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Brain-bound vs. extended: Contrasting approaches to second-language research writing in digital environments

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ABSTRACT

This article responds to calls to better understand the digital literacy practices of second and foreign-language writers. Researchers followed two Arab undergraduates as they completed a research writing task in a first-year writing course, tracing how these students used common digital resources, particularly digital 1) research tools, 2) writing tools and 3) course materials. Via screen-capture and regular interview sessions the participants' research and writing activity was observed over a period of five weeks. To understand the resulting data, Vygotskian notions of mediation were combined with writing as extended mind, a recently introduced theoretical program that emphasizes the distributed nature of cognition. Study participants were found to deploy a wide range of digital resources, often in complex and creative ways. We identify two distinct mediation profiles that we argue mark two distinct approaches to research writing: a relatively brain-bound approach, which uses external resources primarily to structure internal cognitive function, and a more extended approach, which offloads a higher degree of cognitive function to the writer's environment. These findings offer unique insight into the digital literacy practices of an understudied student population. They also raise important questions about how best to teach writing in a digital age.

1. Introduction

Contemporary writing practices are defined by the pervasive integration of digital technology. Thus, not surprisingly, come widespread calls to better understand the digital literacy practices, competencies and needs of foreign and second-language writers (Elola & Oskoz, 2017; Kessler, 2020; Wu, 2020). How writers use digital technology under naturalistic conditions is an area of particular import, and one which, according to Kessler (2020), has been little explored. Existing studies tend to center researcher-led interventions, often involving single tools (Yoon, 2016). They therefore say little about personal use habits or how writers might move "across a constellation of mediational resources" (Wu, 2020, p. 12). Relatedly, the existing literature undertheorizes the complex relationship between digital technology and human cognition. During the writing process, writers may use digital resources to offload cognitive activity and thus enhance writing ability (Kirkpatrick & Klein, 2016; Stapleton, 2010). In-situ observation under naturalistic conditions is needed to reveal the extent and impact of such behavior.

The current study advances existing understandings by tracing how key digital resources were used by two Arabic-L1

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undergraduates during a research writing task assigned in a first-year writing course at an English as Medium of Instruction (EMI) university. In line with recent calls for research on real-world digital literacy practices, we deployed screen-capture and stimulated recall to trace the entirety of our participants' research and writing activities. To understand the resulting data, we combined Vygotskian notions of mediation with a novel theoretical frame: writing as extended mind (Clark, 2008; Overstreet, 2022). This frame provides unique insight into the relationship between writing, digital technology and cognition. It thus allows us to identify two distinct approaches to research writing.

2. Literature review

2.1. Conceptualizing digital literacy practices

2.1.1. Mediating artifacts: technological and symbolic

Writing is a cognitive, social and material act (Hayes, 2017). Theoretical frames informed by sociocultural tenants allow writing scholars to engage all three facets (Prior, 2006). From a sociocultural perspective, the dynamics of writing activity, rather than being determined by universal laws, emerge organically out of concrete interactions, embedded within and responding to specific social and material contexts (Prior, 2006). The notion of *mediation* is key to this process. First proposed by Vygotsky (1978), mediation is the idea that the goal-directed behavior of individuals is always facilitated, and indeed shaped, by prefabricated, socially provisioned *mediating artifacts*. Through engagement with mediating artifacts, actors shape the material world and their own mental processes, leading Lei (2008) to state that mediation breaks down "the Cartesian walls that isolate the individual mind from society and culture" (p. 219).

Within second-language writing studies, the notion of mediation, typically deployed alongside activity theory (Engeström, 2015), has proven useful for studying how writers utilize digital resources. Lei (2008), for instance, in a study of Chinese undergraduates, showed how writing activity was mediated by web-search and online dictionaries, in addition to other social and material factors. Adopting a similar frame, but focusing on source use, Li (2013) examined the mediated activity systems of three Hong Kong undergraduates. Kessler (2020) extended this line of inquiry, finding that Chinese graduate students employed *multimodal strategies* to help organize information and navigate digital environments. They employed *tool-mediated strategies for content development* to help generate ideas and *tool-mediated strategies for language development* to supplement their linguistic abilities. Wu (2020), taking a slightly different approach, elucidated the complex relationship between tools, tool users and context. Wu followed three Chinese undergraduates during an asynchronous telecollaboration project. Though these writers had similar proficiency levels, their mediation strategies were shown to vary widely, shaped by factors such as personal history and learning needs.

All told, recent studies of mediation respond to a similar exigency: digital writing environments are dynamic, with writing processes changing as technology changes. To successfully teach writing, we need to monitor the complex relationship between individual writers, resources and composing contexts. The notion of mediation helps scholars understand this relationship. In practical terms, a mediational approach asks that we attend to resource use as *situated social action*. It asks that we attend to writer, resource *and* context.

The current study responds to the same exigency as the above work. It draws on and seeks to advance recent scholarship on digital writing resources (e.g. Ranalli, 2021), patterns of resource use (e.g. Kessler, 2020) and digital composing processes (e.g. Wu, 2020). We deploy a mediational approach, but unlike existing studies, center the concept of "mediating artifacts" (Vygotsky, 1978) rather than "activity systems" (Engeström, 2015). The result is analysis closely attuned to the details of individualized, material practice. This is a necessary departure from the sociocultural norm. Sociocultural approaches to writing research, to their credit, engage the social dynamics that inform inscription (Prior, 2006). In doing so, though, they may overlook operational-level details (Rule, 2018). Hort (2020), for instance, recently noted a troubling "lack of fine-grained research" on digital writing processes (43). Along similar lines, Rule (2018) has called for attention to the materiality of writing at the "radically local" level (402).

We believe that to understand digital resource use, the operational dynamics of said use must be made visible. To do so requires careful in situ observation, which our chosen data collection method—screen recording—facilitates. It also requires a well-defined, materially grounded theoretical frame, which Vygotsky (1978) provides. We understand writing as goal-directed problem-solving (Flower & Hayes, 1980). Writers set content, communication and rhetorical goals, then engage in discrete patterns of behavior—strategies—to achieve these goals (Green, 2013; Kirkpatrick & Klein, 2016). According to Vygotsky (1978), artifact-mediated strategies may implicate either technological or symbolic artifacts. Both types link human and world. The former allow goal-directed actors to impact the world directly, while the latter impact the world through regulation of human thought and behavior. We might imagine a hammer (technological artifact) vs. a plan for building a house (symbolic artifact). Within the writing process, technological artifacts might include inscription tools (e.g. pencil, laptop) and computer software. Symbolic artifacts might include concepts, language systems and texts.

While generative, we found the above categories too broad to guide research activity. We thus chose to narrow our inquiry and focus on specific types of artifacts, selected via observation as to how Vygotsky's distinction plays out in contemporary practice. In regard to technological or tool-based mediation, we center student use of 1) *digital research tools,* defined as any software program used to access web-based informational content (e.g. Google search), and 2) *digital writing tools*, defined as any software program used to facilitate the production or revision of text (e.g. Grammarly). In recent years, the ability to use online search engines and other web-based research tools has emerged as a key literacy skill (Li, 2012). Along similar lines, the adoption of digital proofreading, paraphrasing and translation tools, also often web-based, is widely acknowledged to be reshaping writing processes (Gánem-Gutiérrez & Gilmore, 2021). They are thus both important objects of study.

