From Sandbox to Laboratory: Refractive and Ethical Human / AI Knowledge Co-Production Through Game-ful Research Practices

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Abstract

The use of artificial intelligence in knowledge production processes and in academia has been illuminated from different disciplinary perspectives. The introduction of digital tools and research software in non-computational disciplines, the emergence of fields like the digital humanities, and the introduction of AI-driven tools for general application in the research process impact the types of engagement and interaction between researcher and tool. Starting from the notion of playing software, I introduce three metaphors for engagement with AI-driven research software: 1) software as laboratory, 2) research software as sandbox game, and 3) the scientific method as game rules. Based on a conceptual analysis of game studies and knowledge production literature, this theory adaptation of research as a game-ful process aims at creating awareness for the agencies within socio-technical epistemic systems by examining one's own practices in relation to (AI-driven) technology and increasing transparency by recognising intra-actions to account for the decisions made in knowledge production processes. By breaking down the components of games they can be mapped onto research processes and the ways digital tools are integrated. Approaching software-supported research as a game-ful process allows for engaging with AI-driven software as a research tool as a more entangled and co-constructive process.

Introduction

AI has come to stay, not only in the form of image generators or chatbots: AI-driven tools and applications have also found their way into academia in the shape of general text generators such as *ChatGPT* (OpenAI 2022) or research-specific tools such as *scite* (Nicholson et al. 2021), changing the way research is done. The introduction of these "artificial assistants" has created new challenges and opportunities for scientific practices and knowledge generation: Researchers have addressed these implications from different disciplinary backgrounds, such as the humanities and social sciences (e.g. (Checco et al. 2021; Christou 2023)), education (e.g. (Pinzolits 2024; Watermeyer et al. 2023)), management studies (e.g. (Barros, Prasad, and Śliwa 2023)) or research done at the intersection of technology and society (e.g. (Bin-Nashwan, Sadallah, and Bouteraa 2023; Eke 2023)).

These implications include research practices such as data analysis turning into an amalgam of human interpretation and AI suggestions (Barros, Prasad, and Śliwa 2023). Other researchers, such as Miao et al. (2024) and Jaakkola (2024) highlight the impact of AI tools on peer review processes, both on the side of work submitted and reviews written. Another concern focuses on the power structures within academia: Based on access to AI tools and their perceived performance optimisation, care work in universities could get further devalued leading to increasing gaps within the racist and gendered hierarchies of universities (Watermeyer et al. 2023). Similarly, depending on the tools used, AI applications increasingly tie researchers and their work to the commercial interests of AI developers, having implications on who can produce what types of research (Jaakkola 2024).

The introduction of artificial intelligence tools similarly gives rise to perceived advantages amongst researchers. As Bin-Nashwan et al. (2023) identify, ChatGPT usage seems to be positively associated with time-saving, academic self-efficacy and self-esteem, as well as a decrease in stress. Similarly, implementing AI is positioned as a possible path to more equitability in scholarship, as translation services become more available (Barros, Prasad, and Śliwa 2023), and an opportunity to regain academic authority (Watermeyer et al. 2023). At the same time, anxieties around AI usage and potential bad-faith actors arise as well. Concerns regarding plagiarism and lacking detectability of AI-generated research highlight vulnerabilities in the academic publishing system (Cotton, Cotton, and Shipway 2024; Eke 2023; Miao et al. 2024). Researchers raise concerns regarding the quality of academic knowledge and the ability to conduct academic research (Livberber and Ayvaz 2023), as well as issues regarding data integrity, hallucinations, and model bias (Hosseini, Rasmussen, and Resnik 2023). At the same time, other concerns address the trust in universities and academic knowledge: A strong focus on cost- and time-efficiency over good governance and academic integrity at universities should not be addressed by implementing AI tools to safe time (Barros, Prasad, and Śliwa 2023).

However, using instruments and technologies throughout the research process is not a digital or software-based phenomenon. Just as to the proponents and critics of AI tools today, the introduction of qualitative data analysis software during the 1980s similarly divided scientific communities

(Davidson and di Gregorio 2011). Despite a long-standing text bias in academia, research instruments have their own place in the history of the sciences (Baird 2004). Baird (2004) accordingly argues that an understanding of technology and science requires an epistemology not solely based on mentalistic accounts and theory but includes material accounts and instruments.

