# Examining perceptions, selections, and products in undergraduates' learning from multiple resources

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**Background.** When learning about complex topics using the Internet, students commonly encounter a multitude of textual, non-textual (e.g., images and graphs), and multimedia (e.g., videos) resources. Yet students' learning from multiple texts and multiple (non-textual) resources (MT-MR learning) has received insufficient consideration in the literature.

**Aims.** We examine the associations among (1) undergraduates' conceptions of reasons for multiple resource access, (2) log-data of resource use when completing a MT-MR task, and (3) writing performance.

**Sample.** Participants were 72 undergraduate students in the United States.

**Methods.** Undergraduates were provided with a library of five texts and one video, with the option of accessing supplemental data (e.g., graphs and maps) in association with each resource. Log-data (e.g., time and supplemental data access) of undergraduates' resource use were collected. Undergraduates were then asked to compose a research report and to describe what they considered the purpose of multiple resource access to be.

**Results.** Four types of conceptions were identified, reflecting a desire to (1) access a lot of information, (2) understand multiple perspectives, (3) corroborate and evaluate information, and (4) develop a personal understanding of a given topic. Undergraduates who considered corroboration and evaluation to be the purpose of multiple resource access were more likely to access more supplemental data sources and performed better on a multiple resource learning task.

**Conclusions.** Undergraduates in our sample held conceptions largely similar to, but in some aspects distinct from, those identified by Barzilai and Zohar (*Cognit Instruct*, **30**, 2012, 39). Conceptions were associated with resource access during task completion and with writing performance.

Since the popularization of the Internet in the early 1990s, reading researchers have recognized the importance of understanding not only how students comprehend single texts but also how students understand, corroborate, and integrate multiple, sometimes conflicting texts. Now, almost 30 years later, there is an emergent interest in how students learn from multiple, multimedia resources as well (List et al., 2020; List & Alexander, 2018). Multimedia resources are defined as those that introduce learners to

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information using two or more symbolic or representational systems (e.g., text and visuals, List et al., 2020), with such multimedia resources potentially introduced to learners either in a stand-alone fashion or alongside other resources (i.e., within a multiple texts, multiple resources MT-MR context). Despite increased interest in learners' MT-MR learning, students' engagement in such learning has been examined only to a limited extent (Lee, 2021). While there is a well-established research-based examining students' learning from (multiple) external representations (e.g., diagrams), presented within a single text (Ainsworth, 2006; Rau, Aleven, & Rummel, 2015; see Renkl & Scheiter, 2017 and Van Meter & Stepanik, 2020, for reviews), less work has considered students' learning from multiple resources, presented in textual and non-textual form, when these are introduced as separate sources of information. In this study, we aim to address this gap by examining undergraduates' MT-MR learning during academic task completion. In particular, we examine (1) undergraduates' conceptions of the importance of multiple resource learning, (2) resource use during task completion, and (3) MT-MR task performance, as well as (4) the associations among these.

### Learning from multiple texts and multiple resources

Understandings of students' multiple resource learning have most often been grounded in earlier conceptions of learning from multiple texts. A prominent model, the *Multiple-Document Task-Based Relevance Assessment and Content Extraction Model* (MD-TRACE, Rouet, 2006; Rouet & Britt, 2011), identifies the process of multiple text learning as unfolding through a series of five, potentially recursive, steps. In Step 1 of the MD-TRACE model, learners interpret and represent the task that they are assigned, forming a task model or a cognitive representation of task demands. In Step 2, learners determine that they have an information need, or that multiple text access is necessary to satisfy task demands. In Step 3 of the MD-TRACE model, learners select, process, and integrate or connect information presented across multiple texts. Finally, in Steps 4 and 5, learners construct a task product, typically a written response, and evaluate the extent to which this response meets task demands.

Although the MD-TRACE model is predominantly focused on students' learning from multiple texts, the model is flexible enough to suggest that the processes of selection, processing, and integration may be carried out in reference to not only texts, but to graphical and multimedia resources as well. That is, during MT-MR learning, students nevertheless need to make determinations regarding which materials (both textual and not) are needed to meet task demands, select, process and integrate these, and incorporate these into the task products that they compose. Mayer's *Cognitive Theory of Multimedia Learning* (CTML, Mayer, 2005; Mayer & Moreno, 1998) posits that when auditory and visual information is simultaneously introduced (e.g., as in the case of animated video, Mayer & Anderson, 1991, 1992), students learn more from information being introduced via both of these channels, simultaneously, than they would from information presented aurally or visually, alone. The CTML has further been extended to describe the benefits of learning from written (rather than aural) explanations accompanied by images, provided certain design conditions are met, including that text and images are presented alongside one another (Mayer, 2003; Mayer & Fiorella, 2014; Moreno & Mayer, 1999, 2000). Here, unlike in Mayer's work, we consider how students may learn from multiple, distinct textual, graphic, and multimedia information resources on a common topic, nevertheless presented separately from one another. We considered such MT-MR learning to well-represent the variety of information resources, both textual

and not, that students are likely to encounter when researching topics on the Internet. We consider the same cognitive processes (i.e., selection, organization, integration) specified by Mayer (1996) and by Rouet and Britt (2011) in the MD-TRACE model, alike, to be necessary for learning, with each of these processes more expansively defined within MT-MR contexts. For instance, selection may include both the accessing of specific resources (Rouet & Britt, 2011) and the identification of important information within each resource (Mayer, 1996); and integration likely refers to students' formation of connections not only between resources and prior knowledge (Mayer, 1996) but also across textual and non-textual resources, as well (Rouet & Britt, 2011).

Unlike work examining students' comprehension of single texts, including external representations, often explicitly referred to in-text (Rau, 2017; Renkl & Scheiter, 2017; Van Meter & Stepanik, 2020), research on students' learning from multiple sources has commonly presented students with non-textual resources alongside texts (e.g., Wiley & Voss, 1999). For instance, in a classic study examining history experts' and Advanced Placement high school students' reasoning about multiple resources in history, Wineburg (1991) asked participants to analyse both textual resources (i.e., historical documents) and pictures and to evaluate the latter's accuracy based on information presented in texts. A variety of differences were found in the reasoning of expert historians and A.P. history students. When evaluating pictures, in particular, historians were found to engage to a greater extent in strategies related to *analysis* (i.e., considering the point of view or goals of the artist), *referencing* (i.e., considering the information provided in texts), and *qualification* (i.e., including conditional statements that contextualized paintings' evaluations). Similarly, Van Meter and Cameron (2018) examined undergraduates' notes, composed during the course of processing texts and images, including a photograph and a political cartoon. Van Meter and Cameron (2018) found these to differ in the content included for textual vis-à-vis non-textual resources. Across two topics, undergraduates' notes on textual content were more complete than their notes on images (e.g., included more main ideas), with the latter further including more affective content. Further, over 40% of students were found not to take notes on the images provided, at all.

Cromley, Kunze, and Dane (2021) recently sought to unify the literatures of learning from multiple representations and multiple texts, using illustrated texts in biology, with images embedded in four-page texts. Using a fine-grained analysis of eye-tracking and think-aloud data, Cromley et al. (2021) found the number of intra-representational switches (i.e., between texts and diagrams on the same page) to predict comprehension; a finding that is consistent with prior work (undergraduates: Cromley, Snyder-Hogan, & Luciw-Dubas, 2010; seventh graders: Mason, Pluchino, & Tornatora, 2015). At the same time, Cromley et al. found intertextual switches, particularly across texts and diagrams on different pages of the same text, to negatively predict comprehension. In part, this may have been because the 'intertextual' aspect of the task provided students with four navigational pages of the same text, rather than presenting distinct (and often conflicting) sources of information, as has most often been done in prior work on learning from multiple texts (Barzilai, Zohar, & Mor-Hagani, 2018; Brante & Strømsø, 2018). In this study, we build on Cromley et al.'s (2021) efforts to examine undergraduates' learning from separate textual and non-textual sources of information to understand a controversial social science topic (i.e., increasing the minimum wage). We do so by examining three distinct data sources: (1) students' conceptions of multiple resource learning, (2) students' use of multiple resources, and (3) students' performance on a multiple-text, multiple resource learning task.