Regarding symbolic mediation, we touch upon student use of notes and sources, but center use of *digital course materials*, defined as any digital artifact shared with students by their instructor for teaching or learning purposes. Such artifacts included essay prompts,

genre exemplars and handouts featuring writing advice.[1] Though certain forms of course material, such as essay prompts (Miller et al., 2016) and genre exemplars (Wu, 2019), have been studied in isolation, to our knowledge no study has examined how course materials, in the aggregate, mediate student writing processes. Likewise, no study has examined student engagement with digital-only materials. With many courses moving online due to the recent global pandemic, such materials have likely taken on an outsized instructional role (Lemay et al., 2021). We believe it is thus apt time to examine how their use impacts writing processes.

Apart from centering important resources, our project also engages an understudied student population. Previous work on mediation in second-language writing has primarily focused on East Asian students (Lei, 2008; Li, 2013; Kessler, 2020). By attending to native Arabic-L1 speakers, writing in a Middle Eastern context, we help fulfill the field's mandate to better understand the full diversity of global literacy practices (Park & DeCosta, 2015).

2.2. Writing as extended mind

We also advance a recently introduced theoretical perspective. Writing as extended mind (Overstreet, 2022) challenges the idea that cognition takes place solely in the head. Based on the work of Clark (2008), and building on ideas about distributed cognition (Solomon, 1993), this frame presents thinking, and thus writing, as a joint venture between human and non-human, internal and external. It takes as its unit of analysis the localized, often highly idiosyncratic thinking systems that individual writers create. Within thinking systems, writers engage in *epistemic action*, physical behaviors that assist internal thinking processes (see Kirsh & Maglio, 1994). Of particular import are behaviors that offload cognitive function from brain to world. Cognitive offloading enhances the capacity of thinking systems, thus allowing for more sophisticated acts of textual production.

Writing processes have always been marked by epistemic action. A writer alone in a room with only paper and pencil, for instance, might jot down points to be addressed in their text. This action frees the writer from having to keep the information in working memory; it is thus epistemic action. There are indications that with the rise of digital, networked writing environments, opportunities for epistemic action have increased. Stapleton (2010), for instance, found that in digital environments, the brain-bound search for semantic resources is often supplemented—or even replaced—by strategic acts of tool use, such as drawing words from a digital dictionary. Along similar lines, Kirkpatrick and Klein (2016) argued that for many writers, the internet now functions as "an external long-term memory" (p. 35). Such tool use, by shifting cognitive labor from brain to world, is again, epistemic action.

Though all writing activity involves externalized cognition to some degree, as the above examples indicate, externalization can take many forms. Thinking systems vary in size, makeup and complexity. Furthermore, in any given period of writing activity thought may be relatively more "brain-bound," meaning a higher degree of cognitive function takes place internally, inside the writer's brain, or relatively more "extended," meaning a higher degree of function is offloaded to the environment. We believe that charting thinking systems, and how cognition is distributed within, is essential to understanding contemporary digital literacy practices. It helps reveal exactly how writers use their tools. Combined with the notion of mediation, writing as extended mind allows researchers to do such work.

In sum, the current study extends existing research on digital literacy practices by tracing how common digital resources were used by two, novice English L2 writers during a university-based research writing task. Particular attention was paid to artifact-mediated cognitive enhancement strategies. Our inquiry was guided by the following research questions:

1. How do these writers use digital research tools?
2. How do these writers use digital writing tools?
3. How do these writers use digital course materials?

3. Methodology

3.1. Context

Our study took place at a research-intensive university in Abu Dhabi, the United Arab Emirates. The participants were Emirati citizens and Arabic-L1 speakers with varying levels of English proficiency. At the time of the study, the participants were first-semester university students enrolled in a course taught by the study's first author. The course was a compulsory academic English course, English 101, the stated goal of which was to develop incoming students' reading, writing, and digital literacy skills with a focus on technical and scientific themes. For the first major assignment in the course, students were asked to write a 1000-word argumentative essay in which they presented an evidence-supported response to a technical or scientific claim. This assignment was the focus of the current study.

As students in English 101 are assumed to be unfamiliar with academic research and writing, the composing process for the assignment was carefully scaffolded. First, during preliminary class sessions, genre exemplars were analyzed, and academic writing and internet research techniques discussed and practiced. The instructor presented "They Say/I Say" (Graff & Birkenstein, 2021) as a heuristic for reading and writing academic texts. Students were then presented with the essay prompt. The prompt, informed by the language of "They Say/I Say," divided the project into five steps. It asked that students 1) select a topic, 2) conduct background

[1] Individualized instructor feedback—a key form of symbolic mediation— is not examined in this study. We hope to examine it separately in future work.

research, 3) formulate a research question and conduct additional research, 4) compose a short draft, and 5) compose a complete draft. Apart from the final draft, all student work was composed in or otherwise pasted into a Google Doc to which the instructor had access. After steps one, three and four the instructor read each student's work and provided feedback. During step five, students also had the opportunity to receive peer feedback.

To further scaffold students' composing processes, an array of supplemental course materials was provided (Appendix A). These materials covered topics discussed in the preliminary class sessions such as the elements of academic writing and best practices for online research. They also included a sample "They Say/I Say" essay and a handout indicating possible variations such an essay might take. The course materials were available to students digitally via the university's learning management system. The instructor frequently referred to them in class and in email communications. They were not made available in print form.

Research logs (Fluk, 2015) were also a key component of the course. A research log is a document in which students keep track of their engagement with source material. In this particular course, the instructor provided research log templates that asked students to answer certain questions about sources used (Appendix B). Students were expected to fill in these templates during the first three, research-focused phases of the project. The templates varied depending on type of source. Students were asked to complete five logs in total.

The purpose of the research log templates was two-fold. First, by requiring students to investigate each source, the instructor hoped to "beneficially slow down the research process" and encourage mindful web-search behavior (Fluk, 2015, p. 494). Second, by requiring students to summarize the content and projected utility of each source, he hoped to help them build a tangible store of information to draw on while drafting.

3.2. Participants

Study participants were recruited via an email invitation sent to all students in the first author's two sections of English 101.[2] Both participants had been educated in partial EMI environments since primary school, taking math and science courses in English, and social studies, Islamic studies and Arabic classes in Arabic. That said, the specifics of their educational histories varied.

Abdullah was a 19-year-old aerospace engineering major. He had attended an elite technical high school and participated in the university's preparatory program, taking an extra year of instruction between high school and college to study math, chemistry and physics. He had also completed a year of national military service. Abdullah did not believe himself to be a strong writer, rating his proficiency at only five or six out of ten. "I don't know how to start… an essay," he stated, "I find some difficulty to connect the paragraphs together [and] explain ideas clearly." Abdullah's EmSAT[3] score was 1425. In high school, he reported writing "basic essays" which focused on grammar and vocabulary. While he used paper and pen early in high school, by grade ten he had transitioned to digital writing tools and now felt comfortable using them.

Shirina was a 19-year-old biomedical engineering major. She had attended a non-elite high school and participated in the university's preparatory program, taking English, chemistry and physics. She rated her writing skills as eight on a ten-point scale, stating she was "medium… not a professional writer." Her EmSAT score was 1400, indicating a level of English proficiency slightly lower than Abdullah, as well as most of her university peers. She expressed dissatisfaction with her high school English-learning experience, stating that the instruction "didn't focus mostly on writing" which left her "not really" prepared for college work. In the university preparatory program she had written short essays and a short research report, indicating some experience with the type of assignment under investigation. Like Abdullah, she had transitioned to digital writing tools late in high school and felt comfortable with them.