Concurrently, digital, software-based, algorithmised, and AI-driven research tools are no longer the sole domain of computational disciplines. Scholars from the social sciences and humanities make use of these tools in their practices as well, while at the same time making them their object of study investigating the social, political, and cultural implications of these technologies. These practices, especially when connected to black-boxed AI-driven tools, open up epistemological questions about the types of knowledges produced at the intersections of disciplines and practices (Rettberg 2022). Hereby, the types of inquiry into these technological artifacts are characterised by methods of probing and experimenting (Seaver 2017; Bucher 2018; Seaver 2019; Rettberg 2022; Dobson 2021), coinciding with the engagement with tools as research instruments (Paßmann 2013; Paßmann and Boersma 2017). The interactions with the technical systems, and the 'weird' or 'wrong' output of algorithms turn into methods for e.g. humanities scholars (Rettberg 2022).

With this contribution, I propose a refractive lens to examine how AI-driven web-based software impacts and shapes research practices and knowledge production across domains. Starting from the practice of tool criticism (van Es 2023), describing the critical engagement with the tools used and the results they produce, I draw on Sicart's (2020; 2023) notion of playing software, and video game studies to conceptualise research as a game-ful process. In line with the interconnectedness of epistemological and methodological questions (Lykke 2010), I draw on agential realism (Barad 2007) and situated knowledges (Haraway 1988) as analytical strategies to examine the knowledge co-construction between researcher and tool as games, facilitating intra-actions between the algorithmic game rules and the researcher-player and their domain rules. Hereby, the human researcher is assumed to be a good-faith actor, acting in accordance with the principles of good scientific practice. Additional constraints, such as time pressure or a pressure to publish, leading to what can be understood as dishonest practices and accordingly bad-faith actors are currently outside of the scope of this contribution.

I start by further untangling the socio-technical epistemic system under examination, before introducing the methodological approach to theory adaptation. Moving on, I propose three engagement metaphors as heuristic devices - software as laboratories, research software as a sandbox game, and the scientific method as game rules - to account for the different agencies within knowledge production processes.

Investigating Socio-Technical Epistemic Systems

I investigate the interactions between technological artifacts, human users, and e.g. the disciplinary traditions shaping these touch points, as entities that can be considered part of a socio-technical epistemic system (Simon 2010). The concept of socio-technical systems design, prioritising equal importance of both technical and human factors in design processes, focusses on participation and democracy as its central values. Within a socio-technical system, the technical system describes the used technology and the connected work structures, while the social system covers the individuals within their organisational structure. Simultaneously, the socio-technical system is impacted by the context it is situated in. Within the tradition of socio-technical systems design, some guiding principles exist: The design process should fit the objectives and be compatible with the desired values, specifications should be held to a minimum, variances should be accounted for within the design, groups should be able to work with a variety of skills, knowledge and experience sharing should be encouraged, paths for information sharing should be as short as possible, social support systems should foster desired behaviours, and lastly the design process should be considered as iterative (Mumford 2006).

Looking more specifically at socio-technical *epistemic* systems, I draw on Simon's (2010) conceptualisation: Socio-technical epistemic systems are made up of "situated and interdependent epistemic agents who engage in knowledge-productive practices by interacting with each other, their objects of inquiry and the technological infrastructure connecting them" (Simon 2010). Both human and non-human actors are understood as epistemic agents within these systems, all of which are part of entangled processes as they work on different epistemic tasks. This approach then consciously weakens the boundaries between human and non-human agency, highlighting their differing contributions to the epistemic process (Simon 2010).

When investigating knowledge production in socio-technical epistemic systems, some epistemological assumptions on how knowledge is understood in this instance need to be clarified. Drawing again on Simon's (2010) conceptualisation, they draw on socio-epistemological theories, defining knowledge as a social status, which can be achieved through community approval of an epistemic product. Accordingly, knowledge is a term given to content as a seal of approval after peer judgement and scrutiny was applied. Thus, knowledge is a result of an epistemic process in which different epistemic agents interact with each other. Further adopting Longino's (2002) classification of knowledge, Simon (2010) differentiates between knowledge as content, cognitive agency, and knowledge production practices (Longino 2002; Simon 2010).

While this understanding of knowledge is applied here to explore the interactions of epistemic agents in the production of knowledge, I additionally draw on feminist epistemologies and new materialism in my understanding of knowledge in the context of this work. Specifically, I draw

on agential realism (Barad 2007) and situated knowledges (Haraway 1988). Both Barad's and Haraway's work emphasise that subject and object of research are not fenced off from one another, but rather both exist in the same context shaped by dynamic processes (Lykke 2010). Accordingly, knowledge in this case is understood as multiple, partially objective, localised, and material-discursive (Haraway 1988; Barad 2007).

As part of socio-technical epistemic systems, software is understood similarly situated, material-discursive, and shaped by dynamic processes. Understood as a both producer and product, object and practice, software is situated within specific contexts, as an agent that can transform and impact its environment (Kitchin and Dodge 2011). Software can be understood as being part of social relation (Mackenzie 2006), without disregarding the materiality and visualisations of software as thing (Chun 2011). Accordingly, following the conceptualisations that emerged from the field of software studies, software is materially operative at different scales, distributed and embedded in different infrastructures, and interwoven in contemporary everyday life (Mackenzie 2006; Fuller 2008; Chun 2011; Kitchin and Dodge 2011; Manovich 2013).

