frontiers | Frontiers in Education

TYPE Brief Research Report
PUBLISHED 06 June 2024
DOI 10.3389/feduc.2024.1365202



OPEN ACCESS

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RECEIVED 03 January 2024
ACCEPTED 28 May 2024
PUBLISHED 06 June 2024

CITATION
Eidman L and Fiorella L (2024) Why don't students draw when learning from science texts?
*Front. Educ.* 9:1365202.
doi: 10.3389/feduc.2024.1365202



# Why don't students draw when learning from science texts?

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This study explored why students rarely create drawings when learning from science texts despite potential learning benefits. Undergraduates ($n = 114$) studied a 10-part text on the human respiratory system and took notes by choosing their own strategies (free choice group) or by choosing to create a drawing or write a verbal summary (forced choice group). Other students were instructed to create drawings (draw group) or write summaries (summarize group). All students then completed a series of post-tests. The forced choice group chose to draw significantly more frequently than the free choice group; however, both groups still overwhelmingly chose summarizing. Participants across all groups reported lower prior experience, lower expectancies for success, lower perceived value, and higher perceived cost of drawing compared to summarizing. Students' prior experiences and beliefs about drawing were also associated with how frequently they chose to draw, providing implications for future instructional interventions.

KEYWORDS

**generative learning, drawing, beliefs, strategies, comprehension**

## Introduction

Creating drawings can be an effective strategy for learning from science texts (Ainsworth and Scheiter, 2021). Reviews of prior research indicate that students generally benefit more from drawing than from only reading the text or using verbal strategies like summarizing (Fiorella and Zhang, 2018; Leutner and Schmeck, 2022). According to the cognitive model of drawing construction (Van Meter and Firetto, 2013), drawing requires learners to integrate the text with their existing knowledge to construct a coherent pictorial representation. For example, when reading about gas exchange during respiration, students must depict the appearance and relationships among the lungs, alveoli, capillaries, and the path of oxygen and carbon dioxide molecules. The process of drawing encourages learners to continually monitor and regulate their performance (Hellenbrand et al., 2019) and generate inferences (Fiorella, 2023). For example, an eye-tracking study by Hellenbrand et al. (2019) found that drawing encourages students to fixate longer and make more transitions between important ideas in the text and their drawings than when learning from instructor-provided visualizations. Furthermore, a study by Fiorella and Kuhlmann (2020) found that creating drawing encouraged students to generate more elaborative oral explanations of the learning material than when students explained without drawing, which in turn contributed to better long-term comprehension.

Most of prior research explicitly prompts students to draw and compares its effectiveness to alternative strategies such as summarizing (e.g., Leopold and Leutner, 2012; Bobek and Tversky, 2016). While valuable, this approach is limited because it does not reflect the types of strategies students use spontaneously when studying on their own

(Manalo et al., 2018). We know of only one existing study that has investigated students' spontaneous use of drawing when learning from science texts. Fiorella and Mayer (2017) asked undergraduates to read a 10-part text about the human respiratory system. After each part, students made notes however they wanted in blank boxes on paper. The researchers categorized students' notes as consisting of (a) verbal strategies—summarizing the text using lists or outlines—or (b) *visual* strategies—translating the text into a visual representation, such as an abstract knowledge map or a pictorial drawing. Students primarily relied on verbal strategies (87% of the time), but students who used visual strategies (39%) performed better on a subsequent comprehension test. Students created pictorial drawings only 11% of the time. This study suggests that students rarely create visual notes such as drawings when learning from science texts, but that those who did tended to exhibit better comprehension of the material. One possible explanation is that when students use verbal strategies to learn from text, they may choose to simply copy or paraphrase from the text rather to integrate it with their existing knowledge. In contrast, visual strategies such as drawing require students to use their existing knowledge to translate the text into a new type of representation, which may facilitate understanding. Of course, there may also be situations in which students choose to take notes that incorporate both visual and verbal elements, such as in preplanning for writing (e.g., Limpo and Alves, 2018).