### Conceptions of learning from multiple texts and multiple resources

Students' conceptions of the purpose or benefits of learning from multiple resources have received relatively limited attention in the literature. When examined, these have been associated with students' epistemic beliefs, or beliefs about knowledge and knowing (Buehl & Alexander, 2001). Epistemic beliefs are reflected in students' reasoning about source and evidence quality when learning from multiple texts (see Bråten, Britt, Strømsø, & Rouet, 2011 for a review; Mason, Ariasi, & Boldrin, 2011; Mason, Boldrin, & Ariasi, 2010); and, believing in the need to justify knowledge claims via multiple sources of information has been introduced as a distinct dimension of students' epistemic beliefs *per se* (Bråten, Ferguson, Strømsø, & Anmarkrud, 2013). In particular, students' endorsement of beliefs that knowledge should be corroborated across multiple sources of information has repeatedly been associated with learners' multiple document comprehension (Bråten et al., 2013; Ferguson & Bråten, 2013; Wiley, Griffin, Steffens, & Britt, 2020). A study modelling secondary school students' processing and comprehension of multiple texts found beliefs regarding the need for justification by multiple sources to predict the time that students devoted to text access, students' reports of deep strategy use, and situational interest, with these in turn predicting comprehension (Bråten, Anmarkrud, Brandmo, & Strømsø, 2014).

Beyond research investigating students' beliefs regarding the need for justification via multiple sources, less work has examined how this need for justification, along with other considerations, figures into students' beliefs regarding the need for multiple resource access at all. As an exception to this, Barzilai and Zohar (2012) interviewed sixth grade students completing two online search tasks and, in part, asked students to respond to the question: *Can there be a single website with the right answer to this question? If yes, what kind of website would it be? If not, why?* as a method for capturing students' conceptions of the reasons for multiple resource access. Students' responses were found to fall into three general categories. First, students considered multiple resource access to be beneficial for the (1) *amount* of information that multiple resources provided; moreover, students considered multiple resource access to be important because it (2) allowed for *multiple perspectives* to be considered and for the (3) *trustworthiness* of information to be determined. Students' endorsement of each of these conceptions was found to be associated with the epistemic thinking profiles that students belonged to. That is, students holding more absolutist beliefs, or considering knowledge to be able to be definitively identifiable as correct or incorrect, were less likely to consider the presentation of multiple perspectives and the ability to determine information trustworthiness to be benefits of multiple resource access. Conversely, students endorsing more evaluativist epistemic beliefs, or considering knowledge construction to require evaluation and personal interpretation, were more likely to endorse these reasons for multiple resource access (i.e., accessing multiple perspectives, determining trustworthiness). In this study, we use Barzilai and Zohar's (2012) approach with a sample of undergraduate students, to examine the ways in which conceptions of reasons for multiple resource access evolve as students mature and transition from middle school to university (Kuhn, Cheney, & Weinstock, 2000; Wiley et al., 2020).

### Present study

Although Barzilai and Zohar (2012) found an association between students' epistemic belief profiles and conceptions of reasons for multiple resource access, they did not

examine the associations among students' conceptions and actual multiple resource use and task performance. In this study, we examine this association, particularly given prior research suggesting that student' epistemic beliefs, or beliefs about knowledge establishment and justification, have a substantive bearing on their interactions with and learning from multiple texts (Bråten et al., 2014; Mason et al., 2010, 2011; Wiley et al., 2020). Specifically, we examine the relations among students' conceptions of reasons for multiple resource access and actual resource use and task performance when completing a multiple resource learning task. Given our interest in MT-MR learning, the resources that students were introduced to in this study included both texts and a video, with the option to access supplemental data, presented in graphic form, available in association with each resource provided. Consistent with prior work, resource use in this study was behaviourally captured via log data of students' information access (i.e., digital records of students' resource use). In prior work, log data (e.g., time devoted to text access, number of texts accessed) have been used as proxies for students' more effortful and strategic resource use and have been associated with task performance (Bråten et al., 2014; List & Alexander, 2017; List et al., 2019). MT-MR task performance in this study was assessed via a writing task intended to capture students' integration of information introduced across multiple resources.

We have the following research questions:

1. What are students' conceptions of reasons for multiple resource access?

Based on work by Barzilai and Zohar (2012), we expected students' conceptions of reasons for multiple resource use to include accessing a large volume of information, accessing a variety of perspectives, and determining information trustworthiness. Nevertheless, because we were examining an undergraduate, rather than middle-school sample, and because students' epistemic beliefs have been found to change with age and instructional experience (Wiley et al., 2020), we were also prepared for additional conceptions of reasons for multiple resource access to uniquely emerge in our data.

2. What is the nature of students' resource use when completing a MT-MR learning task? What is the association between conceptions of reasons for multiple resources access and actual multiple resource use?

We expected students holding conceptions of reasons for multiple resource access to be allowing a lot of information to be gathered, to use the most library resources during MT-MR learning. We expected students holding conceptions of reasons for multiple resource access to be determining information trustworthiness, to spend more time on resource access (indicative of deep-level strategy use, Bråten et al., 2014) and to access supplemental data sources to a larger extent, for corroboration. Broadly speaking, we expected these two conception profiles (i.e., gathering a lot of information; determining information trustworthiness) to align with Bråten and Strømsø's (2011) definition of information accumulation and cross-textual elaboration as the two strategic approaches that students may adopt when learning from multiple texts (and from multiple resources).

3. How do students perform when completing a MT-MR learning task? What is the association between students' conceptions of reasons for multiple resource access and task performance?

We expected students' written responses to the MT-MR task to conform to the multiple source representations described in the *Documents Model Framework* (DMF),

with students forming mush models, separate representations, and documents models of multiple resources (Britt, Perfetti, Sandak, & Rouet, 1999; Perfetti, Rouet, & Britt, 1999). Consistent with the DMF, we expected the multiple resource representations reflected in students' written responses to vary according to whether or not sources of information were explicitly identified (i.e., cited) and in the extent to which disparate resources were linked to one another. We expected students considering the purpose of multiple resource use to be accessing a lot of information to demonstrate limited integration or connection formation across sources of information. Conversely, we expected students whose conceptions of reasons for multiple resource access included determining information trustworthiness to feature both more citations and more integrative links across resources in the written responses that they composed.

## Methods

### Participants
Participants were 72 undergraduate students at a large university in the Northeastern United States (age: $M = 19.12$, $SD = 1.46$). The majority of the sample was female (84.70%, $n = 61$; male: 15.30%, $n = 11$) and White (87.50%, $n = 63$). Other students participating in the study identified as Asian (6.90%, $n = 5$), Latino/Hispanic (4.20%, $n = 3$), and Black/African American (1.40%, $n = 1$). The sample represented a variety of education-related majors, and the majority of students were freshmen (65.30%, $n = 47$).

Participants in the study described in this manuscript ($n = 72$) were drawn from an investigation intending to improve MT-MR task performance ($N = 134$). Nevertheless, the manipulations considered in the full investigation (i.e., engaging students in two different pre-writing activities, either generating main ideas or diagramming connections between resources) were not successful. Still, we considered the core MT-MR task used to evaluate intervention effectiveness to merit investigation. As such, the study described in this manuscript examines MT-MR use and performance among only those participants not receiving any intervention. In this paper, we report procedures for only those students not receiving any pre-writing intervention. Please see Appendix A for a discussion of the full study (i.e., including the failed pre-writing manipulations).