Considering AI-driven software-supported research as taking place within a socio-technical epistemic system and ascribing software an agential role in this requires further grounding in terms of the type of agency attributed to non-human actors. Drawing again on new materialism and specifically Karen Barad's (2007) conceptualisation of agency, agency, as understood by Barad and implemented in this contribution, is neither traditionally humanist, nor tied to human intentionality or subjectivity (Barad 2007). Following this understanding, agency is not something which can be possessed by or attributed to someone or something. Instead, agency is tied to intra-actions, to doing or being. Agency as enactment is "about changing possibilities of change entailed in reconfiguring material-discursive apparatuses of bodily production [...]" (Barad 2007). Ascribing agency to software accordingly highlights its central role in the process of knowledge creation, as it is the result of an entangled process (Simon 2010), in which AI-driven software intra-acts with human researchers and other non-human agents (e.g. datasets or literature). Through these intra-actions software impacts the possibilities of change within the specific apparatus of knowledge production it is part of (Barad 2007). Accordingly, agency is here not aligned with intentionality (Barad 2007; Simon 2010).

Drawing specifically on the notion of playing software adds to an understanding of software through relational strategies. Hereby, play supports users in making sense of software and its rules and processes. As play includes exploring and pushing rules and boundaries, software can similarly be understood through these interactions. Play can therefore facilitate the points of contact between human and non-human agency, especially when interacting with the unknown or opaque elements of artificial intelligence and machine learning (Sicart 2020, 2023).

Subsequently, the following insights and metaphors are built on a partial perspective situated within the disciplinary traditions of new media and software studies, as well as feminist epistemology and new materialism. This accordingly impacts the methods chosen, literature found, and the way the literature insights were synthesised.

Methodology

To conceptualise research as a game-ful process especially in relation to the co-production of knowledge between human and AI-driven software, I draw on methodological considerations related to literature reviews as independent studies and conceptualisation work. Hereby, specifically integrated literature reviews, which aim at assessing, critiquing, and synthesising, allow new knowledge and different perspectives to emerge from a body of literature (Snyder 2019). Rather than an overview or summary of a research area, the integrative literature review should result in new conceptual knowledge based on a critical analysis and examination of the central ideas and relationships in the discussed literature (Snyder 2019).

In order to make sense of the different approaches to literature reviews, Breslin and Gatrell (2023) introduce the miner-prospector continuum to situate literature reviews based on their contributions and their position to the domain they are examining. For the conceptualisation of research as a game-ful process, I situate my work on the prospector-end of the continuum, due to its focus on knowledge acquisition, and its avoidance of domain hierarchies and disciplinary boundaries in bringing together seemingly unconnected ideas and concepts (Breslin and Gatrell 2023), as I am bringing together ideas on research processes and knowledge production with theories situated in game studies. I specifically employ the strategy of transferring theories across domains, seeking to make conceptual contributions by applying theories from play and game studies within the domain of research and knowledge production processes (Breslin and Gatrell 2023).

In line with the process of theory transfer across domains, the approach of theory adaptation as a form of conceptualisation was followed. Here, the focus is on introducing new perspectives on a theory through the introduction of other theories or concepts and proposing alterative frames and extant conceptualisations (Jaakkola 2020). Theory adaptation aims to identify new dimensions of an established theory through the introduction of a new lens. Starting from the concept or theory of interest, other theories are employed as tools to establish alternative frames or to adjust the scope of the original concept (Jaakkola 2020).

When drawing on these multiple disciplinary insights during conceptualisation work, and following a prospector approach, the study still has to be positioned in relation to other domains (Breslin and Gatrell 2023), which requires the identification of domain and method theories (Jaakkola 2020). Domain theories are usually the focus of contribution during the conceptualisation and describe an area of study defined by a particular set of theories, constructs, and assumptions (Jaakkola 2020). Method theories are used to provide new insights into the domain theory and therefore build a meta-level conceptual system contributing to the study of concepts and ideas in the domain theory (Jaakkola 2020).

Within this contribution, the theories and concepts from the area of research and knowledge production processes build the domain theory, which will be studied using method theories from (video) game studies, specifically different conceptualisations of games.

