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‘CORE’ Working Papers
No. 2

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Critical Online Reasoning in Higher Education (CORE) – Research Lab Facilities

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CORE Working Papers on the DFG Research Unit "Critical Online Reasoning in Higher Education"

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Critical Online Reasoning in Higher Education (CORE) – Research Lab Facilities

Abstract

The interdisciplinary and international research unit "Critical Online Reasoning in Higher Education (CORE)" (FOR 5404) funded by the German Research Foundation (DFG) for an initial period of four years (2023 – 2027) aims to explore the online learning behaviors and online information landscapes that students in medicine, physics, economics, and social sciences use for their studies in a novel methods-integrative approach, which requires specific innovative technological infrastructure.

In Working Paper 2, we provide practical organizational insight into the research lab facilities of the FOR CORE and working processes at different participating institutions and subprojects as well as general insights into the different types of data to illustrate the setup in the first year of the research unit.

Key Words

Critical Online Reasoning; Online Learning Environment; Digital Learning; Higher Education; Online Information Landscape; Critical Information Problems; Behavioral Data; Multimodal Text Data; Eye Tracking; Scenario-based Tests

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CORE’s Research Lab Facilities – Preface

Dimitri Molerov, Olga Zlatkin-Troitschanskaia, & Jennifer Fischer

Working Paper 2 exemplifies the FOR CORE's current lab facilities and assessment administration infrastructure. In particular, we provide practical organizational insight into the research lab facilities of the FOR CORE and working processes at different participating institutions and subprojects as well as general insights into the different types of data to illustrate the setup in the first year of the research unit.

Presented labs include a selection of the research capacity to highlight the variety of setups and working connections, including the PLATO lab at JGU Mainz (see Brückner et al.) being used for assessments in economics and sociology, the Research Infrastructure at LMU in Munich being used for assessments in medicine (see Zottmann et al.). Process data labs at LMU Munich, GU Frankfurt and JGU Mainz (see Küchemann et al.) provide the necessary infrastructure for eye-tracking studies and experiments, e.g., for investigating COR processes within and across the different domains.

In this working paper, we outline the technical setup for conducting online assessments using hosted virtual machines (controlled computer environments accessible via remote login). The newly implemented CORE assessment platform enables comprehensive tracking of the test-takers’ web behavior during search tasks. The connected systems from the Educational Technology Chair at DIPF and at GU Frankfurt enable the hosting, administration, and tracking of the COR open web search tasks, designed by the assessment developer teams in cross-site and cross-disciplinary collaborations.

For the content analyses, at the large-scale end, the TextTechnology Lab (see Baumartz et al.) provides extensive computational (pre)processing and analytic capabilities afforded by natural language processing. The integrated tools are utilized for conducting individual computational linguistic analyses on the web sources accessed by students. They can also be used to partially automate repetitive interpretive preparation and labeling steps, serving as pre-annotation support for other projects in the FOR CORE.

Finally, a new virtual classroom learning environment Va.si.li.lab is presented (see Mehler et al.), which can be used in the future to host collaborative learning experiences and COR assessments and training.

In this way, the contributions in this working paper are not strictly associated with CORE projects; rather they highlight cross-project and cross-site collaborations in implementing and using the required technical infrastructure for methods-integrative analyses in the FOR.

PLATO Lab at JGU

Sebastian Brückner, Olga Zlatkin-Troitschanskaia, Susanne Schmidt, Ann-Kathrin Kunz, & Andreas Maur

Technology-based laboratories in educational research have become indispensable to comprehensively and differentially diagnose teaching and learning behavior and describe its causes and effects. Especially in dynamic and increasingly digital learning environments, it is necessary for research to be modern and data-driven, using innovative technologies, and for learning environments to be simulated as realistically and authentically as possible. Both individual and group-based teaching and learning processes must be taken into account.

In the new PLATO research laboratory at JGU Mainz, two experimentation rooms and a control room for the execution and monitoring of the experiments are being set up. Firstly, the laboratory is intended to simulate classical and action-oriented teaching and learning situations from lessons or seminars, including interactions between teachers and learners or exclusively among learners. Secondly, physiological reactions and behaviors in individual learning processes will be captured using eye trackers, verbal data, and other technologies, to immediately analyze learning processes and receive indications of the internal processes leading to a learning outcome and the associated conditions.

Group learning processes can be experimentally tested in a large laboratory room equipped with about 20 digital workstations (including laptops, tablets, document cameras, and smartboards), with tables and chairs configured for mobility and comprehensively observed via the control room with four cameras. The smaller laboratory room is used for conducting behavioral experiments in stationary and mobile settings. Experiments on students' critical online reasoning (COR) in a natural, realistic test environment can be captured and analyzed, for example, by documenting and analyzing response processes and task-solving strategies, using eye-trackers or tracked log data, during assessment task-solving in a controlled environment. Workstations for recording eye movements are set up for the installation of four state-of-the-art stationary (screen-based) eye trackers (Tobii Pro Fusion) and the use of the accompanying analysis software (Tobii Pro Lab). Experiment processing takes place at four mobile workstations, each equipped with a laptop, a monitor, and peripheral devices (mouse, keyboard, webcam, etc.). To guarantee optimal performance of the technology, we have procured six new monitors and high-powered laptops specifically for conducting eye-tracking studies.

