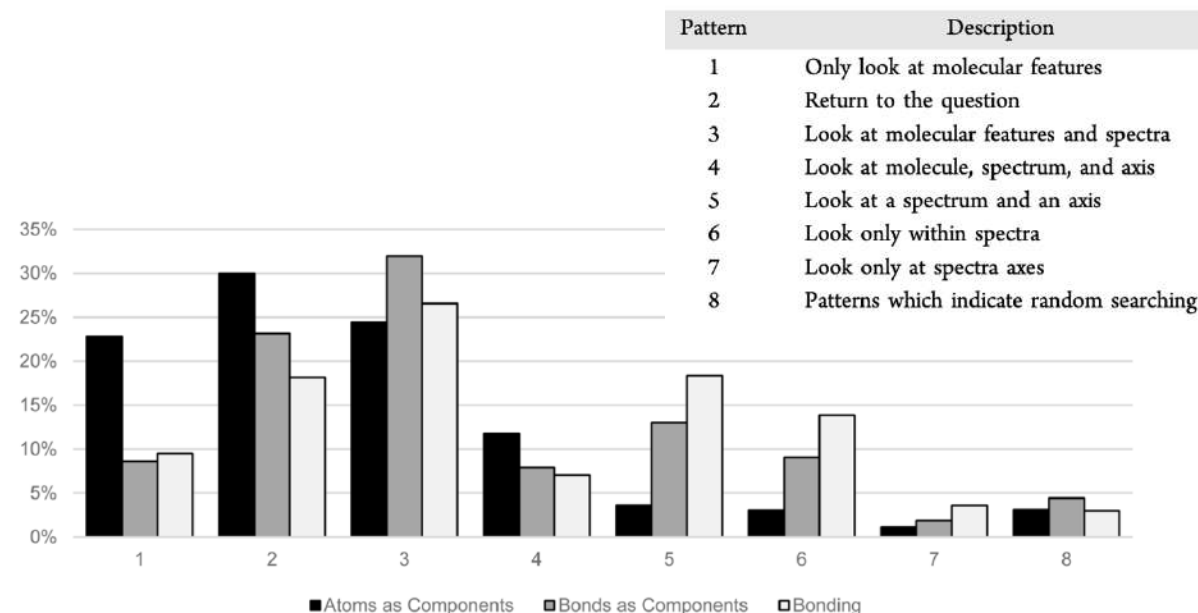
Department of Chemistry, University of Massachusetts, Boston, Boston, Massachusetts 02125, United States

Supporting Information

ABSTRACT: Students often face difficulties when presented with chemical structures and asked to relate them to properties of those substances. Learning to relate structures to properties, both in predicting properties based on chemical structures and interpreting properties to infer structure, is pivotal in students' education in chemistry. This troublesome but critical concept is often referred to as structure–property relationships. While there is no shortage of literature on students' difficulties with this concept, there is a lack of methodologies that can directly and quantitatively reveal underlying assumptions about structure–property relationships that constrain students' thinking. This study applied a “chemical thinking” lens to elucidate assumptions about structure–property relationships thinking. A combination of qualitative analysis using a think-aloud interview protocol was used with quantitative analysis of eye tracking data to probe students' reasoning when relating molecular structures of volatile hydrochlorocarbons to infrared spectral properties. Our initial findings offer partial validation of a newly developed methodology for analyzing eye tracking data to expose reasoning patterns that appear to correspond to identifiable underlying assumptions.

KEYWORDS: First-Year Undergraduate/General, Second-Year Undergraduate, Upper-Division Undergraduate, Graduate Education/Research, Chemical Education Research, Spectroscopy

FEATURE: Chemical Education Research



Underlying assumptions show different gaze patterns.

Diagnosis & Assessment

Problem-solving strategies

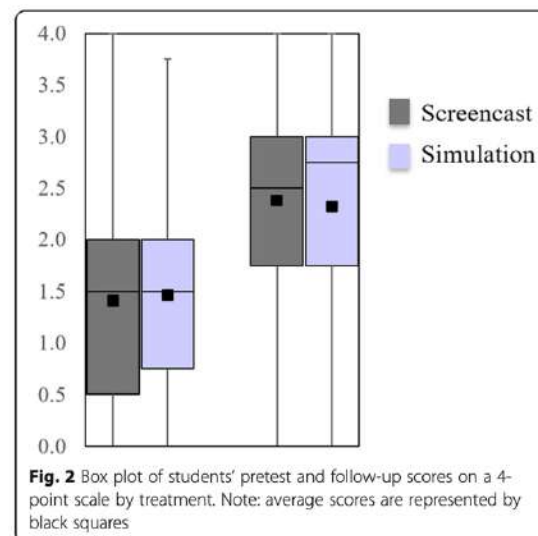
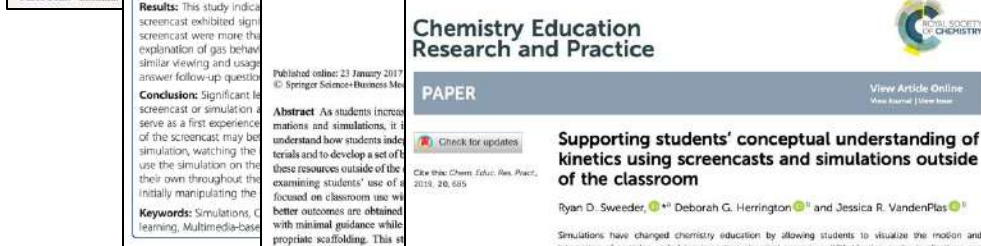
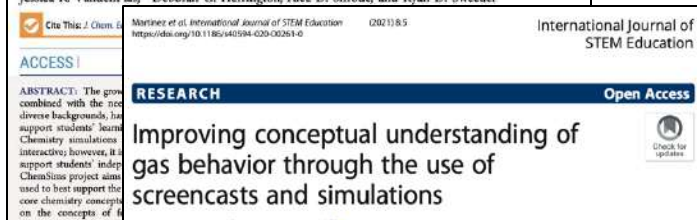
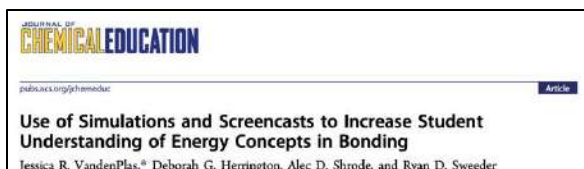
Expertise comparisons

Usage of representations

Evaluation of learning materials

Cognitive demand

Predictability



No differences in learning gains while using instructor-led screencasts vs. simulations.

But eye-tracking data revealed:

- screencasts may allow students to **better integrate different levels of Johnstone triangle**
- screencasts students may have **lower cognitive demand**

Recommendation: Use screencasts to introduce simulations

DISCUSSION

Pros:

- objective, non-invasive sensor
- real-time data
- rich and more detailed data
- unique (visual attention)

Cons:

- expensive
- time-consuming
- challenging

Thoughts:

- Can be replaced by some methods (e.g., pupil dilation vs. questionnaire), but not all
- Quality of research varies highly
- Every ET-research is also methodology research how to use ET in CER
- Potential not exhausted