Literature Selection

As part of a larger research project, the methodological decisions made were strongly influenced by an overarching auto-ethnographic study accompanying this conceptualisation. Accordingly, I compared AI-supported research practices with 'manual' practices. This included specifically the following web-based AI-driven software applications:

- *scite* (Nicholson et al. 2021): The literature search tool can be used for discovering and evaluating research papers based on smart citations. I used *scite* to expand the paper search on literature discussing researcher practices and tool usage in research processes.
- *ZAIA AI Assistant* (Zendy 2023): *ZAIA* is part of the *Zendy Research Library*. The *ZAIA AI assistant* (named after the model it's based on) adds additional features to extract specific information from papers. I used this tool similarly to *scite* to expand the literature search in the area of game and play studies.
- *Lateral* (Lateral GmbH 2024): The tool offers AI-driven searching, saving, and organising of and across papers and aims to support research efforts such as literature reviews. I specifically used the tool to test its impact on the synthesising process of game definitions and elements.
- *OpenRead* (OpenRead, Inc. 2022): *OpenRead* has different features for interacting with and analysing research papers. I specifically used the *Paper Espresso* feature, which summarises journal papers. I utilised it to screen potential papers to include as part of the domain theory. All papers were still read in full to check whether the AI summary fit the content.

No AI-generated results were included one-to-one in this study, rather the experiences with these tools functioned as further refractive (Barad 2007) insights. As this study is not a systematic literature review, this study does not represent an exhaustive review of literature on either game conceptualisations or knowledge production processes.

Literature on the Concept and Object 'Game'

Games and play at large have been discussed from many different disciplinary vantage points, such as anthropology, education, sociology, or psychology (Johnson et al. 2015). In order to orient myself within the disciplinary directions the study of games and play can take, the focus was put on foundational conceptualisations, on which later works on video games were based.

Nevertheless, definitional and conceptual explorations of play and games have been ambiguous, as for example the definitions of Johan Huizinga (1950) and Roger Caillois (2001) focus on play / games as a singular concept due to language differences in Dutch and French. Accordingly, explorations of the concept sometimes focused on games, play, and the act of playing games as one object of study. This opens a decision space whether to focus on games-as-objects or play-as-behaviour. As I am looking at research and knowledge production processes, I therefore want to focus on the game-aspect of research. While the playful attitude of an individual researcher can still be part of this process, this playfulness (especially in engagement with software) then becomes part of an individual approach to interaction, not so much an aspect of the process.

Literature on Knowledge Production and Research Processes

Similar to the scholarly examinations of games and play, knowledge production processes and research practices can be studied from different disciplinary perspectives. In order to conceptualise research as a game-ful process, the focus when identifying key publications in the domain theory was more so on identifying concrete procedures and guiding elements characterising academic knowledge production, then on e.g. the construction of scientific fasts.

Framed by insights from feminist epistemology (e.g. (Haraway 1988)) and new materialism (Barad 2007), I drew on literature from science and technology studies, laboratory studies, as well as method papers with different disciplinary origins focused on implementing digital tools within their research processes. These inquiries, while not exhaustive, allowed for the synthesis of practices and assumptions underlying knowledge production processes.

Engagement Metaphors

Within the conceptual analysis process, game elements and characteristics of research processes were identified. The following section presents an overview of the common components across the literature.

In order to draw together different conceptualisations and definitions of 'game' and 'play', I accrued the different manners in which the selected authors use the notions of 'game', 'play', 'rule', and 'game element'. Overall, these elements were defined by two strands of approaches: On the one hand, play and games were approached more holistically from perspectives such as philosophy and anthropology (Huizinga 1950; Suits 1978; Caillois, Barash, and Caillois 2001; Henricks 2008; Malaby 2009). On the other hand, new media and video game studies put a stronger focus on games as objects and their interactions with players (Salen and Zimmerman 2004; Juul 2005; Sicart 2014).

Focusing on the concept of play, most authors engaging with play describe it as a behaviour or activity (Huizinga 1950; Suits 1978; Avedon and Sutton-Smith 1979; Caillois, Barash, and Caillois 2001; Salen and Zimmerman 2004; Juul 2005; Henricks 2008; Sicart 2014). This attitude or state of being is ascribed to individuals without necessarily being connected to formal game structures (Salen and Zimmerman 2004). Play here gets characterised through freedom (Huizinga 1950; Caillois, Barash, and Caillois 2001; Salen and Zimmerman 2004; Juul 2005), improvisation (Huizinga 1950; Caillois, Barash, and Caillois 2001; Salen and Zimmerman 2004; Malaby 2009), and absorption into a sphere

outside of the 'ordinary world' (Huizinga 1950; Avedon and Sutton-Smith 1979; Caillois, Barash, and Caillois 2001; Salen and Zimmerman 2004). Definitions of 'game' contrarily focus on games as structure-imposing objects, characterised as imposing rules and boundaries, being repeatable, quantifiable, and providing context for interaction (Suits 1978; Caillois, Barash, and Caillois 2001; Salen and Zimmerman 2004; Juul 2005; Sicart 2014).