Since eye-tracking investigations can be supplemented by the use of think-aloud protocols, the laboratory is also equipped with microphones to record the verbally expressed thoughts of the test participants. The analysis facilitates CORE researchers' comprehension of the intricacies surrounding information retrieval on the internet, the critical assessment of online information, and web-based learning processes. This allows for systematic analysis of learning in Internet-based learning environments (see Figure 1).

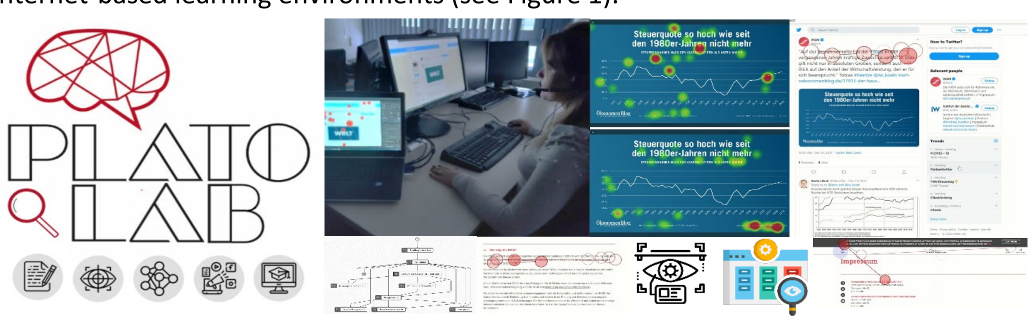

Figure 1. Students‘ Internet-based search processes

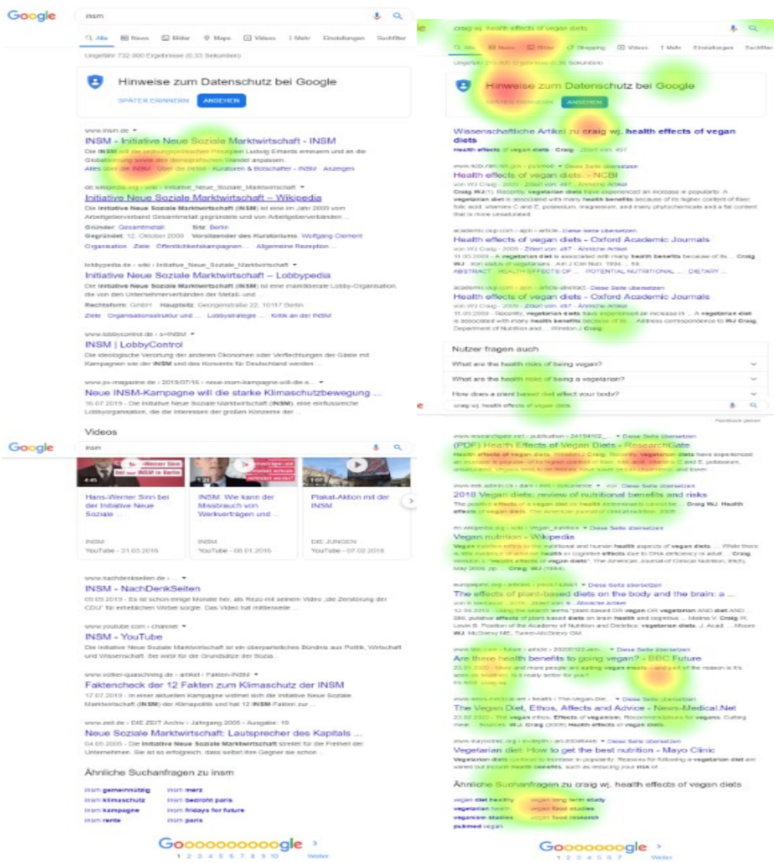

Figure 2. Illustration of PLATO lab results: Gaze heatmap on a SERP during COR task: Differences in the search engine-based research of a suitable source by two test participants (left and right) recorded with a Tobii X3-120 eye tracker, visualized in a heat map. Red areas indicate a longer and more frequent focus on the website content.

The newly established laboratory facilities were put into operation in September 2023 and are scheduled to be fully operational by the winter or spring of 2024. These facilities are dedicated to conducting eye-tracking studies for the research group CORE, enabling them to initiate preliminary experiments with the new eye-tracking technology at an early stage. In sum, this lab marks a significant step towards modern and data-driven educational research. This advancement will not only improve the diagnostics of teaching and learning but also open up opportunities for the evidence-based design of the teaching methods of tomorrow.

Research Infrastructure at LMU

Jan Zottmann, Jochen Kuhn, & Martin R. Fischer

The Munich project partners of the DFG Research Group CORE have an excellent research infrastructure at their disposal. Both the Chair of Physics Education and the Institute of Medical Education are also part of the *Munich Center of the Learning Sciences (MCLS)*[1], which was founded in 2009. The MCLS was established as a result of strategic efforts on the part of LMU to promote an interdisciplinary research platform and infrastructure as well as research capacities in the fields of teaching, learning, and educational research.