Related research from mathematics education reveals a similar pattern of results. An early meta-analysis by Hembree (1992) reported a correlation of $r = 0.31$ between the spontaneous use of drawings and mathematics problem solving performance among secondary students. Despite this link, studies indicate many students do not choose to create drawings spontaneously during problem solving (e.g., De Bock et al., 1998; Uesaka and Manalo, 2012). De Bock et al. (1998) found that almost no students created drawings spontaneously if not given explicit instructions to draw. Uesaka and Manalo (2012) reported a higher frequency of spontaneous drawing (38 to 70%, depending on the nature of the problem), yet many students still do not choose drawing without explicit prompting, even though it is beneficial.

Why don't students draw? Prior research on mathematics problem solving suggests one important factor is students' *strategy-based motivation* (Schukajlow et al., 2022). This work is grounded in expectancy-value theory (e.g., Eccles and Wigfield, 2002; Rosenzweig et al., 2019), which posits that motivation depends on students' expectancies for success, values (including intrinsic, attainment, and utility values), and perceived personal cost (e.g., time and effort required). Uesaka and colleagues (Uesaka et al., 2007; Uesaka and Manalo, 2012) found that students with higher expectancies for success, higher perceived value, and lower perceived personal cost for drawing were more likely to spontaneously draw during mathematics problem solving, and their tendency to draw supported higher problem-solving performance. A recent study by Schukajlow et al. (2022) similarly found that expectancies for success and cost (but not values) were associated with better drawing quality and problem-solving performance, though this study involved training students to draw rather than their spontaneous use of drawing. To date, no studies have examined the role of strategy-based motivation in students' use of drawing when learning from a science text. Understanding the factors that contribute to students' decision to draw is important for designing targeted interventions that promote greater spontaneous use of drawing (Manalo et al., 2018).

# The present study

In the present study, undergraduates studied a 10-part text on the human respiratory system and took notes by freely choosing their own strategies (free choice group) or by explicitly choosing to create a drawing or write a verbal summary (forced choice). Other students were explicitly prompted to create drawings (draw group) or write summaries (summarize group). All students then reported their prior use and strategy-based motivation for drawing and summarizing, and they completed post-tests assessing their understanding of the lesson.

The primary goal of the study was to explore factors that contribute to students' decision to draw while studying science texts. We tested five main hypotheses:

> *Hypothes*is 1: Students will choose to draw more frequently when they are explicitly given drawing as a choice (forced choice group) compared to when they are free to choose their own strategy (free choice group).
>
> *Hypothes*is 2: Across all groups, students will report less prior experience and lower strategy-based motivation for drawing compared to summarizing.
>
> *Hypothesis 3*: Among the free choice and forced choice groups, students' prior experience and strategy-based motivation for drawing will be associated with how frequently they choose to draw during learning.
>
> *Hypothesis 4*: The draw group will outperform the other groups on the post-test measures.
>
> *Hypothesis 5*: Among the free choice and forced choice groups, drawing frequency will be positively associated with post-test performance.

# Method

## Participants and design

Participants were 114 undergraduates recruited from a large university in the southeast United States, who received course credit for their participation. Due to data collection restrictions imposed by the COVID-19 pandemic, participants completed the study synchronously online via Zoom. The mean age was 19.6 ($SD = 1.4$), and there were 16 men and 98 women. Participants were assigned randomly to one of the four groups: free choice ($n = 28$); forced choice ($n = 29$), summarize ($n = 29$), or draw ($n = 28$). The groups did not significantly differ in age, $F(3, 113) = 0.17$, $p = 0.915$, or proportion of men and women, $\chi^2(3) = 4.10$, $p = 0.251$.

## Materials

### Prior knowledge and prior strategy use

The prior knowledge test consisted of six free-response questions assessing background information about the human respiratory system, e.g., "What are alveoli?" Participants received one point for each correct response based on an established rubric. The prior knowledge test was worth a total of 12 possible points, as some questions had multiple correct responses. Because the prior knowledge test required specific answers, one rater scored all responses, blind to experimental conditions. The prior strategy use survey consisted of two items asking participants to rate how often they use drawing or summarizing while studying, on a scale from (1) "never" to (5) "always."