3.3. Researcher positioning

As noted, the study participants were enrolled in the first author's English 101 course. To avoid potential bias, the first author did not know which of his students were participating in the study during the data collection process. The students were also not told that their instructor was involved with the study. The second author performed all communication and data collection activity. She tried to establish a friendly rapport with each student but did not provide feedback on or assistance with their coursework. The third author taught English 101 at the same university. She joined the project at the data analysis stage and did not know or interact with any of the participants. She assisted with data coding and analysis.

3.4. Data collection

After receiving approval from the university ethics committee and informed consent from both participants, data collection took place in the fall semester of 2021. Screen recordings, interview data, student work and instructor feedback were collected.

Study participants were asked to record their computer screens with Scre.io, a simple Google Chrome extension, every time they worked on the essay assignment. During the first interview, the second author provided guidance on how to use Screo.io and upload the resulting videos. After subsequent interviews, she emailed the participants to remind them of the importance of recording their

[2] Four students initially enrolled in the study, but two failed to record all stages of the project, hence are not included in the present analysis.

[3] EmSAT is a national standardized test required for college admissions in the U.A.E. The English-language portion contains reading comprehension questions and a short essay task. The minimum score required for admission to the university in this study is 1400 (equal to CEFR band B2 or an IELTS score of between 5.5 and 6).

work. Each participant was provided a link to a secure folder to which they could upload their videos. About 17 h of video data was ultimately collected.

Study participants also sat for five interviews each, one each week for the duration of the assignment. During the first interview, students discussed their English-learning experiences and proficiency levels, their relationship with writing, their writing processes and preferred writing tools. In the other four interviews participants reflected on their recent research and writing activity (see supplemental file for sample questions, data and codes). The last two interviews also included stimulated recall (Gass & Mackey, 2000). The participants watched short segments of their screen recordings and explained their choices in regard to research tactics, resource utilization and other relevant topics. All interviews were conducted individually, in English, via MS Teams. Each interview lasted between 40 min and one hour, resulting in almost seven hours of interview data. For their efforts, participants were paid approximately 30 USD.

3.5. Data analysis

The current study deployed a multiple case study approach (Yin, 2009). The data was first analyzed to identify artifact mediation strategies: patterns of goal-directed behavior that implicate mediating artifacts (Lei, 2008). Each case study was then considered in light of strategies deployed to establish a mediation profile: an aggregate picture of that individual's mediation strategies. Both video data and individual interview data were used in our analysis (Table 1), the latter primarily to elucidate patterns observed in the former. Student work and instructor feedback were also examined. During data analysis, the authors communicated with study participants via email to confirm inferences and resolve points of uncertainty. Draft versions of the full article were also shared, though neither participant offered substantive feedback. All data coding and analysis was conducted via MAXQDA 2022.

3.5.1. Video data

The first author coded all the video data. The second author then reviewed the video data and checked the codes. The first and second authors then discussed and resolved any disagreements.

To code and analyze the video data, we drew on the analytic framework proposed by Nassauer and Legewie (2021). First, we dissected the data, isolating and labeling individual, operational-level actions. Next, we chained these actions together to identify core mesoscopic actions, then labeled both mesoscopic actions (e.g. *notetaking, composing, reading-academic source*) and specific instances of resource use (e.g. *Google search, Grammarly*). The two categories were then compared to reveal how participants used digital resources to facilitate goal-directed activity.

To be a valid research object, video data should capture complete instances of behavior, so-called "optimal capture" (Nassauer & Legewie, 2021). Towards this end, study participants were asked to record all research and writing activity undertaken in furtherance of the essay project. The participants complied, with both students recording all steps in the project. Since the writing processes under investigation were observed from start to finish, the video data analyzed meets the requirement of optimal capture.

Video data should also depict behavior unaffected by the presence of the recording device (Nassauer & Legewie, 2021). We believe that both participants exhibit natural literacy behaviors in our video data. Both reported that their actions during the project were in line with normal practices. One participant, Abdullah, also engaged in non-task activity during the recording, indicating that he had become accustomed to (or forgotten about) our observation.

3.5.2. Interview data

The interview recordings were transcribed in Otter.ai, after which the second author manually proofread each transcript. Thematic analysis was then conducted via several rounds of iterative coding (Maxwell, 2013). The final codes identify themes related to each participant's background, writing process and use of mediating artifacts (see supplemental material for sample questions, data and codes).

All three authors participated in the development and revision of the codes. To develop a coding scheme, we collectively coded 20% of the data, discussing the codes between sessions. We then coded a shared sample. We similarly coded 72% of the units in the sample (simple percent agreement), which was deemed sufficient to proceed to individual coding (Stemler, 2004). The second and third authors then coded the remaining interviews. To further ensure interrater reliability, the second author also reviewed the data coded by the third author. The second and third authors discussed and resolved any disagreements.

4. Findings

This section describes how study participants used digital research tools, writing tools and course materials. For organizational purposes, we discuss the findings related to each research question separately. We then present each participant's overall mediation profile.

Table 1
Video and Interview Data Collected.

	Abdullah	Shirina	Total
Video Data	8 h 20 m	9 h	17 h 20 m
Interview Data	3 h 8 m	3 h 15 m	6 h 23 m

4.1. Student use of digital research tools

Study participants deployed complex artifact-mediated strategies to both find and access online information. They used Google search most frequently, but also used more specialized digital research tools such as Google Scholar, Scimago and Sci-hub.[4]

Strategic use of found language was a prominent theme in the participants' artifact-mediated research activity. This is defined as copying and pasting language from other documents into a search engine to guide search activity. Abdullah, for instance, began his research activity by simply copying a suggested research question from the prompt into Google. Shirina deployed similar tactics when investigating sources. Twice she was shown to use found language to make search results more specific. In the first instance, while investigating the organizational mission of a source (the *New York Times*), she copied a certain phrase ("what is the agenda of…") from the research log prompt, searching for "what is the agenda of the New York Times." In another, seeking to learn the background of a speaker from a TED Talk, but receiving irrelevant information when searching "who is Alex Mutter," she returned to the source, copied key language ("TedX") and added it to her query. This more detailed search immediately revealed Mutter's identity.

Another notable finding was the participants' *strategic use of alternative access options*. Valuable information on the internet is often locked away behind paywalls and other barriers. These writers appeared adept at circumventing such restrictions. Abdullah, for instance, using Google Scholar, located a relevant law review article. The link in Google Scholar led to the pay-walled site of an academic publisher. Unable to gain access, Abdullah copied the article title and pasted it into Google search, leading to an open-access version of the article. Shirina engaged in similar activity. Also using Google Scholar and coming across a pay-walled article, she turned to the site Sci-Hub to obtain an unlocked version. Shirina also bypassed the paywall for the *New York Times*. On encountering the paywall, she opened her browser's settings and turned off JavaScript, disabling it. As she explained, "I had to fix [the site] to just look at it like login without signing in." An instructor had told Shirina about Sci-Hub; she discovered the JavaScript hack via YouTube. While perhaps ethically suspect, alternative access options helped Shirina achieve her research objectives.