In recent years, the MCLS has established capacities as well as cross-faculty and cross-university cooperation structures through a series of interdisciplinary collaborative projects, such as the International Doctoral School REASON (2013-2022) on Scientific Reasoning and Argumentation, funded by the Elite Network of Bavaria, which has resulted in more than 30 completed doctoral theses under interdisciplinary supervision. In 2016, the DFG Research Group COSIMA[2] was set up to promote diagnostic skills with simulations in medical education and teacher training. Following a positive evaluation, COSIMA was extended for a second funding period (2019-2023). Several collaborative projects funded by the Federal Ministry of Education and Research (BMBF) have contributed to the enhancement of research partnerships. These include (1) FAMULUS, in which simulations with automated feedback based on artificial neural networks were developed and examined in the context of medical education and teacher training, (2) ForschenLernen analyzed the implementation and impact of research-based learning as a measure of the Quality Pact for Teaching, and (3) KOMPARE investigated argumentation with evidence in medical and teacher students.

The research infrastructure of the MCLS has recently been significantly improved through a successful large-scale equipment application to the DFG for a series of associated observation laboratories. For the research group CORE, the extensive network of the MCLS with its approximately 100 researchers proved useful at an early stage of the data collection to gain access to students in all study domains being investigated (Medicine, Physics, Economics, Sociology) in Munich.

The LMU Hospital furthermore has laboratories and technology that are not currently used in CORE but could become relevant with regard to future research projects, e.g. for intervention studies as part of a possible second funding phase. In particular, the *Zentrum für Unterricht und Studium (ZeUS)*[3] offers innovative training opportunities for medical students as part of its teaching and simulation clinic.

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[1] https://www.en.mcls.lmu.de
[2] https://www.en.for2385.uni-muenchen.de
[3] https://www.zeus.med.uni-muenchen.de

Figure 1: Observation in the simulator.

At the center of the training are compulsory, compulsory elective and elective courses of the clinical study section, which take place in state-of-the-art simulation rooms. The focus here is on promoting practical clinical skills in patient care and effective teamwork, including interprofessional collaboration through the promotion of communication skills. By using simulation patients and simulation manikins that realistically represent illnesses, students can practice the challenges of everyday clinical practice in a safe and controlled environment. Students have the opportunity to act in both individual and team constellations and receive direct feedback from their fellow students through the use of one-way mirrors (see Figure 1) and camera systems. This feedback focuses on communication behavior, team skills, and practical medical skills. In addition, watching the video recordings enables self-critical reflection on one's own actions. ZeUS thus creates a learning environment in which students can apply their theoretical knowledge in practice and improve their social and professional skills. The atmosphere in the simulation rooms should also enable students to learn without fear so that they can acquire clinical-practical skills such as examination methods and the use of medical equipment and techniques with confidence and security.

Figure 2: Medical students working with the auscultation trainer.

ZeUS is equipped with high-performance video recording and debriefing technology in the teaching clinic and six other simulation rooms, including camera technology and recording stations (SIMStation). At ZeUS, the simulator equipment consists of six sonography devices, including "Vimedix" simulators for cardiac, abdomen, and gynecology, as well as a "Noelle" birth simulator. Additionally, there are Resusci Anne simulators for resuscitation training, four "SAM" auscultation trainers, a variety of ECG devices, airway management trainers, tube insertion trainers, injection arms, and numerous anatomical models.

The eye-tracking laboratory located at the Chair of Physics Education at LMU and its technical equipment are described in detail in the next chapter of this working paper (see Küchemann et al., p. 8). The Chair also operates an XR-Lab, in which digital learning environments with augmented reality (AR) and virtual reality (VR) are developed (see Figure 3). Their learning effects are investigated in studies with entire school classes or individual learning groups (university students or pupils). This involves the use of 15 AR (MS HoloLens) and five VR HMDs (HP Reverb).

All HMDs have internal eye-tracking systems that are used to capture and analyze teaching and learning processes in these learning settings. These are currently being used in the context of another collaboration between the Institute of Medical Education and the Chair of Physics Education: The AI4MED project aims to improve the physics education of medical students in the introductory phase of studies using intelligent, AI-based learning approaches.

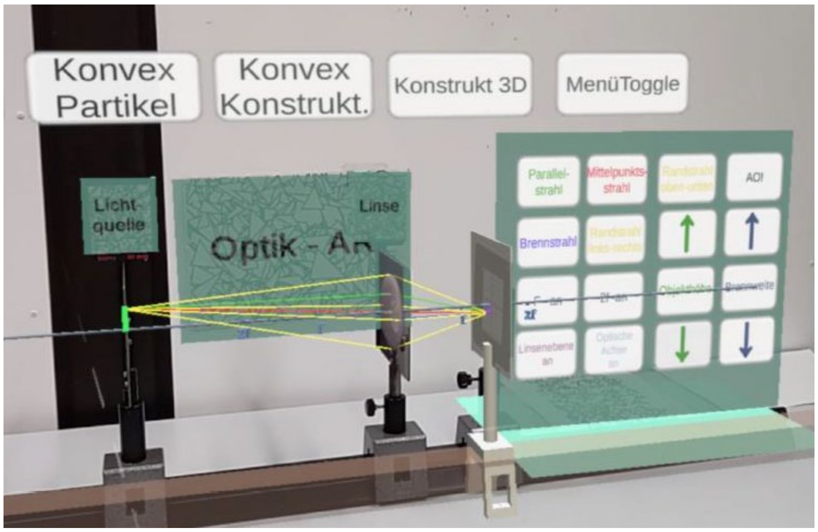

Figure 3: AR experiment on images with converging lenses in the XR-Lab.