Rules seem to be a defining element of games as objects. Rules, as conceptualised by the authors mentioned here, set the limits, boundaries, and options within the game context. They are fixed, unambiguous within one game (but changeable between game sessions), shared, and repeatable. Rules determine what is part of a game and what is not, accordingly defining the game space, which is the only place of applicability for a specific set of rules (Huizinga 1950; Suits 1978; Salen and Zimmerman 2004; Juul 2005; Sicart 2014). Other game elements include the consequences (or lack thereof) of game play (Suits 1978; Avedon and Sutton-Smith 1979; Caillois, Barash, and Caillois 2001; Juul 2005; Malaby 2009), as well as the roles players can take (Huizinga 1950; Avedon and Sutton-Smith 1979; Caillois, Barash, and Caillois 2001; Salen and Zimmerman 2004; Juul 2005). Most of these game elements are summarised within Juul's (2005) definition of 'game':

> "A game is a rule-based system with a variable and quantifiable outcome, where different outcomes are assigned different values, the player exerts effort in order to influence the outcome, the player feels emotionally attached to the outcome, and the consequences of the activity are negotiable." (Juul 2005)

Investigating research practices as part of knowledge production and epistemic processes, no specific definition was sought out, as daily practices are shaped by the types of technology used, disciplinary traditions, as well as the understanding of the researcher's role within different fields. Exploring different themes that emerged during the literature review, insights on the human and non-human actors where gathered. Additionally, the notion of the laboratory was inquired into as well, and practices of knowledge production were extracted when mentioned in the literature.

Regarding the human agents within the socio-technical epistemic systems, the role of the researcher as part of the research field emerged. Here the researcher or scientist is considered as instrument or part of the methods of inquiry themselves. The researcher is understood not only as part of the research field, but also as technical device (Knorr Cetina 1999). Accordingly, as the researcher is part of the research set-up, they are also again shaped by the instruments they use (Knorr Cetina 1999). Connecting this specifically to the use of digital technology, ongoing innovation also requires a continuous re-shaping of researchers' competencies (Dagnino et al. 2020).

Shifting to the non-human agents contributing to epistemic processes, different authors highlight the co-construction of research boundaries that (technological) instruments introduce. Digital technologies are objects and material practices, which contribute to shaping the relation between researcher, and the research environment and object (Pawlicka-Deger and Thomson 2023). Accordingly, research practices are shaped not only by the chosen method but also by software functionalities (Paulus et al. 2017). Software outputs or measurement readings understood as inscriptions similarly contribute to stabilising knowledge networks (Bauer 2006).

Examining research practices, disciplinary practices and traditions seem to shape how technology is implemented in research processes (Tsatsou 2016; Jackson 2017; Le Blanc 2017). Scientific masculine ideals such as rigour, validity and reliability (van Eck, van Amsterdam, and van den Brink 2021) idealise a sanitised and linear account of knowledge production (Jackson 2017), which is similarly encouraged by the argument that qualitative data analysis tools can introduce transparency and trustworthiness into qualitative research, which otherwise can't reach a certain scientific gold standard (Le Blanc 2017).

Lastly, the notion of the laboratory is not just of importance for the natural sciences but also takes hold in form of e.g. Digital Humanities labs. Understood as enhancing environments and improving on natural orders, the power of laboratories is in the enculturation of their objects (Knorr Cetina 1999). Laboratories as virtual space and institutional form provide an infrastructure for different forms of engagement, presenting an opportunity for understanding how knowledge is constructed (Knorr Cetina 1999; Pawlicka-Deger and Thomson 2023).

Mapping these insights on game elements onto the components of knowledge production processes, I develop three central metaphors through which software-supported epistemic processes can be understood as game-ful.

Research as a Game-Full Process

Understanding research as a game-ful process is the central heuristic device upon which the three following engagement metaphors are build. Similarly to discussions on invisible labour and data work in other application areas of artificial intelligence, engaging with AI-driven research software as epistemic agent potentially furthers more transparent and responsible usage practices, which account for labour economies of artificial intelligence and the associated dimensions of power inherent to any data usage (Iliadis and Russo 2016; Henrickson 2019).