### Procedures
Procedures for participants not receiving any pre-task writing intervention (i.e., those analysed in this paper, $n = 72$) included three primary parts. First, students were asked to complete assessment of prior knowledge, interest, and attitudes towards the topic of the task. Second, students were asked to use a library of six digital resources to research the benefits and drawbacks of the U.S. raising the federal minimum wage. During the course of digital library use, log data of students' resource access were captured, as a behavioural measure of processing. Finally, students were asked to complete two post-task performance measures, to report their conceptions of reasons for multiple resource access, and to compose a research report on the topic of the United States increasing the federal minimum wage. All study components were completed during a single study session, taking place in a computer laboratory and lasting, on average, 1 hr ($M = 59.89$ min; $SD = 16.28$ min).

### Measures

#### Individual difference measures

*Prior knowledge.*   Prior knowledge was assessed via two open-ended questions asking students to identify an economic benefit and an economic limitation of increasing the federal minimum wage. Open-ended responses were coded for the number of distinct benefits or limitations that they included (i.e., one or two) and totalled across the two open-ended questions. As such, students received separate scores for the identification of a single or multiple benefits and one or multiple limitations. Prior knowledge scores ranged from zero to four. Inter-rater agreement for students' prior knowledge scores was 86.15%, based on two raters scoring all student responses.

*Interest.*   Participants were asked to rate their interest in five topics related to raising the federal minimum wage. In particular, we asked participants to rate their interest in: (1) the federal minimum wage, (2) workers' rights, (3) public policy, (4) labour issues, and (5) economic issues, on a five-point Likert scale, from *not at all interested* to *very interested*. Cronbach's alpha for the interest measure was $\alpha = .79$.

*Attitudes.*   We asked participants to both report their attitude stance on increasing the federal minimum wage and to rate three items tapping attitude certainty. Specifically, participants were first asked: *The federal minimum wage in the United States is $7.25 an hour. Do you support increasing the federal minimum wage?* with *yes* (62.50%, $n = 45$), *no* (9.27%, $n = 7$), *I can't decide* (4.17%, $n = 3$), and *I don't know enough to decide* (23.61%, $n = 17$) options provided. Then, participants were asked to rate: (1) *how sure are you?* (2) *how certain are you?* and (3) *how strongly do you feel?* All three items were rated on a five-point scale ranging from *not at all* to *very*. Cronbach's $\alpha$ for attitude certainty was .95.

One-way ANOVAs were used to examine whether these three individual difference factors were associated with differences in students' conceptions of reasons to access multiple resources. While prior knowledge did differ across students holding different conceptions of reasons for multiple resource access, $F(3, 66) = 3.58, p < .05, \eta^2 = .14$, interest ($p = .62$) and attitude certainty ($p = .88$) did not. See Table 1 for descriptives (List et al., 2020). In particular, students considering the purpose of multiple resource access to be gathering multiple perspectives had significantly lower prior knowledge scores ($M = 0.91, SD = 1.00$) than students considering the purpose of multiple resource access

**Table 1.** Average interest and attitude certainty across conceptions

| Conceptions category | Interest M (SD) | Attitude certainty M (SD) |
|---|---|---|
| Information volume | 2.50 (1.13) | 3.50 (2.12) |
| Multiple perspectives | 3.25 (0.99) | 3.29 (1.13) |
| Corroboration and evaluation | 3.20 (0.71) | 3.41 (1.31) |
| Personal understanding | 3.26 (0.78) | 3.59 (0.87) |
| Total | 3.19 (0.78) | 3.44 (1.15) |

to be developing personal understanding ($M = 1.78$, $SD = 1.00$), $p < .05$. As such, prior knowledge was used as a covariate in all relevant analyses.

*Multiple resource task*
Students were asked to complete a MT-MR task, which required them to research and write a research report about the U.S. raising the federal minimum wage.

*Resources.*    All students had access to six digital resources, including five texts and one video. Each resource had the option for students to access supplemental data on a separate page associated with each resource. While the initial resources that students accessed, aside from the video, only included text, supplemental data were presented using a variety of visualization formats (e.g., bar graph, map). See Figure 1 for an example of the supplemental data that students had available. Texts were designed to present complementary information on increasing the federal minimum wage, including overlapping and largely unique information presented within each text. All resources were designed to be trustworthy in nature and attributed to reputable governmental and non-profit sources and publications in the popular press (e.g., Bureau of Labor Statistics; Washington Post). Moreover, resources represented a variety of document types including newspaper articles, policy briefs, and a video. The video was taken from an evening news broadcast on increasing the minimum wage. The video was presented without captioned text and only with aural narration. The video was naturally occurring and was selected based on its credibility, produced by CBS Evening News, content, including perspectives from both minimum wage workers and business owners, and length. It can be viewed at: https://www.youtube.com/watch?v=TIWaG7tBMiA&t=5s&ab_channel=CBSEveningNews
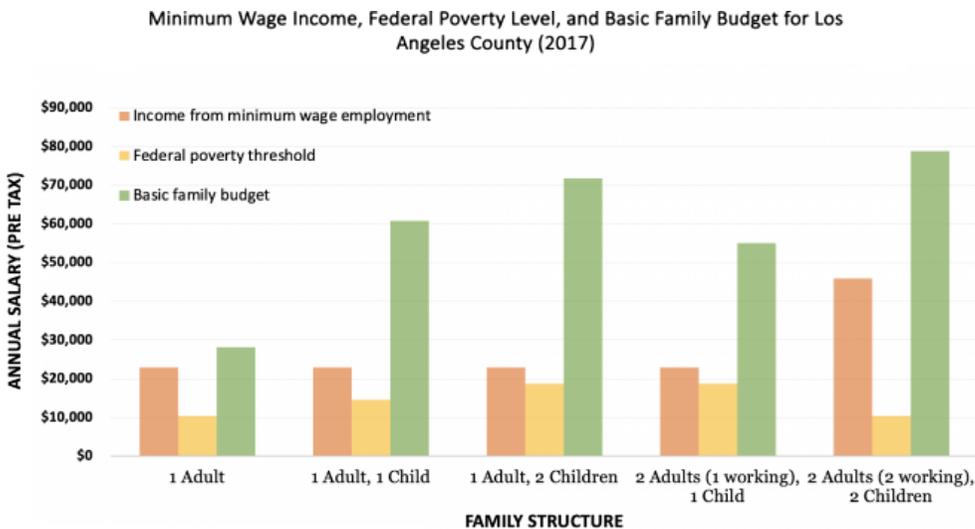


**Figure 1.** Example of supplemental data provided.

Raising the federal minimum wage was chosen as the topic of the task for three reasons. First, this was a controversial topic about which multiple resources, introducing distinct, complementary, and conflicting points of view could be introduced. Second, this is a topic commonly discussed in the popular press, that could be explored by students within a relatively limited study period, and about which a variety of document types could be introduced. Finally, this is a topic which has often been explored using data visualizations (e.g., graphs of the real and inflation-adjusted minimum wage over time), allowing for the easy identification of supplemental data, to be included in association with each library resource.

After students accessed each resource, they were provided with the option to: *see additional data related to this resource*. If students selected the additional data option, a multimedia representation was displayed in association with each resource. Each representation was a visualization of data related to the main topic of each resource. These data both overlapped and expanded on other data provided within the original resource. For example, the policy brief, which discussed regional differences in cost of living, was supplemented with a map displaying average rents within each state. Although the primary resource (i.e., the policy brief) only described average rents in Arkansas and San Francisco, the additional data showed average rents in all 50 states. In addition to the map, visualizations included, a bar graph and a pie chart, among others. All multimedia representations, except one, were drawn from sources in the popular press, with one created by study authors; a source was included for each visualization. See Table 2 for a description of resources and supplemental data sources available in the digital library.

In the digital library, resources were arrayed by document type and title (e.g., *Public Opinion Poll: Who Supports Increasing the Minimum Wage?*) and presented in a random order. Students were provided with a notes sheet to record information during the research phase of the study.