Process Data Labs at LMU, GU, and JGU

Stefan Küchemann, Maruschka Weber, Verena Klose, Sebastian Brückner, & Andreas Maur

The study of students' critical online reasoning (COR) skills is rooted in extensive prior research, focusing on how students interact with and process information found on the Internet. This research is crucial because the Internet, while a rich source of information, often contains inaccurate or biased content. To understand how students navigate this complex information landscape, researchers have developed a behavioristic framework, examining both the cognitive processes and behavioral actions involved in online information problem-solving (see also CORE Working Paper No.1).

One of the most influential models in this field is the Information Problem-Solving while using the Internet (IPS-I) model. It outlines a five-step process that students typically follow when engaging with online information: defining the information problem, searching for information, scanning the information, processing it, and finally, organizing and presenting this information. This model serves as a foundation for understanding the various stages at which students interact with and make decisions about online content.

A significant part of a CORE subproject (C07, see for a project overview CORE Working Paper No.1) involves using eye-tracking technology and verbal data collection. Eye-tracking allows us to see exactly where students look when they are presented with online tasks, offering insights into what information they consider most relevant or engaging. Verbal data, often collected through 'think-aloud' methods, provides a “window” into the students' thought processes, revealing why they focus on certain areas and how they interpret the information they encounter.

This project also builds on the differences between novices and experts in online information processing. Prior research shows that experts, often with substantial content knowledge and experience, display a more efficient approach to selecting and evaluating online information. They are adept at ignoring irrelevant content and quickly identifying credible sources. This contrast between novices and experts will enable us to better understand how critical online reasoning skills develop over time and with experience.

Additionally, the role of gaze behavior and cognitive load in learning and problem-solving is emphasized. Studies show that the areas on which students focus their gaze and the mental effort they expend while processing information critically affect their learning outcomes. This aspect of the research helps in understanding how students interact with different types of online content, such as texts, graphs, and images, and how these interactions influence their learning and comprehension.

Finally, the impact of students' web search behavior on their learning and problem-solving abilities may play a central role in the outcomes of COR tasks. Many students tend to rely heavily on search engine rankings or the visual appeal of websites, often at the expense of content credibility. Understanding these behaviors is crucial for developing strategies to improve students' online research skills.

This project builds on the aforementioned research and aims to delve deeper into the strategies students employ in solving COR tasks, particularly focusing on how these strategies evolve throughout their studies. The project targets students from four different domains, including economics, sociology, medicine, and physics, providing a broad perspective on how domain-specific knowledge influences COR skills.

A key objective is to analyze both gaze and verbal data to understand the detailed COR task-solving strategies students use. By examining how students' eyes move across the online information landscape and what they verbally report during gaze-cued retrospective recalls, we aim to uncover the nuances of how students process online information. This approach is expected to reveal the cognitive processes behind students' interactions with online content and how these processes change as students gain more domain-specific knowledge and COR skills.

The project also intends to explore the influence of domain-specific expertise on COR task-solving strategies. It hypothesizes that students with more knowledge in a specific area, like medicine or economics, approach online problem-solving differently from those in other domains or with less expertise.

Additionally, the project investigates the impact of narrative and linguistic features of online content on students' problem-solving strategies. This aspect of the research recognizes that the way information is presented online—its structure, language, and narrative style—can significantly affect how students interact with and understand it.

The overarching goal of this project is to enhance educational outcomes in the digital age by providing a deeper understanding of students' critical online reasoning processes and the factors that influence these processes. By dissecting the various strategies students use to solve COR tasks and how these strategies develop, the project aims to contribute significantly to the fields of educational psychology and digital literacy education.

The eye-tracking studies are being executed at three process data labs, where a standardized eye-tracking system was implemented for this project:

- Institute of Neurophysiology at the Goethe University of Frankfurt (GU)
- Chair of physics education at the Ludwig-Maximilian's University of Munich (LMU)
- Chair of business and economic education at the Johannes Gutenberg University of Mainz (JGU)

At **LMU**, the processing lab is equipped with five Tobii Pro Fusion Eye Trackers, nine Tobii Pro Nanos, and 4 Tobii Pro Glasses 2. In this way, high-resolution eye-tracking studies can be performed and combined with verbal data from think-aloud protocols. Moreover, the junior research group AI in physics education has significant expertise in the statistical and machine learning-based analysis of eye-tracking data, which allows additional insights into the cognitive processes of students.

The FOR at **GU** has recently set up a state-of-the-art eye-tracking lab, complete with a dedicated room housing a Tobii Pro Fusion eye tracker (screen-based), a high-performance computer, and the accompanying analysis software (Tobii Pro Lab). The lab is also equipped with 3 Invisible eye-tracking glasses from Pupil Labs. The junior research group in physiology has extensive medical teaching experience and expertise in analyzing eye-tracking data as part of the BMBF-funded BRIDGE study.[4]

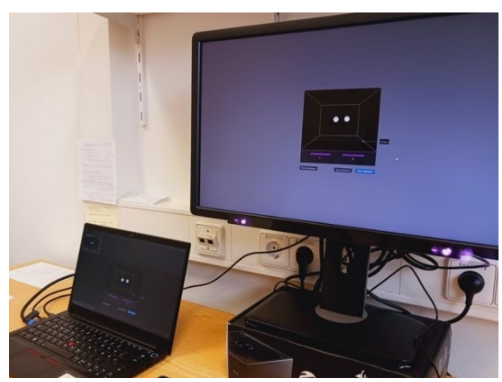

Figure 1. Tobii Pro Fusion Eye-Tracking Setup (GU)

At **JGU,** the project used the infrastructure of the PLATO Lab (see Brückner et al., p. 3).