While the following engagement metaphors more thoroughly build up the analytical aid of research as a game-ful process, a short excursion back to Juul's (2005) game definition functions as a first mirror between games and knowledge production processes: Games as rule-based (Huizinga 1950; Suits 1978; Avedon and Sutton-Smith 1979; Caillois, Barash, and Caillois 2001; Salen and Zimmerman 2004; Juul 2005) mirror the boundaries that disciplinary traditions and the rules of the scientific method set for research endeavours. Similarly, depending on the research one is engaged in, experiments for example can yield variable and quantifiable outcomes, an outcome which is shaped and influenced by the researchers who are determining analysis parameters, just as a game can have different outcomes which are shaped by player behaviour (Juul 2005). Both games and specific

studies are or should be repeatable to some extent, and usually take place within the boundaries of a specific context in which their rules apply, as neither the rules of the scientific method nor those of *Mario Kart* apply outside of the specific context they are used in (Huizinga 1950; Salen and Zimmerman 2004).

Accordingly, understanding software-supported research as a game-ful process builds on the understanding of software as a space for epistemic processes, which imposes boundaries and rules upon the interactions users have with the technology, as is discussed in the following sections. Employed as a heuristic device these metaphors can support the analysis or evaluation of research practices and knowledge products.

Connecting this understanding of research as game-ful to actual decision-making processes, the aim is to support the existing normative frameworks guiding academic research and good research practices. Drawing on the example of the *German Research Foundation* (DFG) and its code of conduct to safeguard good research practice, the here assumed normative framework that guides decision-making contains principles such as transparency, reliability, and accountability (Forschungsgemeinschaft 2025).

Software as Laboratories

This metaphor considers software as a (virtual) space for epistemic processes, similar to laboratories (Knorr Cetina 1999). Hereby, software creates a space similar to that of a laboratory and therefore facilitates various epistemic processes. Accordingly, the metaphor of software ***as*** laboratory, can be distinguished from other forms of software laboratories, which are safe environments for practising and testing coding.

Nevertheless, just like laboratories, in this framing, the epistemic space afforded by research software provides an infrastructure for engagement with different forms of data (Pawlicka-Deger and Thomson 2023). Laboratories allow scientists to improve upon natural orders when these are ”brought home” (Knorr Cetina 1999), similarly software allows an improved engagement with data gathered in specific contexts, in the field so to say. Through visualisations, summaries, statistical tools, and search rankings, software allows to improve upon the ‘messiness’ of data, just as laboratories’ power can be attributed to the enculturation of their research objects (Knorr Cetina 1999).

Researchers are shaped and impacted by their laboratory environment as well, becoming a specific epistemic agent together with their research devices (Knorr Cetina 1999). At the same time, interacting with software also shapes user patterns through its affordances, and the settings and functions offered (Curinga 2014). With the experiment as unit of analysis in the laboratory, different facets of the research object become hidden: the object of research does not remain in the form it was gathered in, but can be researched in a partial or transformed form. Laboratories allow a manipulation of context and environment, and additionally do not have to rely on natural occurrences or events (Knorr Cetina 1999). Software similarly offers options to ‘clean up’ data, remove unfavourable cases, re-run simulations, and change parameters for search or statistical analysis (Gitelman 2013).

While laboratory experiments already incorporate technological devices in their set-ups (Knorr Cetina 1999), software in and of itself constitutes a depot of materials and devices, which facilitate the experimentation and research that reconfigures natural and social orders (Knorr Cetina 1999). Software as made up of code, amongst other things, while at first relying on discrete data as input, can transform, filter, and reassemble information once the data are encoded (Berry 2011), facilitating a similar reconfiguration as the laboratory. The material practices and affordances of software thus shape the relation between researcher and research environment (Pawlicka-Deger and Thomson 2023), just as scientists are shaped by their processing devices and laboratory environment (Knorr Cetina 1999).

Research Software as Sandbox Games

This engagement metaphor draws on the genre of sandbox games[1] (Adams 2010) in order to conceptualise the interactions with AI-driven research software. This genre of game is characterised by its player freedom, non-linear gameplay, open world design, creative freedom, and role-playing elements (Adams 2010). Sandbox games allow freedom to explore, create, and interact with and within the virtual world, setting minimal - but still existing - limitations and boundaries (Adams 2010). Following Barad’s (2007) notion of research as consisting of researcher, methods, and distinct differentiated worlds, the virtual environments of sandbox games similarly make agential cuts defining a space for interaction (Barad 2007). With computers as enablers of games (Juul 2005), software can not only be framed as laboratory, but research software specifically can be cast as sandbox game, offering a virtual space for exploration.

As facilitator of knowledge production, research software takes an agential role (Kitchin and Dodge 2011), contributing to the epistemic process, which it is programmed to support while also pre-defining what can be found (Gorp et al. 2015). Accordingly, to understand these dynamic processes researchers are not only faced with changing requirements in regard to their skills and competencies (Dagnino et al. 2020) but must also rethink the materiality of software (Gorp et al. 2015) examining where researcher and technology meet (Jackson 2017). In order to do so, ideas of positivist research, such as binaries, linear cause-effect arguments, and simplistic explanations, cannot be drawn on (Jackson 2017), when interacting with these technologies, making the sandbox game a useful device for understanding.