4.2. Student use of digital writing tools

The students in the study deployed a range of digital resources to produce and revise text. Most drafting took place in Google Docs, though Shirina also drafted in Microsoft Word. Both writers took advantage of these programs' spelling and grammar checkers, which flag errors and offer suggestions for correction. Use of these resources was largely productive, with 51 out of 55 accepted recommendations coded as accurate per the criteria in Ranalli (2021). When inaccurate suggestions were accepted, three out of four times the writer immediately recognized the sentence was still incorrect and made additional changes.

Apart from shared use of spelling and grammar correction, participants' use of writing tools varied widely. While engaging sources, Abdullah used Google Translate three times to look up unfamiliar vocabulary (e.g. "biopsy") or idiomatic expressions (e.g. "startups followed up on the main course"). Otherwise, he did not use writing resources outside his primary inscription tool (Google Docs). Notably, Abdullah made frequent use of Google Doc's word count feature. He displayed a persistent pattern in his use of this resource, checking the word count upon starting a writing session or resuming work after a break. This ritual helped structure his writing process.

Shirina, in contrast to her classmate, heavily incorporated supplemental digital writing tools into every stage of the project.[5] In particular, she engaged in what we might call *strategic integration*—the act of combining various resources, in this case, writing tools, in order to leverage their different affordances. Throughout the project, Shirina consistently used Quillbot ($n = 42$), an online paraphrase tool, Grammarly ($n = 14$), an automated writing evaluation tool, and to a lesser extent, Adobe Reader's annotation tool ($n = 6$). She used these tools both in the research and drafting stages of the project. While reading academic sources in PDF form during research activity, for instance, Shirina would summarize key ideas in a text box within the source document using Adobe Reader's annotation tool. She would then copy and paste from the text box into Quillbot. This program automatically paraphrases text as well as offers options for further refinements, such as alternative vocabulary. Shirina would rework the inserted text, then paste it back into the original text box. In this way, she integrated the affordances of Adobe Reader (annotation) and Quillbot (paraphrase).

Shirina engaged in additional acts of integration during the drafting phases of the project. When writing and revising she would compose a sentence or short paragraph in Google Docs or Microsoft Word and copy it into Quillbot. She would review the text, make refinements, then paste the resulting product into the online version of Grammarly.

Notably, Shirina did not accept all changes offered by these programs. In Quillbot, she would often browse and carefully select among suggested vocabulary options. Describing her process, she stated she would "[take] a look and see if [it] like matches as what I want to write." Shirina's use of Grammarly was equally mindful. Using the free version of the program, she was provided both

[4] All of the participants' search activity was in English.
[5] A supplemental writing tool is one used in addition to a primary inscription tool.

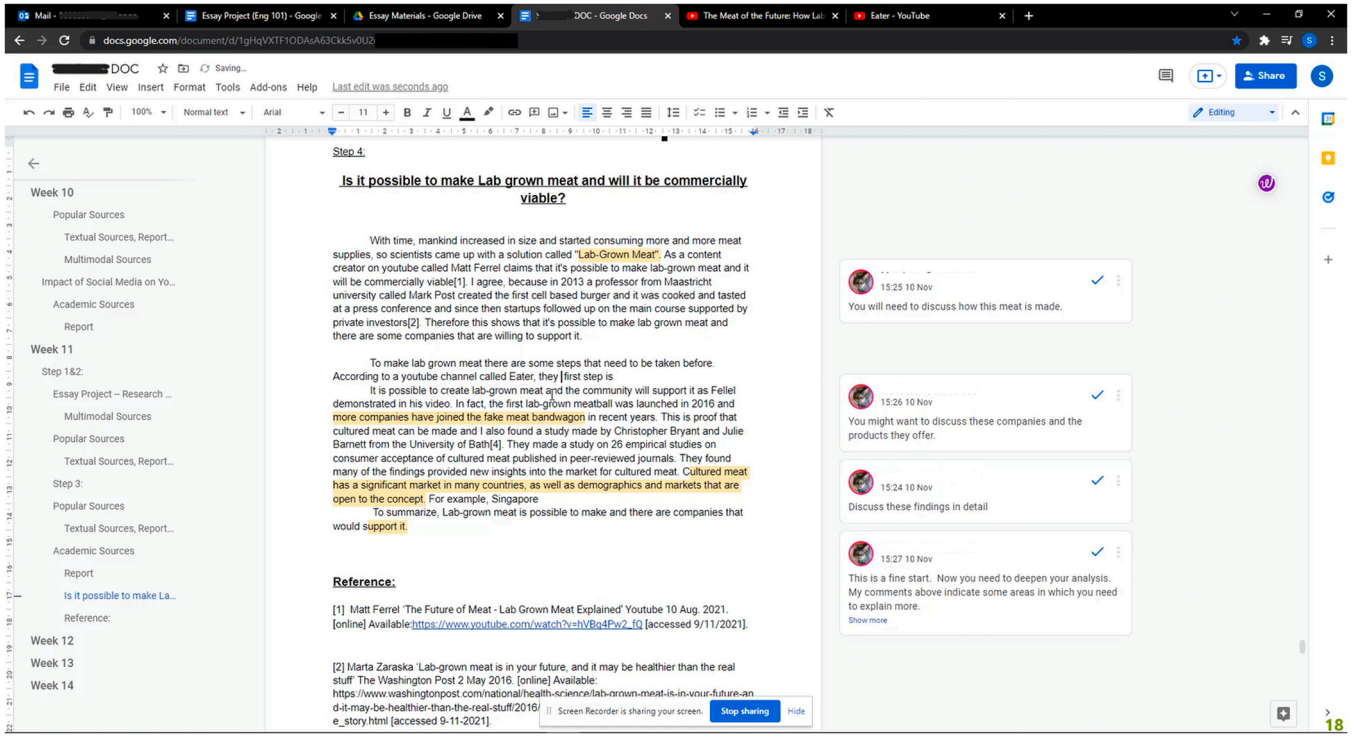

Fig. 1. Abdullah's workspace.