*Log data.*   During students' resource access, three types of log data indicators were collected. These were which resources students accessed, whether or not students accessed supplemental data in association with each resource, and the total amount of time that students devoted to accessing library resources and accessing supplemental data associated with each resource.

*Response composition.*   After students indicated that they had accessed enough information from the digital library, they proceeded to the response phase of the study. Specifically, students were asked to write a research report on the topic of increasing the federal minimum wage in the United States. Students were instructed to: *Please write a research report for policy makers to help them decide whether or not to support increasing the federal minimum wage*.

Students' research reports were scored according to the Documents Model Framework (Britt et al., 1999; Perfetti et al., 1999). The DMF suggests that, when learning from multiple texts, students need to both connect information introduced across texts (i.e., integrate content) and to link information, from disparate texts, to sources of origin (i.e., form source-content connections), allowing information from distinct sources to be evaluated and compared. Here, the DMF is applied to learning from multiple, multimedia resources as well.

**Table 2.** Resources in the digital library

| Title | Document type | Source | Word count | Supp. data type | Supp. data source |
|---|---|---|---|---|---|
| Who earns the federal minimum wage? | Fact sheet | Bureau of Labor Statistics | 229 | Chart | Fivethiryeight; Current Population Survey |
| Would increasing the minimum wage help workers? | Policy brief | Center for American Progress | 280 | Map | National Low Income Housing Coalition |
| Senators split on the benefits and drawbacks of increasing the minimum wage | Newspaper article | Washington Post | 301 | Line graph | Pew Research Center |
| Who supports increasing the minimum wage? | Public opinion poll | Pew Research Center | 252 | Stacked bar graph | Pew Research Center |
| Seattle raised the minimum wage: here's what happened | Economic research report | American Enterprise Institute | 297 | Pie chart | The Seattle Times |
| U.S. states and cities raising the minimum wage | Video | CBS Evening News | 357[a] | Bar graph | U.S. Census Bureau |

[a]Word count based on a transcription of video content.

Students' written responses were coded in two primary ways, for (1) the type of multiple resource model they represented (i.e., as specified in the DMF) as well as for (2) the number of cross-resource connections that these included (i.e., instances of integration).

*Multiple resource models* – Responses were coded according to the four different types of multiple resource models that they could represent (i.e., mush models, separate representations models, with and without citations, and documents model). Students' responses categorized as mush models included the integration of information across multiple resources, but did not attribute this information to source(s) of origin (i.e., did not include citations). Responses coded as separate representations included information from multiple resources in a sequential manner, with no cross-resource connections drawn. The difference between models categorized as separate representations with citations vis-à-vis separate representations without citations was that the former included the attribution of information to sources (i.e., citation), while the latter did not. Responses coded as reflecting a documents model connected information obtained from different resources (i.e., integration) and included explicit citation. Cohen's kappa inter-rater agreement for the types of multiple text models reflected in students' responses was $\kappa = .87$, based on all responses coded (exact agreement: 90.28%). Sample responses are included in Table 3.

*Integration* – Students' responses were further analysed for the total number of cross-textual connections these included. Exact agreement between raters was 93.06%, based on all 72 responses scored.

*Students' conceptions of reasons for multiple resource access*
After multiple resource task completion, students were asked to report their conceptions of reasons for multiple resource access. Specifically, students were asked to respond to the prompt: *In this study, you were asked to learn about a topic using multiple sources of information. Is learning from multiple sources of information important? Please explain why*. Asking students to report conceptions following research task completion is consistent with methods used by Barzilai and Zohar (2012). Students' responses were coded according to whether or not they represented each of four possible conceptions. These conceptions were as follows: (1) gathering a large volume of information (i.e., *information volume*), (2) gathering information from different perspectives or from diverse points of view (i.e., *multiple perspectives*), (3) identifying bias and obtaining reliable information (i.e., *corroboration and evaluation*), and (4) constructing a personal understanding of a given topic (i.e., *personal understanding*). Two students' conceptions could not be classified (i.e., 'Yes because you have to take into account what the source is and what its stance is'; 'Yes it is always good to have as multiple sources to help refute the claim and support the claim being made'). While three of these categories (i.e., information volume, multiple perspectives, corroboration and evaluation) were previously identified by Barzilai and Zohar (2012), the personal understanding category emerged uniquely in these results. In this way both top-down and bottom-up coding approaches were used, such that categories initially identified by Barzilai and Zohar (2012) could be augmented with additional conceptions categories uniquely appearing in

**Table 3.** Sample responses

| Representation of multiple resources | Sample response | Percentage (N) |
| --- | --- | --- |
| Mush model | While covering statistics across economists and popular policy favoured by liberals, a majority vote in both groups found raising the minimum wage would benefit workers. <u>But, 60% of small business owners found it would harm their business</u> **[American Enterprise Institute]**. Nevertheless, <u>large corporations have taken action to raise the minimum wage to $15, like done in Seattle, likely by the year 2021</u> **[CBS Video]** | 19.44% (n = 14) |
| Separate representations model with no citations | '. . . The standards of living are rather high in America and the minimum wage does not coincide with this. Furthermore, increasing the minimum wage will be an economic benefit, because it means that less federal public assistance funding will need to be allocated and disbursed **[Washington Post]**. If those who were receiving such funding are now working for an increased minimum wage, there will not be as strong of a need for federal funding to make ends meet. Taking all of that into account, many of the minimum wage jobs are done hourly and are in hospitality based fields **[Bureau of Labor Statistics]**. . .' | 20.83% (n = 15) |
| Separate representations model with citations | '. . . **The Congressional Budget Office** released a report about projected economic changes if the federal minimum wage increased to $10.10 an hour. In a newspaper article from the **Washington Post**, small businesses provided their perspectives for how they felt about minimum wage | 18.06% (n = 13) |

**Table 3.** (*Continued*)

| Representation of multiple resources | Sample response | Percentage (*N*) |
|---|---|---|
| | changes. Senator Murray (D-WA) explained that, 'increasing federal minimum wage would provide businesses with more, wealthier customers [and] employers would also benefit from a reduction in hiring and training costs, since better pay decreases employee turnover' **(The Washington Post)**. . .' | |
| Documents model | '. . . It is important to take into consideration that raising the federal minimum wage could impact workers negatively. **Senator Cassidy** said that: 'Businesses paying more for employees, hire fewer workers and move more quickly to automation, replacing workers entirely.' **The Public Opinion Poll from the Pew Research Center** proved this in a 2014 Gallup Poll, interviewing 600 small-business owners. 60% of respondents believed an increase would hurt small businesses, 28% said an increase would cause them to reduce employees, and 31% said they would reduce worker benefits. . .' | 37.50% (*n* = 27) |

*Note:* Integration is underlined; citations are bolded.

our data. Exact agreement between raters for the coding of students' conceptions was 89.42%, based on all responses coded. Table 4 includes sample students' conceptions of multiple resource access.

In all cases (i.e., in coding students' prior knowledge, written responses, and conceptions of multiple resource access), disagreements were resolved through discussion and by comparing responses on which raters disagreed to category definitions and exemplar responses from other students.