[4] https://bridge.uni-mainz.de/

Surveys are currently underway at all three lab locations. The aim is to measure 25 participants each from the domains of medicine, economics, physics, and sociology. While the first-semester students in medicine and physics work on a medical task in the form of an Internet search, the participating first-semester students in economics and sociology are given an economics task. In addition, the participants of all four domains work on an identical generic COR task. After each completed task, an additional 10-minute interview (based on 10 minutes of recorded eye-tracking data) is conducted.

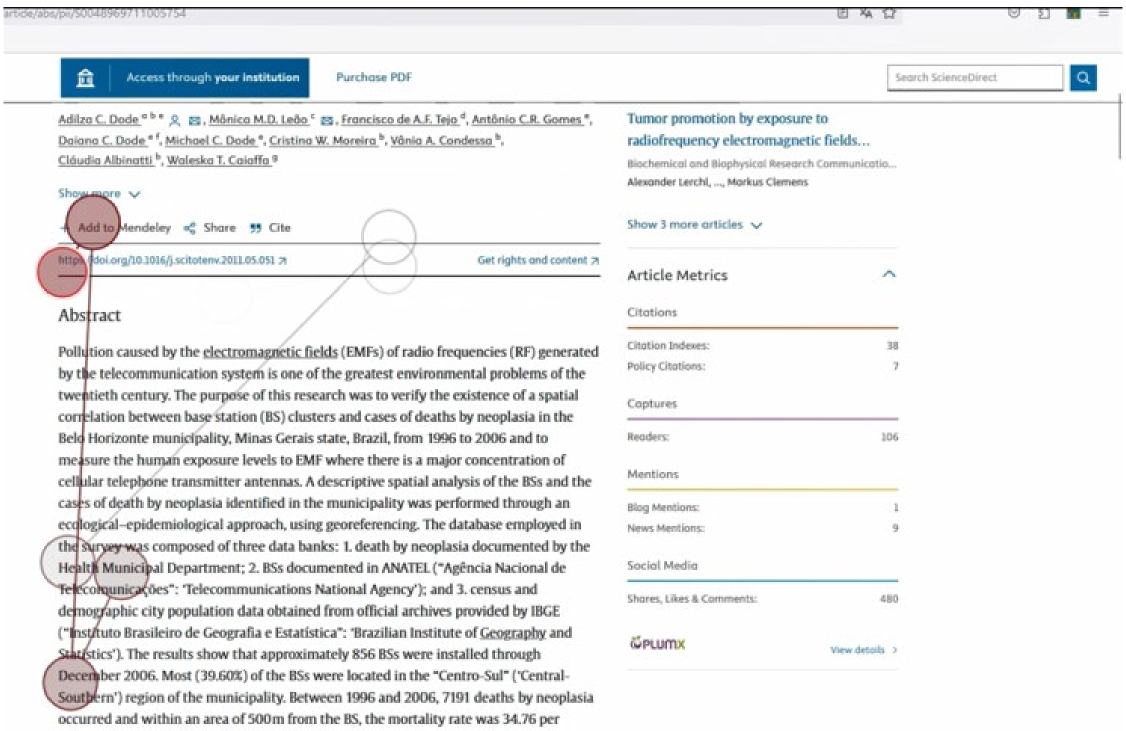

Figure 2. Example of a test participant's eye-tracking generic COR task Internet research.

The TTLab (Web & Virtual) Environment for the Analysis of Text & Multimodal Data in the Social Sciences

Daniel Baumartz, Giuseppe Abrami, & Alexander Mehler

The annotation of texts and multimodal content is a core component of every project, regardless of the modality, the medium as well as the underlying task and subject area. As part of the CORE (Critical Online Reasoning in Higher Education) project, study participants generate large amounts of textual data to complete their tasks. This includes web pages visited, written responses to questions, survey results, and more. This data forms the basis for the application of state-of-the-art tools to analyze COR data in order to uncover COR processes and the underlying strategies. The preparation of the data and the subsequent analysis and annotation cannot be done manually due to the amount of data involved, but must be automated: educational science relies on the automatic analysis of large volumes of text (hundreds of thousands for COR experiments) using the latest NLP methods and keeping pace with new developments, especially in the field of Generative AI. To meet these needs, the TTLab (Web & Virtual) environment for the analysis of text & multimodal data in the social sciences includes systems for web-based and virtual annotation of data (needed as training data for machine learning tools) and for the deployment of distributed orchestrated NLP tool chains that perform the automatic analysis of the data. For the first two tasks, we briefly describe TextAnnotator, VAnnotatoR, and Va.Si.Li-Lab, and for the second task, we describe DUUI. Figure 1 gives an overview of the TTLab system architecture. It shows the currently available range of functions for (multimodal) annotations on the left and automatic pre-processing using DUUI on the right. There are two tools at the top of Figure 1 that are of a general nature, as they provide general functions and resources: the *Resource Manager*, which is responsible for the management of various resources, and the *Authority Manager*, which is in charge of group and user-based access management and user authentication. Both tools stem from extensions of the eHumanities Desktop [10].