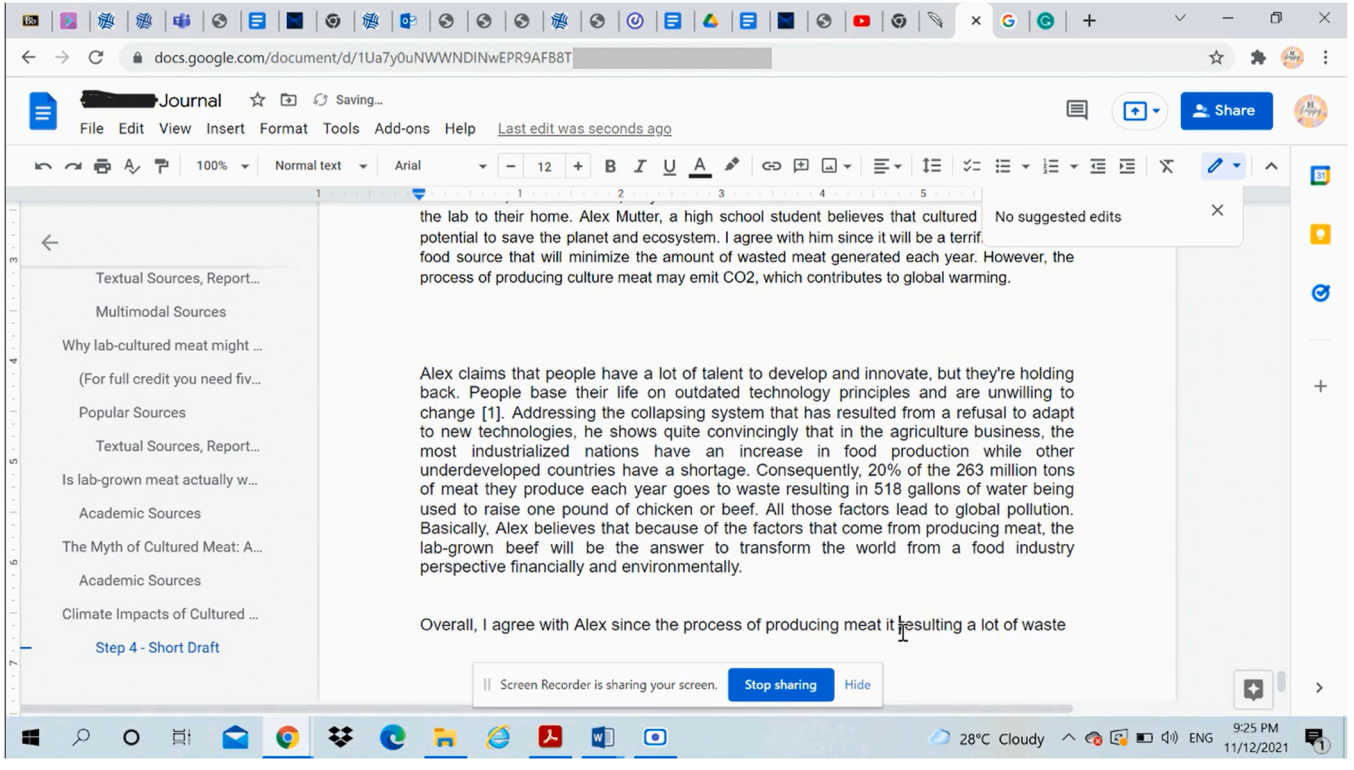

Fig. 2. Shirina's Workspace.

corrective feedback—edits which could be implemented with a click—and what Ranalli (2021) labeled "generic" feedback—suggestions for improvement that the writer must take up manually. Shirina engaged meaningfully with both forms of feedback. She would spend up to fifteen minutes at a time in the Grammarly interface, in essence using it as a drafting platform. When satisfied with her work, she would paste the results back into Google Docs or Word. All told, the sequential use of multiple digital writing resources, each offering slightly different affordances, deeply informed the text Shirina eventually produced.

4.3. Student use of digital course materials

As noted, students in English 101 were provided a range of digital course materials. These included research log templates which they filled with content information, an elaborate assignment prompt, two model essays and various handouts (Appendix A). During drafting and revision, study participants engaged these resources as well as notes and source materials.

Throughout the hours of video data, distinct patterns emerge in regard to how the study participants worked with and through symbolic mediating artifacts. Mediation strategies in regard to such artifacts were, in fact, remarkably consistent within each writer's practice. Across writers, *strategic integration* once again emerged as a dominant theme.

Research logs (Fluk, 2015) were a key part of English 101 and could be expected to play a large role in the participants' writing processes. This expectation was only partially born out. Both participants completed their logs as directed. Both participants also engaged their completed logs while drafting, though language in the logs seldom made it into their final drafts.

Abdullah used his completed logs only to access links to the original information sources. He appeared to rarely read or otherwise pay attention to the content of the logs. Instead, he would open the original source in a separate web-browser window, and as he drafted, switch back and forth rapidly between source and inscription space. In other words, Abdullah used no secondary documents to mediate between source material and his own text. This pattern was consistent throughout his drafting and revision process. Notably, Abdullah also wrote his entire essay in a single Google Doc document: with each new step he simply expanded the existing text. Overall, his digital workspace appeared quite "clean," with few windows or tabs open at any one time (Fig. 1). Perhaps as a result, he only spent 1.2% of his work time "navigating," defined as moving between windows, scrolling through documents or otherwise searching for resources.

Shirina's use of symbolic mediating artifacts was also internally consistent. Unlike Abdullah, Shirina did engage the content of her research logs while drafting. She understood the purpose of the logs and how they might be used, stating that in the logs she had "explained" various sources and "summarized the idea," and that the pre-drafting work could "save you time and help you as you want." That said, Shirina's use of the logs was overshadowed by heavy use of notes. As discussed in the previous section, Shirina made annotations within source materials. She kept a list of source URLs in a dedicated Word document. She also heavily utilized notetaking within her primary drafting space. As she worked on the final essay for the project, for instance, Shirina continually pasted excerpts from source material, research logs, and previous drafts and notes into her drafting space. Rather than working linearly within this space, she skipped from section to section, engaging, reworking and merging different pieces of text. She utilized both Word and Google Docs, as well as numerous supplemental writing tools, during the writing/research process, often having many different windows, tabs and applications open at once (Fig. 2). Increased complexity seems to have come at a cost: Shirina spent 3.4% of her work time navigating digital space. As with Abdullah, the patterns within her practice were distinct and consistent across the drafting and revision process.

Apart from the research logs, both students utilized other digital course materials. Overall, the sample essays proved the most commonly used resource. There were two of these documents, both annotated to highlight key structural elements. During the drafting process, study participants referred to these documents 21 times, more than twice as much as the next most commonly viewed documents: the assignment prompt ($n = 7$) and a handout providing information about transition sentences ($n = 8$). Though both participants did refer to the prompt, during the drafting stages of the project, the sample essays provided the majority of guidance as to required elements and form. Abdullah explained that the instructor "said check the sample essay and check your draft," because the sample essay, contains the elements "we have to include." He also mentioned that the instructor emphasized the importance of using transition sentences. Other course materials were used much less frequently (Appendix A).

As important as *how much* digital course materials were used is *how* they were used. When using such materials, Abdullah and Shirina both engaged in *strategic integration*, combining course materials with other mediating artifacts as well as brain-bound resources. Ultimately, though, they displayed different patterns of integration. Abdullah's work on his short draft (step four) is instructive. Before beginning to write, Abdullah reviewed the prompt, sample essays and information about the They Say/I Say (TSIS) structure. He typed an introductory sentence, then a "They Say" claim. He then paused and returned to the TSIS information sheet, where he read about the "Yes, and…" essay format, which allows a writer to respond to a claim by agreeing and providing additional information. He then did exactly that. After reviewing two YouTube videos and gathering information, he returned to his draft and wrote that a certain YouTube personality is correct that artificial meat can be commercially viable because of the creation, in 2013, of an artificial hamburger. Though the TSIS information sheet provided sample sentences reflecting the "Yes, and…" structure, notably, Abdullah did not replicate the form of the sample or even borrow vocabulary. Instead, he engaged with the material, internalized a certain concept ("Yes, and…") and deployed that concept in his text. Later he displayed the same behavior in regard to topic sentences and then quotes. Each time, he engaged with the course material, learned and deployed. He did not directly copy vocabulary or sentence structure.

Shirina used digital course materials differently. Starting her short draft, for instance, she typed a few sentences, then left the draft document and reviewed a sample essay. Realizing she needed a "They Say" claim, she then reviewed her research logs. Upon finding an appropriate claim, she returned to the draft and integrated the form of the sample essay with content from the research logs. She

directly copied the vocabulary and sentence structure of the sample essay, resulting in a slightly awkward construction ("Alex Mutter believes that it's cultured meat might save the world…"). Throughout the drafting process, Shirina copied vocabulary and structural patterns from the course materials. In other words, whereas Abdullah more often internalized concepts and deployed them in his text using novel language, Shirina more often directly borrowed semantic resources.