### Text on human respiratory system

The text on the human respiratory system [adapted from Leopold and Mayer (2015)] consisted of approximately 800 words segmented into 10 paragraphs (see Supplementary materials).

### Learning activity prompts

For each part of the lesson, participants were prompted to use pen and blank sheets of paper to engage in a learning activity. The *draw* group was prompted to "draw a picture" of what they read, the *summarize* group was prompted to "write a summary" of what they read, the *forced choice* group was prompted to "draw a picture OR write a summary" of what they read, and the free choice group was prompted to "make notes" on what they read. All participants were asked to explicitly number their notes 1 to 10, corresponding to each part of the lesson. Before progressing to the next part of the lesson, participants responded to one question to check whether they followed the instructions.

To determine drawing frequency among the forced choice and free choice groups, we asked participants to take pictures of their notes during the learning phase and email them to the experimenter. A research assistant used the notes to code (a) whether the participant chose to create a drawing for at least one part of the lesson (yes or no); and (b) the total number of parts of the lesson for which they chose to create a drawing (ranging from 0 to 10). A drawing was defined as any attempt to depict the appearance of a physical structure or structures of the respiratory system, such as a picture of the lungs, heart, bronchial tubes, etc. Examples of student drawings are included in the Supplementary materials. As shown in the example student drawings, it was common for students to create drawings that also included some brief verbal notes, mainly as labeling key parts of the drawings. However, students rarely included elaborated verbal notes with their drawings, such as summary or explanation statements.

### Learning outcome measures

The post-tests [adapted from Fiorella and Mayer (2017)] consisted of an explanation test and a transfer test. The explanation test was one free-response question asking participants to explain how the human respiratory system works in detail. Participants received one point for each correct idea unit (out of 52 possible) in their explanation, e.g., "capillaries facilitate exchange of oxygen and carbon dioxide." The transfer test consisted of five free-response questions ($\alpha = 0.51$) asking participants to apply their knowledge of the human respiratory system to new situations, e.g., "Suppose there is oxygen in the lungs, but the cells in the body do not get enough oxygen to make energy. What could have caused this problem?" For this question, correct responses included: the heart is not pumping because it is too weak, and the alveoli are not sending enough oxygen to the capillaries. Participants received one point for each correct response; each question had between 4 and 7 acceptable responses.

Two research assistants scored the explanation and transfer tests for 30 participants, blind to experimental conditions. Inter-rater reliability was good (ICCs = 0.79), and so one rater scored all remaining responses.

### Strategy-based motivation questionnaire

The strategy-based motivation questionnaire [adapted from Schukajlow et al. (2022)] assessed students' motivational beliefs about learning strategies. All participants completed two versions of the questionnaire: one referring to drawing and one referring to summarizing. Each version contained 14 items; 3 items each targeted expectancies for success, intrinsic value, utility value, and cost; and two items targeted attainment value.[1] Students responded to each item on a 5-point Likert scale ranging from (1) completely untrue to (5) completely true. The full questionnaire is presented in the Supplementary materials.

## Procedure

Participants were assigned randomly to one of the four groups: free choice, forced choice, summarize, or draw. Participants completed the session individually over Zoom using a Qualtrics link provided by the experimenter. Prior to the study, participants were asked to have a pen and blank sheets of paper available to them for completing their respective learning activities.

First, participants completed a brief demographics survey (e.g., age, gender) and the prior knowledge test. Following the prior knowledge test, all participants received the same general instructions that they would study a 10-part lesson on the human respiratory system, engage in a learning activity, and then take a test of their understanding of the lesson. The lesson was presented sequentially on 10 separate pages in Qualtrics. For each part of the lesson, participants received specific instructions corresponding to their assigned learning activity. All participants used the pen and paper in front of them to complete their respective learning activities. Participants worked at their own pace but could not return to previous parts of the lesson.

After the learning phase, the experimenter asked participants to put away their notes for the testing phase of the experiment. Then participants completed the post-tests, prior strategy use survey, and the strategy-based motivation questionnaires at their own pace. At the end of the experiment, participants were asked to take pictures of the notes they took on paper during the learning phase and email them to the experimenter.