Before describing the individual components, it should be noted that all annotations (automatic or not) within the TTLab environment are based on *UIMA* [8], a central annotation format in the field of NLP, offers a wide range of functions for the annotation of unstructured information. On the top left-hand side is the TextAnnotator [6;2] which is the core application for the manual annotation of multimodal content.

TextAnnotator enables browser-based, platform-independent, collaborative and simultaneous annotation of UIMA documents by multiple users across multiple media platforms. This platform flexibility is based on the integrated *WebSocket*, which allows flexible use of annotation software, as seen in the example of *MobileAnnotator* [7] and VAnnotatoR (see below). The functional scope of annotations of TextAnnotator depends on the underlying *TypeSystem*s, which define the annotation schema based on UIMA. UIMA documents are maintained by a database using UIMA Database Interface [3], which can be accessed and reused collaboratively via the TextAnnotator-API. Thus, all annotation entities defined in the TypeSystem can be annotated, provided that a corresponding interface is implemented. For a variety of applications, the TextAnnotator (see Figure 1) includes *tools* for annotating rhetorical, temporal, argumentative, propositional, and dependency structures, as well as for linking text segments to knowledge bases (e.g., for wikification). In addition, named entity and part of speech annotations, as well as multi-span token annotations, can be performed and maintained. Finally, inter-annotator agreement can be calculated for the annotations. All these tools are used by VAnnotatoR and indirectly by Va.Si.Li-Lab to perform annotations.

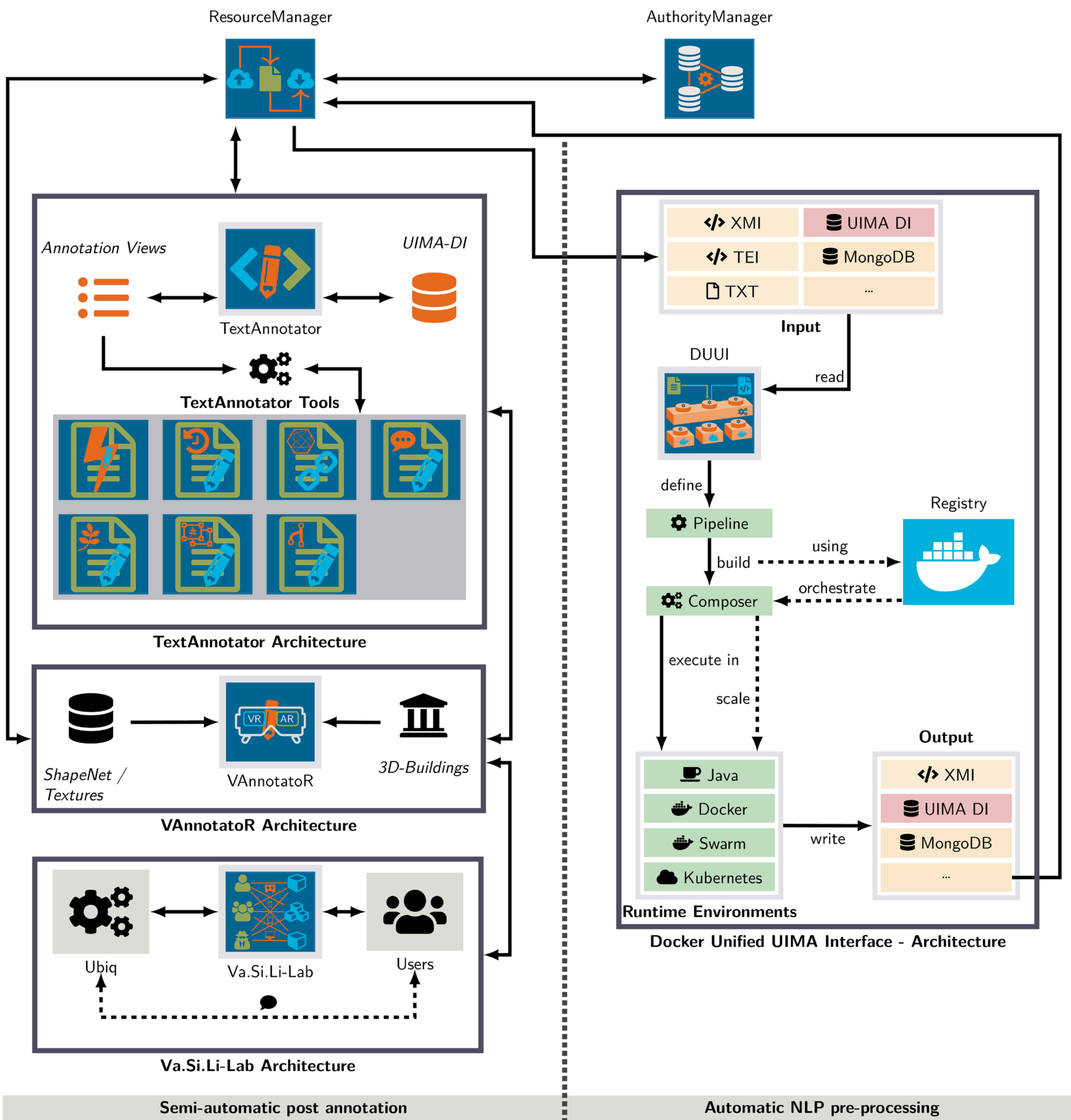

Figure 1: The systems landscape of the Texttechnology Lab (TTLab) (https://www.texttechnologylab.org/).