4.4. Student mediation profiles

The previous subsections describe how study participants used digital writing tools, research tools and course materials. Bringing these three strands of analysis together, distinct mediation profiles emerge. Both participants deployed a range of resources (Fig. 3). Their mediation profiles can be distinguished, though, by the relative intensity of utilization.

4.4.1. Abdullah

Abdullah's mediation profile is defined by heavy use of digital research tools, substantial use of course materials, little use of supplemental writing tools, and no use of mediating documents such as notes. Abdullah performed more Google searches and engaged with more sources, more often, than Shirina. He alone also investigated the background of a source organically, without the prompting of a research log template.

As discussed above, with some small exceptions, Abdullah did not utilize writing tools other than Google Docs. He also wrote

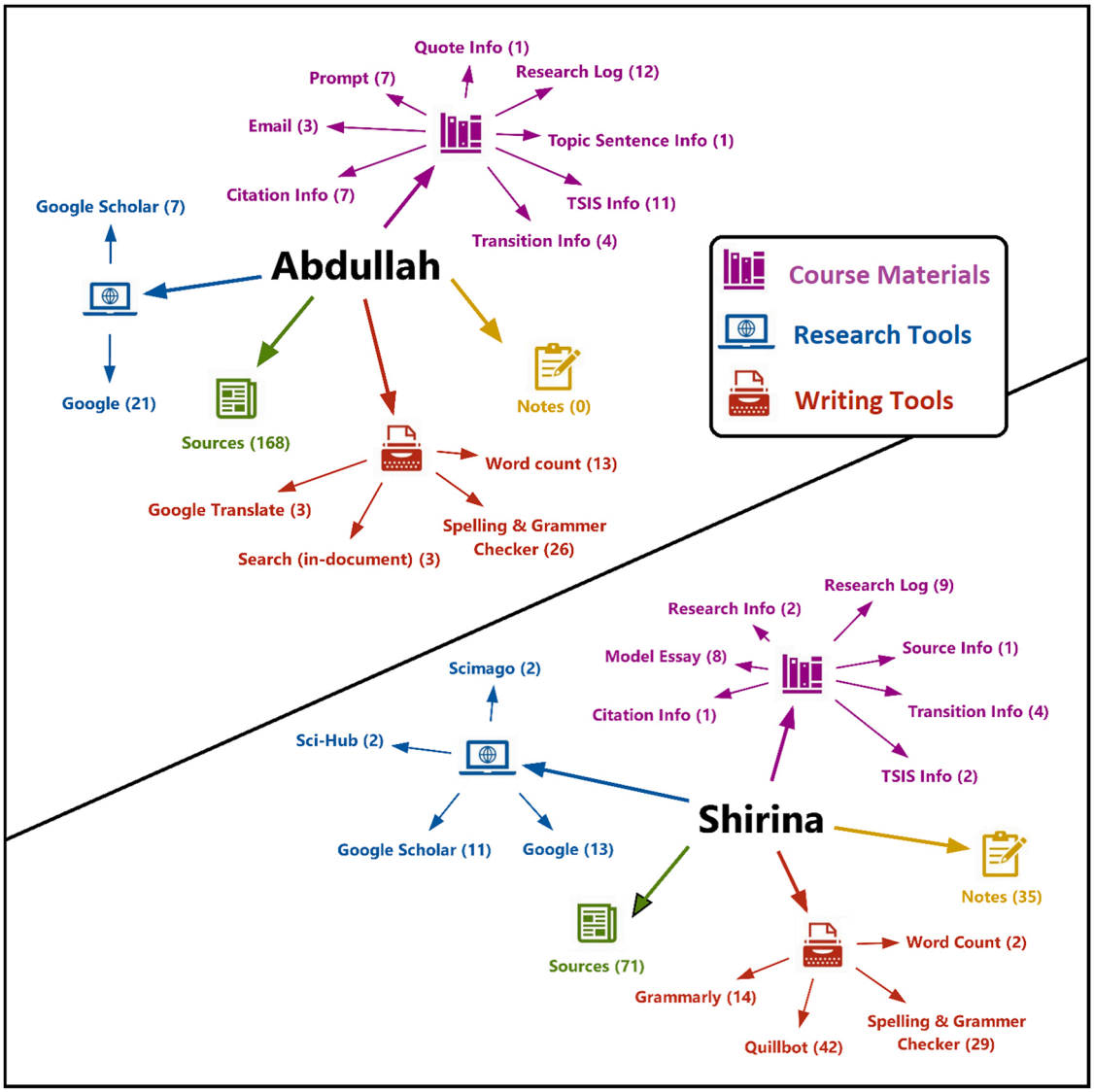

Fig. 3. Mediation networks of Abdullah & Shirina.

straight from sources, foregoing use of notes. He did, however, productively utilize course materials. In the interview sessions he displayed a desire to receive a top score for the assignment; he believed that close attention to the course materials, particularly the model essays, was key in this regard.

Abdullah's efforts paid off. Upon review of his final text, the instructor praised the organization and level of detail. He suggested that Abdullah had "obviously learned a lot about [his] topic" and awarded him full credit.

4.4.2. Shirina

Shirina's mediation profile is defined by heavy use of notes and supplemental writing tools. She used supplemental writing tools at all stages of the research and writing process. Her engagement with these tools can be labeled "high impact" as it resulted in significant alteration to her text. Writing tools were also integrated with one another, as well as other mediating artifacts, such as research logs and notes, in complex ways. As discussed above, rather than linearly working through a single document, Shirina frequently transferred text between different documents and applications, combining the affordances of various resources. Overall, she displayed a highly recursive and non-linear writing style.

Shirina used the content in her research logs significantly and integrated research tools into her drafting process to a degree, moving between logs, notes and source material as needed. She displayed a high degree of discernment among sources, preferring those that contained "specific information" and recognizing the need to "search the background information" of a source before citing it. As noted, Shirina used course material for structural guidance as well as a source of specialized vocabulary.

Shirina's final text was praised by her instructor for being "well structured" and displaying a "clear main point." The instructor suggested, though, that certain sections required more detailed explanation. He also felt her text would be stronger if counterarguments were addressed. Despite these issues, Shirina, like Abdullah, received an "A"—the assignment's highest possible mark.

5. Discussion

The above findings connect with a variety of ongoing conversations in L2 writing studies. In this section we discuss these connections, then analyze our findings in relation to writing as extended mind.

5.1. Mediation in digital writing environments

5.1.1. Technological

Regarding use of research tools, our findings largely parallel existing work. Li (2012), for instance, noted how in digital environments, research and writing are increasingly intermingled, with writers deploying research tools, particularly web search, at all stages of the writing process. Search queries, Li found, tend to get more specific as texts develop. Our findings evidence the same trends. Strategic use of found language, in particular, contributed to the narrowing of search queries. As writers learned more about their topic, and encountered more specialized and relevant vocabulary, they deployed this vocabulary to satisfy more specific informational needs. Li concluded that the writers observed in his study "were generally resourceful, strategic, and efficient in conducting online research" (2012, p. 213). The writers in the present study displayed a similar degree of resourcefulness, especially in regard to bypassing restrictions on information access, an academic skill, to our knowledge, previously unacknowledged in the literature.