## Results

### Research Question 1: Students' conceptions of reasons for multiple resource access

Our first research question examined the nature of students' conceptions of reasons to learn from multiple resources. Four types of conceptions were examined. Specifically, we

**Table 4.** Examples of students' conceptions of multiple resource access

| Conception category | Sample response | Percent[a] (N) | Percent unique[b] (N) |
|---|---|---|---|
| Information volume | Yes I really do believe that learning from multiple sources of information is important. I think this because every source had new information to read. I took notes from every source and I kept writing things down. They didn't have the same exact thing written on every single source. If I had only stayed on one source I wouldn't have gotten all the information I needed to conduct a research report | 20.83% (n = 15) | 2.78% (n = 2) |
| Multiple perspectives | Learning from multiple different sources is important because it gives you insight into many different view points | 59.72% (n = 43) | 31.94% (n = 23) |
| Corroboration and evaluation | Yes – in order to 'fact check' and verify your information, you have to visit several sources in order to make sure none of the information is biased | 51.39% (n = 37) | 37.50% (n = 27) |
| Personal understanding | Learning from multiple sources is important so that the researcher is able to obtain their own opinion from other opinions and facts | 25.00% (n = 18) | 25.00% (n = 18) |

[a]Percentages computed based on students reporting multiple conceptions.; [b]Percentages computed based on students' assignment to their most sophisticated category of conceptions reported.

considered the extent to which students conceptualized the purpose of multiple resource access to be: (1) accessing a lot of information, (2) understanding multiple perspectives, (3) corroborating or evaluating information, or (4) developing a personal understanding of a given topic. Students' responses were often classified into more than one category. In our sample, students most commonly identified the purpose of accessing multiple resources to be understanding multiple perspectives (59.72%, $n = 43$) and corroborating and evaluating information (51.39%, $n = 37$).

For the remainder of the analyses in this study, consistent with Barzilai and Zohar (2012), we categorized students into the most sophisticated category of conceptions they identified. This was done to distinguish, for instance, students who were *only* considering information volume in conceptualizing reasons for multiple resource access from students who considered the purpose of multiple resource access to include more sophisticated conceptions as well. The ordering of conceptions according to their relative sophistication was based on Barzilai and Zohar (2012), building on Kuhn and colleagues' work (Kuhn et al., 2000; Kuhn & Weinstock, 2002). In their developmental

conceptualization, individuals were considered to shift from holding absolutist, to multiplist, to evaluativist views. Given that evaluativist views were reflective of those 'coordinating[ing] and balanc[ing] between the subjective and objective dimensions of knowledge. . ..consider[ing] knowledge as constructed' (Barzilai & Zohar, 2012, p. 42), in this study the development (i.e., construction) of a personal understanding was positioned as proceeding in sophistication from students' recognition of the need to corroborate and evaluate information. See Table 4.

### Research Question 2: Students' conceptions of reasons for multiple resource access and behavioural indicators of multiple resource access

For our second research question, we were interested in the nature of students' multiple resource access during task completion. Four primary indicators of resource access were examined. These were (1) the number of resources that students accessed, (2) the percent of resources for which supplemental data were accessed, (3) the duration of resource access, and (4) the time that students devoted to supplemental data access. Prior knowledge was used as a covariate in all relevant analyses. Descriptive data regarding multiple resource access are presented in Table 5. See Table 6 for the correlations among indicators of multiple resource access.

A series of ANCOVAs were used to examine whether each of these resource access indicators differed across students holding different conceptions of multiple resource access. Skewness and kurtosis were examined to assess whether the normality assumption for each variable was met. The results suggested one instance of deviation from normality in the distribution of time devoted to supplemental data access among students considering the purpose of multiple resource access to be understanding a multitude of perspectives. However, this deviation from normality was deemed acceptable as the *F*-test is considered to be robust to slight and moderate deviations from normality, when sample sizes are reasonably large (Blanca, Alarcón, Arnau, Bono, & Bendayan, 2017; Stevens, 2009). Levene's test was used to determine whether the homogeneity of variance assumption was met (Levene, 1960). The results of Levene's test for all resource access indicators were not significant. See Table 7 for descriptive information on behavioural indicators of multiple resource access across conceptions groups, including measures of skewness and kurtosis.

### Number of resources accessed

The number of resources that students accessed was not found to differ for students holding different conceptions of the purpose of multiple resource access ($p = .87$).

### Per cent of resources for which supplemental data were accessed

Supplemental data access was found to differ for students holding difference conceptions of reasons for multiple resource access, $F(3, 65) = 4.27$, $p < .01$, $\eta^2 = .17$. Prior knowledge was not a significant covariate in the model ($p = .82$). *Post-hoc* comparisons of estimated marginal means found that students considering the purpose of multiple resource access to be gathering multiple perspectives accessed significantly less supplemental data sources ($M = 0.26, SD = 0.36$) than students considering the purpose of multiple resource access to be corroborating and evaluating information ($M = 0.59, SD = 0.40$), $p < .05$.

**Table 5.** Resource access metrics by document type

| | Percent accessed | Average time | Percent accessed supp. data | Time on supp. data access |
|---|---|---|---|---|
| Fact Sheet: Who earns the federal minimum wage | 87.50% (n = 63) | 3.60 (1.71) | 44.44% (n = 28) | 0.69 (0.85) |
| Policy Brief: Would increasing the minimum wage help workers? | 80.56% (n = 58) | 4.31 (1.69) | 55.17% (n = 32) | 0.65 (0.85) |
| Newspaper Article: Senators split on the benefits and drawbacks of increasing the minimum wage | 79.17% (n = 57) | 4.49 (1.89) | 47.37% (n = 27) | 0.31 (0.27) |
| Public Opinion Poll: Who supports increasing the minimum wage? | 79.17% (n = 57) | 2.79 (1.73) | 43.86% (n = 25) | 0.28 (0.32) |
| Economic Research Report: Seattle raised the minimum wage: here's what happened | 77.78% (n = 56) | 4.36 (2.37) | 55.36% (n = 31) | 0.60 (0.70) |
| Video: U.S. states and cities raising the minimum wage | 56.94% (n = 41) | 3.02 (1.45) | 56.10% (n = 23) | 0.96 (1.17) |

*Note:* All descriptive information is based on the subset of participants (n = 72) analysed in this study. Percent of students accessing supplemental data is computed based on the total number of students accessing a particular resource. Time on resource access and supplemental data access is computed based only on those students accessing a particular resource.

**Table 6.** Correlations among individual difference factors, indicators of multiple resource access, and performance ($n = 72$)

| Measures | 1. | 2. | 3. | 4. | 5. | 6. | 7. | 8. |
|---|---|---|---|---|---|---|---|---|
| 1. Interest | 1.00 | | | | | | | |
| 2. Attitude certainty | .18 | 1.00 | | | | | | |
| 3. Prior knowledge | .24* | .19 | 1.00 | | | | | |
| 4. Number of resources accessed | .01 | −.02 | .07 | 1.00 | | | | |
| 5. Percentage of supplemental data accessed | .02 | .04 | .10 | .06 | 1.00 | | | |
| 6. Time on resource access | .02 | −.10 | .16 | .69** | .27* | 1.00 | | |
| 7. Time on supplemental data access | −.05 | −.02 | .17 | .15 | .66** | .36** | 1.00 | |
| 8. Citations | .00 | .01 | .06 | .23 | .26* | .20 | .26* | 1.00 |
| 9. Integration | −.04 | −.01 | .05 | .12 | .05 | .19 | .09 | .26* |