The metaphor of research software as sandbox game provides a context for interaction. Players may explore, inhabit, and transform the provided spaces and objects (Salen and Zimmerman 2004). This represents a conscious interaction between what is offered within the sandbox game and how player actions impact these spaces and objects. Instead of engaging with research software as a fairly linear input-

[1]Not to be confused with a sandbox as used in computer science, describing a disconnected software environment safe for experimentation.

output process, the sandbox game metaphor renders research software as a material part of the research process, just as the microscope in a laboratory would be.

Framing research software as sandbox games highlights the tools materiality and situatedness (Haraway 1988; Barad 2007). From this understanding follows an awareness for the situated viewpoint and partial knowledge, research software contributes to epistemic work (Maalsen 2023), both through its affordances and boundaries. Acknowledging this can increase researchers' awareness for the impacts of software on knowledge production processes and push against claims of technological objectivity (Maalsen 2023).

The Scientific Method as Game Rules

Drawing parallels between the rules of a game and the principle of the scientific method allows for a more transparent understanding of the boundaries and limitations not only of one's own discipline, but also of the additional boundaries drawn by the software itself. Both the ideals of the scientific method and the rules of a game shape the practices and behaviours in the space they take place in, both in analogue and digital settings (Tsatsou 2016), making it a suitable heuristic device.

To start, I further specify the features of game rules in order to draw parallels to the qualities associated with scientific research, as well as disciplinary and field-specific assumptions. In general, game rules determine the permitted player actions and responses, constructing what Juul (2005) terms a state machine responding to player input. Accordingly, rules describe how a certain goal should be reached, what is permitted to reach this goal, and the space in which the goal needs to be achieved (Huizinga 1950; Suits 1978; Salen and Zimmerman 2004; Juul 2005). Breaking a game rule then means not being able to reach that goal (Suits 1978), while at the same time the rules only apply to this instance of play (Salen and Zimmerman 2004). Player engagement with rules is built on a fixed and unambiguous understanding, as rules need to be explicit and binding for a game to be playable (Suits 1978; Caillois, Barash, and Caillois 2001; Salen and Zimmerman 2004; Juul 2005). Nevertheless, between game sessions rules allow for variation and are open for discussion, as adjustments can be made which become fixed again for the instance of the game session, as soon as it starts (Juul 2005).

Drawing on the example of Qualitative Data Analysis Software (QDAS) for software-supported (and in some cases now also AI driven, see MAXQDA's AI Coding Tool (VERBI Software 2023)) knowledge production, QDAS creates rules and boundaries for researchers through its interfaces, settings, and features, which leads to negotiations between a method's implications and rules, and those of the software (Paulus et al. 2017). In return, the tools chosen by researchers depend on the disciplinary or traditional rules they act within (Tsatsou 2016). Specifically, QDAS is sometimes regarded as strengthening the rules of science: Perceived benefits of QDAS include for example an increase in confidentiality, rigour or transparency (Le Blanc 2017; Oswald 2019).

Beyond the increase of scientific ideas through software affordances, the dual representation of rules in both research and gaming activities highlights the importance of being aware of all agents in socio-technical epistemic systems. The overlaps between the role and handling of rules in games and research further calls attention to this: As described earlier, laboratories work through the detachment of research objects from their environment, experimenting on them based on specific methodological considerations and test procedures (Knorr Cetina 1999). Video games similarly apply computationally defined rules to fictional worlds (Juul 2005). Rules, as embedded in hardware and software, are the formal foundation that allows the manipulation of information, or the game state (Salen and Zimmerman 2004), just as research data can be manipulated and changed. Related similarities arise when examining the interaction with rules. Both the adjustments made to methods and experimental set-ups or theoretical lenses, as well as the ubiquity of the ideal of academic integrity (Barros, Prasad, and Śliwa 2023) mirror the conceptualisations of game rules as variable between game sessions (e.g. adjusting difficulties or implementing house rules) and an unambiguous respect for the game rules (such as represented in sportsmanship or fair play) (Juul 2005).

Coming back to specifically software-supported research practices, the affinity between game rules and digital technologies adds an additional layer to the understanding of this engagement metaphor. Juul (2005) describes the definitiveness of rules as a driver for the synergy between games and computers. Because game rules can be formulated within programming languages, computers, consoles and other game media aid game processes in terms of computation and game state representation. Game software ran on computers upholds the rules of a game and executes them based on player input; at the same time the game medium keeps track of the current game state (Juul 2005). Similarly, research software imposes rules on users as well, responding to input based on these rules, when e.g. coding interviews or running statistical tests. At the same time, research software keeps track of the 'game state' for its users, generating output or results based on actions taken or providing a log of the software operations the user applied.