Regarding use of writing tools, our findings both confirm and extend existing research. As noted, studies which observe writers under naturalistic conditions are rare. Indeed, to our knowledge, ours is the first study to observe use of an artificial intelligence-powered paraphrase tool like Quillbot. Previous studies of paraphrase tools, even those that are fairly recent (e.g. Bailey & Withers, 2018), depict a writing landscape which, in light of technological advance, is now much changed. The implications of the rise of sophisticated AI-powered writing tools are many and will be discussed in detail below.

The range of writing tools used in our study largely tracks with existing research, with the caveat that tool use patterns seem to vary widely among different student populations. Naghdipour (2022) recently examined, via survey, the range of digital writing tools used by Arabic-speaking, university-level English learners in Oman. Like the participants in our study, these students reported mainly utilizing online translators, proofreading apps and to a lesser extent, online dictionaries. This contradicts findings from Gilquin and Laporte (2021), who tracked the tool use of similarly situated French-speaking English learners. These writers primarily utilized online dictionaries (e.g. Reverso) and bilingual concordancers (e.g. Linguee). Online translators accounted for only 1.5% of the tools used and grammar checkers, outside of resources in Microsoft Word, did not warrant mention. The difference in tool use patterns among writers of similar age and proficiency is notable. It may stem from learner positioning, educational history or even regional variation, with certain writing apps not available or widely used in certain regions or among certain language groups.

The present study also confirms the high degree of individual difference in tool use patterns. Though our participants were the same age and in the same writing course, they had unique histories, abilities and needs. Their mediation profiles thus differed substantially. This observation tracks with existing research which consistently finds that patterns of tool use vary widely among individuals (Yoon, 2016; Wu, 2020).

5.1.2. Symbolic

In regard to symbolic mediation, the above findings add to a small body of work discussing the role of research logs in L2 writing (Helms-Park et al., 2007). As noted, the instructor had two goals in assigning the logs: 1) to encourage mindful web-search behavior and 2) provide each student a store of knowledge to draw on while drafting. Though our study design cannot establish causation, the

first goal might well have been met. Even when not using the logs, Abdullah was observed to conduct source investigation of the sort the logs were designed to scaffold. Shirina also showed increased concern for source quality after completing the logs.

The evidence pertaining to the second goal is more ambivalent. Abdullah, as discussed, used his completed logs only to access the underlying sources. Shirina engaged the content of the logs while drafting, but little of that content made it into her final essay. These data points indicate that, by and large, the participants did not use the logs directly as an information store. The dynamics of the research process are perhaps partially to blame. Early in the research process—when the logs were filled out—the sources engaged were often very general, chosen to provide an overview of the topic. Information from such sources might be less useful once a specific claim has been developed. That said, both participants did access the logs while drafting. Overall, the logs appear to have assisted organization and navigation by providing easy access to links (Abdullah) and key ideas (Shirina).

Our findings also speak to existing research regarding writing prompts (Miller et al., 2016) and genre exemplars (Wu, 2019), as well as course scaffolding more generally (Benko, 2012). All told, digital course materials were used by both study participants, but at rates perhaps lower than expected: excluding research logs, participants spent only about 27 min (out of 17 h of video data) reading or otherwise working with digital course materials. As noted, taken together, the two model essays were viewed by participants much more than any other resource. This phenomenon corresponds with existing research, which indicates that students often find genre exemplars the most accessible form of instruction (Macbeth, 2010). The literature, however, cautions that students might over rely on genre exemplars, blindly following the formal structure without regard to content (Macbeth, 2010; Wu, 2019). Overall, there is little evidence of this tendency in our data. Though the models were used heavily, they were also used productively, with Abdullah, in particular, displaying what Wu (2019) refers to as "imitation," use of models with understanding of the underlying principles that inform them. Apart from the model essays, other materials also appear to have been used productively, if sparingly. As a general rule, participants used supplemental materials (e.g. handouts featuring writing advice) when the relevant skills were highlighted by their instructor as being connected to their final grade.

5.2. Research writing as extended mind

Writing as extended mind (Overstreet, 2022) can further illuminate the behaviors observed. An extended approach attends to the various ways writers combine internal and external resources within localized thinking systems. Viewing the data through the lens of extended mind, a clear distinction emerges between how Abdullah and Shirina distributed cognitive function within their respective thinking systems.

5.2.1. Abdullah's brain-bound approach to research writing

Abdullah, as noted, wrote directly from sources. This strategy is not unprecedented in digital writing environments. Kirkpatrick and Klein (2016), in a study of the internet research strategies of high-achieving high school students, found that about half of their participants, when drafting a short research essay, wrote directly from sources. The other half utilized mediating documents such as notes or outlines. The authors also noted the importance of environmental structuring in digital literacy activity. To write directly from sources, for instance, writers must arrange their workspace in order to "establish a fluent dialectic" between drafting and information search (Kirkpatrick & Klein, 2016, p. 35).

In Abdullah's case, we see the dialectic described. His ability to write directly from sources was facilitated by a sparse, neatly organized digital workspace that allowed him to move quickly between source and inscription site (Fig. 1). When information was needed during the drafting process Abdullah engaged the relevant source, internalized the needed information, then reproduced it in changed form within his text. In other words, he performed conventional paraphrase. Notably, this process was largely internal: environmental structuring facilitated Abdullah's paraphrase activity, but the primary work of paraphrase happened in his head.

A similar dynamic informed Abdullah's use of course materials. Abdullah did not copy either the language or structure of model texts. Instead, he reviewed the materials, deduced certain principles, then deployed those principles. In doing so he engaged in abstraction, a key marker of higher order thought (Dewey, 1910). Again, the primary site of cognitive activity was internal. Indeed, throughout the research and writing process Abdullah relied primarily on brain-bound cognitive resources. Though his internal thinking processes drew on and were supported by non-human elements, we can say that, overall, Abdullah displayed a relatively *brain-bound* approach to research writing.

5.2.2. Shirina's extended approach to research writing

Shirina's approach to research writing was markedly different than that of her classmate in that, via notetaking and tool use, she offloaded a higher degree of cognitive function to her environment. While drafting, Shirina took segments of text from source material, as well as her own previous drafts and notes, and pasted them into her drafting space, slowly bringing these disparate pieces together to form a single, coherent text. Her drafting process, in other words, did not just involve the "translation" (Flower & Hayes, 1980) of information from an internal to external state. Instead, a large part of her process—perhaps the primary part—involved physical manipulation of semantic resources.

Shirina's collage-like drafting process worked to offload cognition in two primary ways. First, the use of notes saved her from having to hold source information in working memory; both key ideas and the language with which to express them were instead stored in her drafting document. She could, and did, tap into these resources as needed during the drafting process. This creation and use of an external information store likely freed up brain-bound cognitive resources, allowing Shirina to focus on higher-order concerns (Kellogg, 2008).

The layout of Shirina's drafting document, with its disparate mix of source material and original ideas, might also have helped

facilitate higher-order thought. In the most basic sense, meaning making is the drawing of connection between different pieces of data (Dewey, 1910). Though we typically imagine the brain alone doing such work, the process can be facilitated by the physical juxtaposition of items in space (Clark, 1998). As Shirina copied, pasted and physically manipulated disparate pieces of data, she likely noticed connections she would not have otherwise. External activity, in other words, was used to assist internal thinking processes, the very definition of epistemic action.