$*p < .05; **p < .01; ***p < .001.$

**Table 7.** Descriptives of students' multiple resource access across conceptions

| Conception | M (SD) | Skewness Stat. | Skewness SE | Kurtosis Stat. | Kurtosis SE | Levene's test F | Sig. |
|---|---|---|---|---|---|---|---|
| **Number of resources accessed** | | | | | | | |
| Information volume | 4.50 (0.71) | – | – | – | – | 0.46 | .76 |
| Multiple perspectives | 4.43 (1.31) | −0.65 | 0.48 | −0.50 | 0.94 | | |
| Corroboration and evaluation | 4.74 (1.26) | −0.47 | 0.45 | −1.01 | 0.87 | | |
| Personal understanding | 4.56 (1.15) | −0.28 | 0.54 | −0.19 | 1.04 | | |
| **Percent supp. data access** | | | | | | | |
| Information volume | 0.00 (0.00) | – | – | – | – | 0.73 | .58 |
| Multiple perspectives | 0.26 (0.36) | 1.11 | 0.48 | −0.27 | 0.94 | | |
| Corroboration and evaluation | 0.59 (0.40) | −0.48 | 0.45 | −1.45 | 0.87 | | |
| Personal understanding | 0.58 (0.38) | −0.39 | 0.54 | −1.31 | 1.04 | | |
| **Time on resource access** | | | | | | | |
| Information volume | 14.00 (3.60) | – | – | – | – | 1.43 | .24 |
| Multiple perspectives | 14.88 (7.56) | −0.18 | 0.48 | −0.81 | 0.94 | | |
| Corroboration and evaluation | 19.01 (7.84) | 0.19 | 0.45 | −1.33 | 0.87 | | |
| Personal understanding | 18.94 (6.76) | −0.06 | 0.54 | 0.39 | 1.04 | | |
| **Time on supp. data access** | | | | | | | |
| Information volume | 0.00 (0.00) | – | – | – | – | 1.86 | .13 |
| Multiple perspectives | 0.63 (1.48) | 3.51 | 0.48 | 13.87 | 0.94 | | |
| Corroboration and evaluation | 1.77 (2.14) | 1.09 | 0.45 | −0.02 | 0.87 | | |
| Personal understanding | 1.84 (2.12) | 1.58 | 0.54 | 2.75 | 1.04 | | |
| **Total integration** | | | | | | | |
| Information volume | 0.00 (0.00) | – | – | – | – | 1.32 | .27 |
| Multiple perspectives | 0.61 (1.12) | 1.95 | 0.48 | 3.23 | 0.94 | | |
| Corroboration and evaluation | 1.74 (1.65) | 1.49 | 0.45 | 2.89 | 0.87 | | |
| Personal understanding | 1.00 (0.97) | 0.87 | 0.54 | 0.17 | 1.04 | | |

*Amount of time devoted to initial resource access*
The amount of time that students devoted to resource access did not differ for participants holding different conceptions of reasons for multiple resource access, $p = .31$.

*Amount of time devoted to supplemental data access*
No significant differences in the amount of time devoted to supplemental data access were found across students holding different conceptions of reasons for multiple resource access, $p = .20$.

### Research Question 3: Students' task performance and conceptions of reasons for multiple resource access

Our third research question examined students' multiple resource task performance and the extent to which this was associated with students' conceptions of reasons to learn from multiple resources.

*Conceptions of reasons for multiple resource access and multiple resource task performance*
We examined whether the type of multiple resource model reflected in students' written responses was associated with their conceptions of reasons for multiple resource access. A chi-squared test of association was significant, $\chi^2(9) = 21.01$, $p < .05$, Cramer's $V = .32$. A $z$-test to examine column proportions found students considering the purpose of multiple resource access to be gathering multiple perspectives to be significantly more likely to construct a separate representations model with citations (40.00%, $n = 8$) as compared to a documents model of multiple resources (15.00%, $n = 3$). Conversely, students who considered the purpose of multiple resource access to be corroboration and evaluation were significantly more likely to construct documents models (55.60%, $n = 15$) and significantly less likely to form separate representations of multiple resources without citations (7.40%, $n = 2$).

*Conceptions of multiple resource access and integration*
We further examined whether the degree of integration reflected in students' written responses differed in association with students' conceptions of reasons for multiple resource access. Prior knowledge was again entered as a covariate. Significant differences were identified, $F(3, 65) = 3.59$, $p < .05$, $\eta^2 = .14$. *Post-hoc* analyses comparing estimated marginal means determined that students considering the purpose of multiple resource access to be gathering multiple perspectives included significantly fewer instances of integration in their written responses ($M = 0.61$, $SD = 1.12$) than students considering the purpose of multiple resource access to be corroboration and evaluation ($M = 1.74$, $SD = 1.65$), $p < .05$.

### Discussion

The goals of this study were threefold. First, we wanted to examine how students at the undergraduate level conceptualized the purpose of multiple resource access. Second, we wanted to investigate log-data indicators of students' multiple resource use in association

with students' conceptions of the purpose of multiple resource access. Finally, we wanted to examine the extent to which students' conception of reasons for multiple resource access were associated with task performance. We discuss each of these goals in turn.

### Conceptions of reasons for multiple resource access

Our initial goal in this study was to examine students' conceptions of the purpose of multiple resource access. To our knowledge, such conceptions have only been examined by Barzilai and Zohar (2012) in a sample of sixth grade students. Barzilai and Zohar identified these conceptions to include (1) identifying a lot of information, (2) gathering multiple points of view, and (3) corroborating and evaluating information. In our data, we too found such conceptions of multiple resource access to be discernible. At the same time, students' conceptions manifest in a somewhat different proportion in our study than they did in Barzilai and Zohar's (2012) work. In particular, Barzilai and Zohar (2012) found between 56% and 60% of students to consider the goal of multiple resource access to be gathering a lot of information; however, this conception was endorsed by only 20% of the students in our sample, with only 2.78% of students citing this reason for multiple resource access uniquely. At the same time, while Barzilai and Zohar (2012) found between 15% and 36% of students in their sample to consider gathering multiple perspectives to be the purpose of multiple resource access, this conception was among the most commonly cited in our study, endorsed by 59.72% of the sample. Accessing multiple resources to establish trustworthiness and for corroboration were similarly commonly cited conceptualizations across both studies.

While these results may be explained in a variety of ways, we considered these differences in students' conceptions of reasons for multiple resource access to potentially be developmental in nature. In particular, Perry (1970), examining the epistemic development of university students, found students early in their college careers to move from holding *dualistic* (i.e., considering knowledge to come from authority and to be objectively correct) to more *relativistic* (i.e., considering knowledge to be subjective) beliefs. Students in our sample were primarily freshmen and sophomores (i.e., first-year and second-year university students), with these students' transitioning to holding more relativistic beliefs potentially reflected in the conceptions of reasons for multiple resource access that they cited. In particular, this transition to relativism may have been reflected by undergraduates in our sample considering the purpose of multiple resource access to be understanding a variety of perspectives. Further consistent with this relativistic perspective, a unique profile identified in our data was students conceptualizing the development of personal understanding to be the goal of multiple resource access, referred to by Perry (1970) as reflecting *commitment*. This conception was endorsed by 25% of the sample and was reflected in responses such as 'If I only read a source, I will believe what I read and can be biased based on what I read. However, by reading several sources I can make my own opinion about the issue'. This conception was not found in Barzilai and Zohar's (2012) data. This conception may reflect students' efforts to both understand a variety of perspectives and to make these personally meaningful. Such a conception seems consistent with students understanding knowledge as personally constructed, considered to be a hallmark of epistemic sophistication (Barzilai & Zohar, 2012).

An additional consideration in comparing our study to Barzilai and Zohar's (2012) work is the gender make-up of our respective samples. While Barzilai and Zohar's sample included 21 boys and 21 girls, our sample was 85% female. Given that prior research has

found gender differences in students' learning from multiple texts, with males reporting higher rates of Internet use but females reporting more text-processing-related strategy use (Bråten & Strømsø, 2006) and demonstrating improved multiple text task performance (Stang Lund et al., 2019), the role of gender in students' conceptions of reasons for multiple resource access needs to be further considered.

### Conceptions of reasons for multiple resource access and multiple resource access behaviours

In this study, we were interested not only in students' conceptions of multiple resource access but also in the extent to which these translated into resource access behaviours, as captured via log data during task completion. In examining log data, we first found evidence for the newly introduced multiple resource use construct of *behavioural engagement*. Behavioural engagement, as defined by Bråten, Brante, and Strømsø (2018), refers to the *time, effort*, and *persistence* that students spend on task completion. In this study, in addition to examining the number of resources that students accessed and duration of resource access, as log indicators of such engagement, we specifically examined students' supplemental data access during MT-MR task completion. We considered supplemental data access to be a behavioural indicator of students' efforts to corroborate, validate, or further explore the information presented within the library resources provided. This interpretation was borne out by the association between students' conceptions of reasons for multiple resource access and supplemental data access behaviours. Comparing these findings to prior work, our results parallel those of Bråten et al. (2014), who found students' epistemic beliefs regarding the need for justification via multiple texts to predict both time devoted to text access and students' reports of deep-level strategy use. At the same time, we did not find conception-related differences in access time, suggesting the need for further examination of behavioural engagement as a construct, in future work.