VAnnotatoR [15] allows multimodal information units to be explored and annotated in three-dimensional, virtual runtime environments using 3D glasses and augmented reality (AR) devices. Text, images and their segments, video and audio content as well as 3D objects can be related to each other and annotated [15]. In addition, geo-referenced annotations can be performed as re-used in virtual and augmented reality [13] The use of *ShapeNet* and the creation of virtual scenes [1] is also supported, as is the annotation of text using TextAnnotator [11].

Another tool for manual annotation in virtual 3D environments is **Va.Si.Li-Lab** [14]. Va.Si.Li-Lab enables multimodal and collaborative simulation of virtual scenarios in which agents in different roles interact and perform a time-limited task. Within Va.Si.Li-Lab, users can communicate and interact with each other through audio, visual, and collaborative and simultaneous manipulation of objects using *Ubiq* [9]. In addition to the explicit annotation of objects using VAnnotatoR, Va.Si.Li-Lab also has the capability of implicit annotation, as it records all user actions, i.e. all movements, gestures, facial expressions, spoken words, and user positions. As a result, different scenarios can be realized in virtual reality and the simulation results can be evaluated both qualitatively and quantitatively. Va.Si.Li-Lab is a novel technology that stands out from existing solutions due to its model-based structure [14] extensibility, and versatility [4].

In addition to the annotation of multimodal content, the TTLab system landscape includes the automatic analysis of text and multimodal documents. For automatic text analysis, the *Docker Unified UIMA Interface* (DUUI) is used, which enables text processing across platforms, programming languages, models, versions and dependencies. **DUUI** [12] uses UIMA and adopts various input formats for NLP. It focuses primarily on encapsulating processes (and their independent operational use) using Docker images, which allow the use of different models, using different versions and maintaining defined conditions to reproduce the corresponding annotations. DUUI supports the use of different runtime environments, allowing processes to be deployed horizontally (on different systems) and vertically (multiple times on one system) in order to process large text corpora in a moderate amount of time. This means that processes can run in local Docker runtime environments, in a cluster-based Docker swarm, and in cluster-based Kubernetes networks, the latter allowing the use of GPU processes that can be automatically orchestrated. As a result, DUUI can execute different pipelines as tasks, which can be defined through a lightweight API, and serialize the results in different output formats. Evaluations have shown that DUUI is a versatile tool for the unified processing of texts and is highly efficient in terms of processing time. All tools (TextAnnotator, VAnnotatoR, DUUI) can be used together, with DUUI for NLP and TextAnnotator or VAnnotatoR for manual pre- or post-annotation.

With the advent of generative AI, automatic text processing will continue to improve. However, we will increasingly be confronted with situations in which the texts to be processed are themselves artificially generated. The integration of generative AI methods for data analysis will therefore become just as relevant for educational science as the integration of tools for recognizing artificial texts. DUUI is well prepared for both challenges.

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Va.Si.Li-Lab – Multi-agent Virtual Learning Environments for Simulation-based Learning and (Group) Critical Online Reasoning

Alexander Mehler, Patrick Schrottenbacher, Giuseppe Abrami, & Mevlüt Bagci

Many learning processes are collaborative, so their outcomes are shared and cannot be attributed to any one individual. Examples of collaborative learning processes include study groups, peer learning, project-based learning, and case studies. At the same time, any interaction in which a student communicates with someone from their social circle to receive assistance in completing a task can be considered a form of interpersonal learning. In the context of *Critical Online Reasoning* (COR) [5,6], interactivity and in particular collaboration is a crucial factor in learning outcomes and the way they are achieved. This is true for all three facets of COR: critical information evaluation (CIE) and reasoning with evidence, argumentation, and synthesis (REAS) both benefit directly from discussion and debate. But online information acquisition (OIA) can also profit from collaborative behavior, for example, when peers give reading recommendations, point to search media, or recommend skipping certain alternatives (see also CORE Working Paper No.1).

Collaboration can therefore be identified as a key condition for (critical) online learning: in addition to task, time, resources, personal background, and similar factors, face-to-face communication between learners in the context of the same task or in the extended context of interpersonal communication (e.g., to support learners even when the respondent does not have the same task to complete) is an everyday contextual factor of learning. Vygotsky [7] has expressed this in his models by referring to conversations between learners and peers that influence their learning behavior. Here, a distinction must be made between short- and long-term communication relationships and those based on joint participation in the same task or not, possibly based on different participation roles (as organizer, learner, supporter or companion, etc.). To study such multi-agent processes, it is necessary to overcome the limitations of existing methods for observing learning behavior, which are mostly based on the evaluation of click events and eye movement behavior to