Conclusion

In the preceding argument, I introduced three engagement metaphors as heuristic devices intended to support ethical and transparent use of AI-driven software in epistemic processes by making visible the agents and decisions along the way. Based on game studies literature and insights from science and technology studies amongst others, game elements were mapped onto knowledge production practices to conceptualise research as a game-ful process. Understanding *software as laboratories* supports the understanding of software as a space for epistemic processes similar to a laboratory (Knorr Cetina 1999). Accordingly, framing software as part of an experimental set-up for knowledge production can be a strategy to tackle the alternating investigation of research data and research instrument (Jackson 2017). The metaphor of *research software as sandbox game* draws on a

genre of games characterised by non-linear gameplay, open worlds, creative freedom, and role-playing elements. Similarly, research software provides an environment with minimal instructions and limitations, but still within boundaries to facilitate knowledge production (Juul 2005). Lastly, drawing parallels between *the rules of a game and the principles of the scientific method* allows for a more transparent understanding of the boundaries and limitations not only of one's own discipline, but also of the additional boundaries drawn by the software itself (Juul 2005; Kuhn 2009; Tsatsou 2016).

These engagement metaphors can accordingly have implications for research practices and academia's engagement with AI-driven tools. Developing these metaphors into an aid for understanding research as a game-ful process can raise the awareness for one's own practices when using AI-driven software. Additionally, this awareness can support the examination of agencies within the socio-technical systems one is a part of. Considering software as an agent and reframing it as a sandbox game highlights the materiality of software-based tools in research, making their instrumental character as visible as that of a microscope or Bunsen burner. Understanding digital research processes as acting within a set of rules from different sources, can lead to an easier recognition of the intra-actions within these processes, and to more thorough and transparent accounts of the decisions made along the way.

On a more practical application level, these engagement metaphors may support decision making in research on multiple ways: The metaphors can be employed as a teaching tool to introduce students working with or studying AI to the basic ideas of knowledge production within socio-technical epistemic systems and make them aware of all the decision spaces to consider when conducting research. The metaphor of research software of sandbox game can for example be used to identify parameters students can impact and which are impacted by the black-boxed AI component of software. Similarly, listing the 'rules of play' of a specific research situation can be a useful exercise in tool criticism. Considering individual researchers, when designing studies or experiments, the metaphors can add an additional level to the methodological considerations by mapping out which decision spaces are to account for, and where the AI-driven software introduces its own rules to the playing field. Using these metaphors in the research process as part of a 'lab book' can add transparency to the reporting of results in terms of their knowledge sources. As part of a reflexive research practice, the metaphors might be helpful in adding to the considerations of knowledge sources in research practices. Considering the laboratory character of AI-driven software, as well as the rules with which one is interacting could lead to a more differentiated view on the conditions of knowledge production.

As this study is part of a wider work in progress, further research on these engagement metaphors will focus on exploring interface features supporting these game-ful interactions, and the assumptions and practices of human researchers using AI-driven software. Based on these insights, further research on how to operationalise these metaphors to support researchers and students and how they can function as heuristic devices should be done. Regarding the shortly introduced normative framework grounding decision-making, future research could investigate the similarities and differences between the principles of good research practices and fair play. Additionally, future research could address the implementation and practicality of the notions presented here, both in practical usage of AI-driven software, and in other technology-supported research practices. Similarly, disciplinary differences in technology and AI usage could be explored, to further the knowledge on the current assumptions and practices.

These directions for future research stem partly from this study's limitations: While the theoretical work in this study can inform the presented metaphors, it currently lacks any empirical groundings, which gives the study a more speculative character in terms of its impact on practical research. Accordingly, it is important to reiterate that the metaphors function purely as a heuristic device. Additionally, by focusing on AI-driven web-based software, the conclusions of this study cannot be applied to all technology-supported research, which again impacts the current possibilities for practical implication without further investigation.

Despite the currently only partial insights provided in this study, the engagement metaphors of (research) software as laboratory, sandbox game, and shaped by game rules and scientific ideals might be one step towards a refractive and transparent human / non-human knowledge co-production through playing around.

Positionality Statement

As part of this submission, I want to provide a positionality statement to further situate this work and provide further information on its context. As a disabled, first-generation university student from a rural community, I am experiencing most processes within academic research for the first time. Accordingly, as of now I am in the position to examine academic traditions and practices from a newcomer or outsider perspective. Nevertheless, I am still researching from the position of a white, female-presenting person, which leads to a lacking understanding to facets of academic power relations impacting knowledge production processes.

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