### Conceptions of reasons for multiple resource access and task performance

Crucially, in this study, we found students' conceptions of the reasons for multiple resource access to be associated with task performance. In particular, students considering the purpose of multiple resource access to be corroborating and evaluating information were disproportionately likely to compose written responses reflecting documents models of multiple resources. Such documents models are notable because they include both integration (i.e., connection formation across resources) and citation use, allowing conflicting information presented across resources to be juxtaposed and evaluated. Indeed, these dual components of documents model construction were reflected in the conceptions of reasons for multiple resource access that students introduced. That is, students holding corroboration and evaluation-focused conceptions identified the purpose of multiple resource access to be both comparing information across texts, fostering integration, and using such comparison in judging the quality and validity of different sources, associated with citation use. This association was particularly notable given that students have been found to struggle with documents model construction and integration when writing (Britt & Aglinskas, 2002; Du & List, 2020; List et al., 2019). These parallel findings from Wiley et al. (2020), who found that students who endorsed the belief that causal explanations in history are developed through evaluation and corroboration, rather than there being a singular and certain causal explanation,

included more causal concepts and corroborative statements in their writing, based on multiple textual and non-textual (i.e., a graph and a political cartoon) sources.

Interestingly, in this study, endorsing a multiplist conception of resource access (i.e., considering the purpose of multiple resource access to be gathering a variety of perspectives) was associated with separate representations model construction, in the written responses that students composed. These findings may suggest that appreciating multiple perspectives may not be sufficient for undergraduates to construct integrated understandings of complex topics; rather more deep-level processing, including corroboration and evaluation, may be required. However, the association between multiplist conceptions and learning outcomes requires further investigation, as Barzilai and Zohar's (2012) study had so few students belonging to this profile ($n = 3$) that these were excluded from analyses.

### Supplemental analyses

This study was among the first to include a video among the resources that students had available to access (see also Lee, 2021 who introduced undergraduates to a YouTube video and two accompanying texts; and Salmerón, Sampietro, & Delgado, 2020, who presented elementary school students with either three texts or three videos when learning about the benefits and limitations of bottled water). Prior work has largely only included static images (Wiley & Ash, 2005; Wineburg, 1991), alongside texts, in examining students' multimedia resource learning. At the same time, examining how students learn from videos alongside text is important not only because videos are increasingly common on the Internet but also because differences in strategic processing have been suggested when students view videos vis-à-vis read texts (Lee & List, 2019; List, 2018; List & Ballenger, 2019). Based on this initial examination of video use during multiple resource learning, some preliminary conclusions may be drawn. First, the video resource was the least accessed in the digital library, out of the six resources provided. Given the popularity of videos online, this may suggest either a textual preference when completing academic work or a contextual effect (e.g., students may have been hesitant to view the video in a group setting, as group administration was used in this study). Second, on average participants spent the least amount of time on viewing the video resource, as compared to reading; this is despite the video resource including more words, when transcribed, than the texts provided. This speaks to the nature of video as a modality which, in part, restricts students' pacing of information access (Ding & Marchionini, 1998). Moreover, as has been found in prior work (Lee & List, 2019; List, 2018; List & Ballenger, 2019), students seemed to watch the video only once, based on a comparison between average viewing time and video length, although more precise behavioural data are needed to understand students' specific navigation behaviours during video viewing. This third speculative conclusion would benefit from the collection of more precise eye-tracking data to capture students' engagement during reading and video viewing.

All-told, the contributions of this study are fourfold. First, we extend Barzilai and Zohar's (2012) investigation with sixth graders, to examine undergraduates' conceptions of reasons for multiple resource access. We find conceptions that both parallel those identified by Barzilai and Zohar (2012), as well as conceptions (i.e., accessing multiple resources to achieve personal understanding) uniquely emerging in this study. Second, we build on Barzilai and Zohar's analyses to demonstrate that students' conceptions of multiple resource access are related to both resource use behaviours (i.e., accessing of supplemental resources) and to writing performance (i.e., documents model vis-à-vis

separate representations model construction). Third, we examine patterns in undergraduates' resource use behaviours within a fairly unique informational context, a library allowing students to access texts or a video, along with supplemental data sources. Prior work has either required students to access both texts and a video (Lee, 2021) or has randomly assigned students to view multiple resources as either texts or videos (Salmerón et al., 2020). Although emergent, we consider the finding regarding students' more limited video access to be an interesting one. Finally, using the DMF as a guiding framework, we further demonstrate that this model can be used to characterize students' writing based on multiple resources, of various types.

### Limitations

Despite the strengths of this study, a number of limitations must be acknowledged. Principally, the conceptions of multiple resource access examined in this study were based on a study conducted with middle-school students in Israel. The sample examined in the present study differs in both culture and age, limiting the direct comparisons able to be drawn. In particular, students have been found to develop in their epistemic sophistication (and likely in their conceptions of reasons for multiple resource access) throughout high school and college (Wiley et al., 2020), suggesting the need to further interrogate differences in results found across our study and that of Barzilai and Zohar (2012). Moreover, the sample we used was predominantly female, limiting its generalizability to university-level students as-a-whole, since gender differences have been found in students' learning from multiple texts (Bråten & Strømsø, 2006). Such gender differences should be explored further, particularly as the directionality of findings has been mixed. For instance, Strømsø, Bråten, and Britt (2010) found males to perform better on a measure of intratextual, but not intertextual, integration, while Stang Lund et al. (2019) found girls to outperform boys on a measure of source-content integration.

Additionally, only a single controversial, social science topic was chosen for this study (i.e., increasing the federal minimum wage). Although we were purposeful in selecting this topic, the extent to which students would access and use different materials in a similar manner when learning about another topic (potentially in another domain) remains an open question. While we sought to contribute to prior work on multiple text, multiple resource learning, the task design used in this study differentially aligns with tasks used in prior work in a number of ways. For one, while Cromley et al. (2021) examined students' learning from illustrated documents using print resources, all materials were presented digitally in this study. Although this is consistent with much of prior work on learning from multiple texts (e.g., Cerdán & Vidal-Abarca, 2008; Sullivan & Puntambekar, 2019), processing differences when resources are presented in print vis-a-vis digitally require further investigation (Delgado, Vargas, Ackerman, & Salmerón, 2018; Peterson & Alexander, 2020). More generally, the literature on learning from multiple representations has most often included diagrammatic representations in science (Ainsworth, 2006); less is known about how the strategies identified in this prior work may apply to learning from video, as students were asked to do in this study. Moreover, the video was the only truly multimedia resource introduced in the digital library, with the majority of resources that students had access to constituting only texts or data visualizations. Data visualizations, as supplemental data sources, were used only to a limited extent by students in this study. In part, this may be because the data visualizations introduced were presented as distinct sources of information (i.e., with distinct attributional features, like author), rather than embedded alongside text, violating

Mayer's principle of contiguity (Mayer & Fiorella, 2014; Moreno & Mayer, 1999). As such, consistent with prior work on students' learning from multiple representations (Richter, Scheiter, & Eitel, 2016; Scheiter & Eitel, 2015), embedding data visualizations in text and referring to these explicitly is an important direction for future work. More generally, future work on MT-MR learning should further expand the repertoire of resources provided to learners and the ecological validity of the tasks used. For instance, although a time limit was not imposed for this study, students may nevertheless have felt compelled to finish the study within 1 hr.