Shirina also offloaded a high degree of cognitive function to her tools. Shirina's drafting process involved constantly monitoring her textual output for usage errors. Rather than allocating internal cognitive resources to this task, she delegated the work to Grammarly. This delegation, as with her note-taking activity, presumably allowed her to devote brain-based resources to other concerns. Along similar lines, rather than performing paraphrase internally, like Abdullah, she performed this work externally, on the screen, with the assistance of Quillbot. This program functioned both as an external information store and inventive mechanism, generating phrasing and vocabulary options. Notably, Shirina's use of Quillbot was not automated or "mindless." Instead, she carefully considered the various options offered, taking substantial time to find those that fit her communication aims. Shirina, in short, via Quillbot, opted to allocate her brain-based cognitive resources to selection and evaluation, rather than recall, of English grammar and vocabulary.

All told, throughout the drafting process, Shirina, like Abdullah, strategically integrated both human and non-human resources. Compared to her classmate, though, the cognitive activities Shirina offloaded to her environment were both more extensive and more complex. Therefore, we can say she displayed a relatively more *extended* approach to research writing.

6. Implications

The above analysis can inform both writing research and pedagogy. In broad terms, our work evidences the theoretical potency of both Vygotskian notions of mediation and writing as extended mind. These theoretical frames, either separately or together, might be used to analyze literacy practices across various sites. Likewise, screen recording, with its unique ability to capture the nuances of digital literacy practices, is deserving of more widespread use.

In terms of specific behavior observed, we believe that student use of alternative information access options—who accesses what information, how and why—is worthy of further study. It may be assumed that such practices are particularly widespread among technologically savvy students and those without institutional access to academic resources. There might also be fruitful connections between the use of alternative access options and self-sponsored literacy behaviors. In other words, how do students adapt hacks learned during non-school activity for academic purposes and vice versa?

Tool use patterns among different student populations—and the cause of potential differences—also warrant further inquiry. These differences may present an opportunity for pedagogical arbitrage in that tool use practices shown to work for certain student populations could be introduced to other populations. For instance, the writers in Gilquin and Laporte's study may benefit from increased familiarity with proofreading tools. At the same time, considering the apparently high efficacy of concordancers (Yoon, 2016), their introduction to Arabic-L1 students might present an instructional opportunity.

Finally, and perhaps most importantly, the difference in mediation profiles observed is of consequence. It has long been acknowledged that with the shift from print to screen, writing processes are changing (Stapleton, 2010). Our research hints at these changes. Shirina's highly extended approach to research writing is of particular note. With the availability of increasingly powerful writing tools, including tools capable of generating text, a high degree of cognitive extension may well become the norm. This shift will impact both writing and writing instruction.

Speaking in broad terms, thinking and learning have conventionally been understood to take place inside the head; mediating artifacts have been viewed as cognitive aids, but not fully part of a learner's cognitive system (Pea, 1993). For Vygotsky (1978), for instance, the fundamental feature of human development is the *internalization* of social and cultural operations. The very metaphor of "scaffolding," rooted in Vygotsky's work, suggests mediation's provisional nature: a scaffold is, after all, a temporary structure, designed to be removed once construction is complete. Contemporary discussions of tool use in L2 writing make similar assumptions about thought and learning. Ranalli (2021), for instance, in a recent study of Grammarly, wrote that to effectively support learner development, writing tools must help students "understand the generalizable properties of specific errors" (3). Understanding, as used here, is a brain-bound activity. It involves abstraction of the sort performed by Abdullah. It does not involve the sort of cognitive offloading performed by Shirina. In other words, Ranalli argued that tools like Grammarly are best used to train internal cognitive processes. Once the training is complete, and the social and cultural operations internalized, the scaffolding can be removed.

Following the line of thought above, we might assume that the goal of writing instruction should be to help students advance along a continuum from extended to brain-bound writing activity. We should privilege Abdullah's linear, relatively brain-bound process over Shirina's recursive, highly extended one. Extended mind suggests that this view might be a mistake. It holds that we should judge thinking systems (human + non-human) by their overall functionality. In Shirina's case, the thinking system created was quite functional. Despite lower English proficiency than Abdullah, and obvious inefficiencies in her process (as revealed by the excessive time spent navigating, for instance) she too was able to produce a complex academic text.

As digital writing tools become more sophisticated, new opportunities for cognitive offloading emerge. With AI-powered text-generation tools like ChatGPT, for instance, writers can now produce complex texts with only a few short prompts. Extended mind suggests that this power should be embraced rather than feared. Shirina's experience, we believe, suggests the same. Despite offloading significant cognitive function, Shirina remained in control of her writing process. Student writers using ChatGPT could do likewise. Writing teachers, however, need to develop strategies to help students use emerging technologies productively. They might do so by engaging new writing tools in the classroom, moving students to explore both their strengths and weaknesses (of which there are undoubtedly many). Students need to reflect on how such tools might impact not only their texts but themselves as writers. How can we

use digital resources to enhance our writing ability rather than stunt it? This is a question that students, teachers and researchers all must ask.

7. Conclusion

The present study adds to a growing body of scholarship seeking to trace L2 writers' literacy practices in digital environments. It shows how two writers use common mediating artifacts to achieve their research and writing goals. Key mediation strategies include the use of found language and alternative information access options, and the strategic integration of resources. We map two distinct mediation profiles. These profiles, we argue, mark two distinct approaches to research writing. One approach involves the use of external resources primarily to structure and stimulate internal thinking processes. The other approach, while also involving structure and stimulation, offloads a higher degree of cognitive labor to the writer's physical environment through the use of notes and supplemental writing tools.

Admittedly, the small sample size of this study works to limit its generalizability. Likewise, we make no claim that Abdullah and Shirina are "average" students—they are likely both more tech savvy and self-regulating than most of their peers. That said, when writing is viewed as situated social action, social and material conditions come to the fore. And at the present moment, many, if not most writers, work within digital environments that look very much like that of our participants. There is thus, we believe, a strong likelihood that the behaviors observed—and the contrasting approaches charted— are widely shared.

Data Availability

Data will be made available on request.

Appendix A. List of course materials and usage rates

Name	Description	Accessed (#)	Time Spent (minutes)
Citation Info	Guidelines for IEEE citation format and model reference list.	**8**	**1:38**
Email	Communications from instructor listing due dates, giving advice & linking to course materials.	**3**	**1:33**
Essay Prompt	Contains detailed description of assignment, including word count for essay, necessary elements, etc.	7	**4:35**
Model Essay	Model They Say/I Say essay annotated to highlight key elements.	**8**	**5:55**
Quote Info	Handout discussing proper use of quotations in academic writing.	**1**	**1:11**
Research Info	Advice regarding best practices for online research.	**2**	**1:05**
Research Logs	Set of templates filled by students; completed logs contain summaries of source information.	**21**	**7:45**
Source Info	List of reliable English-language sources.	**1**	**00:11**
Topic Sentence Info	Handout discussing how to use topic sentences in academic writing	**1**	**00:36**
Transition Info	Handout discussion transition words & sentences.	**8**	**2:50**
TSIS Info	Handout explaining They Say/I Say principles; contains sample TSIS language & a short model essay.	**13**	**6:57**

Appendix B. Sample research log template (non-academic source)

(*continued on next page*)

(*continued*)

Title:	
Author:	
Name of publication or organization:	
Date published:	
Who or what is this source? What is their **agenda**?	
Summary of what you learned from this source. What is the topic? What does the author claim about this topic? (40-80 words)	
1 or 2 sentences that you think might be important:	
URL:	

Appendix C. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.jslw.2023.101019.

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