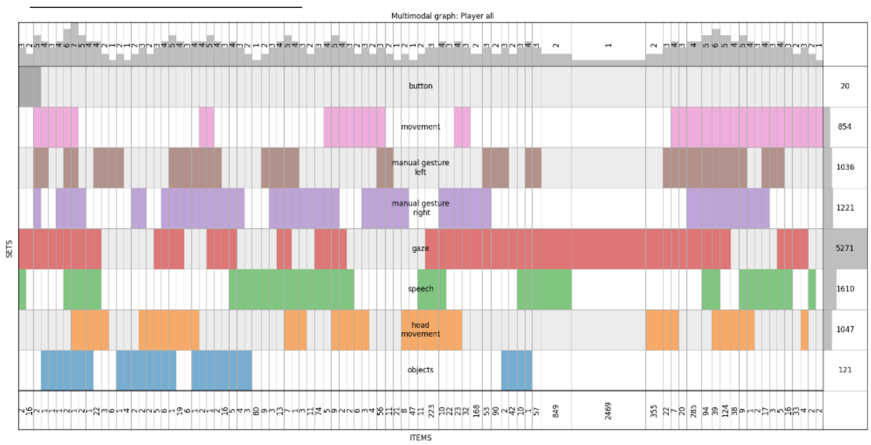

Figure. 1 A so-called supervenn diagram [2] showing the manifestation of multimodal information channels by a group of persons who played a simulation-based learning game with Va.Si.Li-Lab. The rows indicate the manifestation of each mode over time, the columns the multimodal ensembles based on information units of different modes. We consider button use, body movement, manual gestures (with left and right hand), gaze, speech, head movement, and object manipulation.

control the analysis of the multiple texts generated. Virtual environments represent a promising alternative here, as they make human behavior (manifested by avatars) observable across a very broad spectrum of multimodal communication.

We have developed such a system which is called Va.Si.Li-Lab – a virtual reality-based lab for simulation-based learning (see [4] for the foundation of Va.Si.Li-Lab; see [1] for a comparison of Va.Si.Li-Lab with related systems). The main field of application of Va.Si.Li-Lab is simulation-based learning, whose advantages it combines with those of approaches that investigate COR. To this end, we have defined the notion of multiple documents as the outcome of collaborative online learning and placed it on a formal basis that captures the emergence and (inter)textual characteristics of these documents in a fine-grained way.

Figure 1 shows a Venn diagram that was created as part of a Va.Si.Li-Lab-based simulation. It illustrates the range of multimodal information that can be captured with Va.Si.Li-Lab: beyond linguistic information (some of which is already automatically analyzed using NLP routines with the help of *Docker Unified UIMA Interface* [3]), it includes gestures, eye movements, lip movements, head movements, and body movements. Such a range of information, while maintaining the degree of freedom for interpersonal communication, is virtually impossible to achieve with conventional observation methods for COR. Va.Si.Li-Lab integrates bots that allow its users to interact with large language models such as GPT-4. Va.Si.Li-Lab thus provides the usability of a wide range of web applications together with the interaction data involved in a fine-grained and pre-annotated form. In this way, in Va.Si.Li-Lab, learners can interact in natural language and search the web for information without being tied to the limited interactivity of traditional web applications. Rather, they are unrestricted in the way they are used to in face-to-face communication.

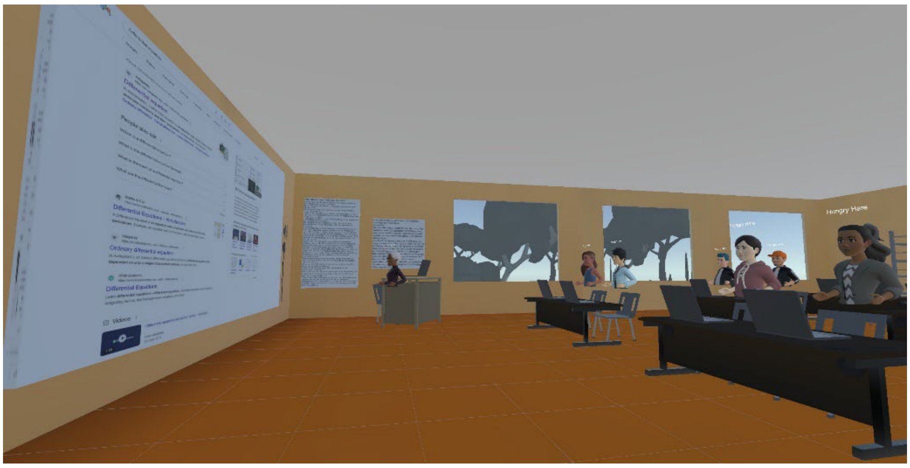

Figure 2. A classroom situation as part of school pedagogy. There are screens on the wall where students can use interactive browsers to search for information on the web, or they can do this with their virtual laptops. Alternatively, they can interact with LLM-driven chatbots.

Figure 3. A dialogue situation at the periphery of a simulation-based learning scenario.

Figures 2 and 3 show Va.Si.Li-Lab in action: The first image exemplifies a teaching situation in which simulation-based learning is used to test the mastering of potentially conflicting situations involving several interacting learners. The second image shows an informal communication situation in which learners engage in fully self- directed dialogue on the periphery of a simulation-based learning scenario. With Va.Si.Li-Lab, different learning situations (at university, at school, in administrative offices, in companies, in everyday situations, etc.) can be simulated and tested thereby giving access to a wide range of linguistic and multimodal data.

With all the confidence in the possibilities of Va.Si.Li-Lab, it is important not to lose sight of its special character, namely its virtuality. This virtuality brings both with it: the loss of direct experience of a real environment (with all its complexity and arbitrarily expandable depth), but also the freedom of an experimentally controllable design of learning contexts that offer far greater scope than would be possible under laboratory conditions. In this way, if research into COR and related learning processes wants to get closer to the natural conditions of real learning, there is currently no way around virtual learning environments – and Va.Si.Li-Lab has been developed as such a system.

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