### Conclusion

In this study, we examine students' conceptions of reasons for multiple resource access and associate these with students' resource access behaviours and task performance during a MT-MR learning task. We have four key findings. First, confirming prior work, discernable patterns in students' conceptions of reasons for multiple resource access could be identified. Second, students who conceptualized the purpose of multiple resource access to be corroborating or evaluating information had increased supplemental resource access. We considered such supplemental resource access to reflect deep-level strategy use, or students' engagement in corroboration or inter-resource elaboration. Third, students holding corroboration- and evaluation-related conceptions were also more likely to compose written responses reflecting documents model construction and to include more integration when writing. Finally, in a novel investigation examining students' learning from video, alongside texts, insights into the nature of students' multimedia use during MT-MR task completion are provided.

## Conflicts of interest

All authors declare no conflict of interest.

## Author contributions

Hye Yeon Lee (Conceptualization; Data curation; Formal analysis; Methodology; Writing – original draft; Writing – review & editing) Hongcui Du (Conceptualization; Data curation; Formal analysis; Methodology; Writing – original draft; Writing – review & editing) Eunseo Lee (Conceptualization; Data curation; Formal analysis; Methodology; Writing – original draft; Writing – review & editing) Alexandra List (Conceptualization; Data curation; Formal analysis; Methodology; Writing – original draft; Writing – review & editing) Gala Campos (Conceptualization; Data curation; Formal analysis; Methodology; Writing – original draft; Writing – review & editing).

## Data availability statement

Data supporting results presented in this manuscript are available by request.

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## APPENDIX A:

### Performance for the full sample

This study was initially carried out to determine if students' academic writing based on multiple resources could be improved via two pre-writing activities (i.e., diagramming or planning key points) or by prompting students to revise their writing. This resulted in a total of four conditions examined, including (1) a control group ($n$ = 45, 33.58%), (2) a group asked to diagram the connections across texts, prior to writing ($n$ = 37, 27.61%), (3) a group asked to identify main points, prior to composing a research report ($n$ = 23, 17.16%), and (4) a group asked to self-evaluate their performance, after writing, and provided with the opportunity to revise their research report ($n$ = 27, 20.15%), accordingly.

The experimental manipulations in this study were not successful and, in fact, the diagram condition resulted in lower student performance. We are currently exploring why this may be in a follow-up study (e.g., we suspect a fatigue effect). Although the experimental manipulation was not successful, we nevertheless considered the data

collected to merit analysis. Therefore, the analyses in the main body of this manuscript only examine results from two of the conditions (i.e., the control group and the revision group, prior to their revision process). These two conditions may be considered the 'business as usual' conditions, wherein students were asked to read and write about a set of resources, without completing any pre-writing activities. Nevertheless, results for all four conditions are presented here.

### Participants

Participants were 134 undergraduate students at a large university in the Northeastern United States (age: $M$ = 18.91, $SD$ = 2.04). The majority of the sample was female (85.38%, $n$ = 111; male: 14.61%, $n$ = 19) and White (90.00%, $n$ = 117). Other students participating in the study identified as Asian (5.38%, $n$ = 7), Latino/Hispanic (3.07%, $n$ = 4), and Black/African American (1.53%, $n$ = 2). The sample represented a variety of education-related majors and the majority of students were freshmen (61.07%, $n$ = 80). Four students did not provide demographic information, and percentages are computed based on those students reporting demographic information.

### Methods

Methods for the full sample were identical to those described in the body of the paper, aside from target manipulations. In the diagram pre-writing condition, after students had indicated that they had enough information from the digital library to compose a written response, students were directed to a diagram page. Specifically, students were asked to: *create a diagram or a visual representation of all of the texts and how they relate to each other*. Students were then able to use the diagrams that they created during writing, with the hope that these would foster integration. Students in the planning condition were asked to *identify the main points or issues that a policy maker needs to understand when deciding whether or not to support increasing the federal minimum wage*.

Students in the revision condition wrote a research report directly after accessing library resources, as did students in control group. However, students in the revision condition, after submitting their written response were asked to rate this response, using a letter grade system from A to F, and were provided with the opportunity to revise their writing. Once students had assigned a letter grade to their responses, they were presented with the research report that they had composed initially and an additional text box, allowing them the opportunity to revise their response as needed. The specific instructions that students received were as follows: *Think about your self-evaluation and the letter grade you assigned to your research report. You now have the opportunity to revise or improve your research report*.

Only five students' responses (18.52%) were revised to a sufficient extent so as to merit a different score for multiple resource model construction or for integration or citation. Students' original responses, without revision, were analysed in the main body of this paper. This Appendix includes scores for students' revised responses in all analyses.

The three individual difference measures examined in this study (i.e., prior knowledge, interest, and attitude certainty), did not differ in association with experimental condition (prior knowledge: $p$ = .67; interest: $p$ = .41; attitude certainty: $p$ = .51).

### Results

Results are presented in two parts. First, we examine students' conceptions of reasons for multiple resource access and multiple resource access behaviours, across task conditions. These were not expected to differ as all students had the same experience of using the digital library with only their process of research report writing manipulated. Second, we examined all of our outcome measures of interest across conditions; here, experimental differences were possible.

### Conceptions of reasons for multiple resource access

A chi-squared test of association examined whether students' conceptions of reasons for multiple resource access were associated with task condition; however, no significant association was identified, $p = .28$.

### Process of multiple resource use

Four processing-related indicators of multiple resource access were examined across task conditions (i.e., number of resources initially accessed, time on resource access, percent of resources for which supplemental data were accessed, and time on supplemental data access). Four ANOVAs were conducted. First, the number of resources that students accessed were found to differ across conditions, $F(3, 128) = 2.75, p < .05, \eta^2 = .06$. *Post-hoc* analyses using Tukey's HSD determined that the only significant difference was that students assigned to the diagram condition ($M = 3.78, SD = 1.86$) accessed significantly fewer resources that students in the control group ($M = 4.64, SD = 1.19$), $p < .05$.

Moreover, the four conditions differed significantly in the amount of time that they devoted to supplemental data access, $F(3, 131) = 4.97, p < .01, \eta^2 = .10$. *Post-hoc* analyses using Tukey's HSD determined that students in the revision condition accessed supplemental data for significantly longer ($M = 1.79, SD = 2.28$) than students in both the planning ($M = 0.65, SD = 1.10$) and diagram ($M = 0.35, SD = 0.54$) conditions, $p$s $< .05$.

No significant differences across conditions were identified in students' total time on resource access ($p = .09$) nor in the percent of resources for which supplemental data were accessed ($p = .22$).

### Performance

Finally, we examined whether the four experimental conditions differed on various writing-based and objective indicators of multiple text integration and source recall. Writing performance was first examined holistically, with a chi-squared test used to determine whether there was a significant association between students' experimental condition and the multiple resource model reflected in their written responses. Then, ANOVAs were used to determine whether instances of integration and citation in students' written responses differed by condition.

First, the type of multiple resource model included in students' written responses was not significantly associated with experimental condition $p = .95$. However, significant differences in integration performance [$F(3, 128) = 2.96, p < .05, \eta^2 = .07$] and citation use [$F(3, 128) = 5.40, p < .01, \eta^2 = .11$] across conditions were identified. *Post-hoc* analyses using Tukey's HSD found that participants in the revision condition exhibited a significantly higher level of integration ($M = 1.30, SD = 1.59$) than participants in the

diagram condition ($M = 0.49$, $SD = 0.82$), $p < .05$. Further, participants in the control condition included significantly more citations in their responses ($M = 2.27$, $SD = 1.97$) than participants in the diagram condition ($M = 0.49$, $SD = 0.82$), $p = .001$.

### Discussion

The results identified in this study were unexpected. In particular, students assigned to the diagram condition seemed to have not only low multiple resource task performance, but deficits in multiple resource processing, as well, as compared to the other task conditions. This was unexpected as students in the diagram condition were provided with the same digital library and the same task instructions as students in any other condition. Therefore, replicating this study, potentially with a larger sample, represents an important direction for future work.