1 We originally planned for the questionnaire to contain 15 unique items (3 items per construct). However, due to an experimenter error, one of the items targeting attainment value was accidentally repeated for both the drawing and summarizing versions of the questionnaire. Therefore, we dropped the repeated item from the analysis, resulting in 14 unique items.

TABLE 1 Drawing frequency among free choice and forced choice groups.

| | Created drawing for at least 1 Part | Total parts containing a drawing (out of 10 possible) | |
|---|---|---|---|
| Group | % | *M* | *SD* |
| Free choice | 12% | 0.23 | 0.8 |
| Forced choice | 56%* | 1.64* | 1.8 |

*Significantly higher than free choice group at $p = 0.001$.

TABLE 2 Strategy-based motivation for drawing vs. summarizing collapsed across groups.

| | Strategy-based motivation for drawing | | Strategy-based motivation for summarizing | |
|---|---|---|---|---|
| Construct | *M* | SD | *M* | SD |
| Expectancies for success | 2.6* | 1.1 | 3.7 | 0.9 |
| Intrinsic value | 2.8* | 1.0 | 3.7 | 0.9 |
| Attainment value | 3.0* | 0.9 | 4.0 | 0.9 |
| Utility value | 3.2* | 0.9 | 4.1 | 0.8 |
| Cost | 3.4* | 0.9 | 3.0 | 0.9 |

*Significantly different from strategy-based motivation for summarizing at $p < 0.01$.

# Results

## Data screening and preliminary analyses

Fourteen participants were removed because they failed to send pictures of their notes to the experimenter, the quality of their pictures was too poor to interpret, or they did not follow their assigned strategy instructions. The remaining 100 participants were included in the analyses reported below.

Next, we tested whether the four groups significantly differed in their prior knowledge of the respiratory system or their prior use of drawing or summarizing. One-way analysis of variance (ANOVA) indicated no significant differences across groups in prior knowledge $F(3, 96) = 0.47$, $p = 0.707$, prior use of drawing, $F(3, 96) = 2.53$, $p = 0.062$, and prior use of summarizing, $F(3, 96) = 2.37$, $p = 0.075$. Participants across all groups reported greater prior use of summarizing compared to drawing, $t(99) = 9.21$, $p < 0.001$, $d = 0.92$.

## Drawing frequency among free choice and forced choice groups

Table 1 presents descriptive statistics for drawing frequency among the forced choice and free choice groups. Consistent with Hypothesis 1, a chi-squared test indicated that the forced choice group was far more likely to create a drawing for at least one part of the lesson, $\chi^2(1) = 11.34$, $p < 0.001$, Cramer's $V = 0.47$. Only 3 out of 26 participants (12%) in the free choice group created at least one drawing, compared to 14 out of 25 participants (56%) in the forced choice group. Next, we examined the total number of parts of the lesson (out of 10) for which students in the free choice and forced choice groups created drawings. Levene's test indicated unequal variances between groups, so we used an independent samples t-test without assuming equal variances. Consistent with Hypothesis 1, the forced choice created significantly more total drawings than the free choice group, $t(33.4) = 3.62$, $p < 0.001$, $d = 1.03$. Nonetheless, the forced choice group still chose to draw only 16% of the time (i.e., 1.6 times out of 10) and thus chose summarizing 84% of the time.

## Strategy-based motivation for drawing vs. summarizing

Next, we examined participants' strategy-based motivation for summarizing and drawing. We used a mixed 4 × 2 ANOVA with group as the between-subjects factor, learning strategy as the within-subjects factor (i.e., motivation for drawing or motivation for summarizing), and each of the five strategy-based motivation constructs as dependent measures: expectancies for success, intrinsic value, attainment value, utility value, and cost.

Table 2 presents the means and standard deviations for strategy-based motivation for summarizing and drawing collapsed across the four groups. Consistent with Hypothesis 2, there were large significant main effects of learning strategy for all five strategy-based motivation constructs: expectancies for success, $F(1, 96) = 82.80$, $p < 0.001$, partial $\eta^2 = 0.46$, intrinsic value, $F(1, 96) = 47.43$, $p < 0.001$, partial $\eta^2 = 0.33$, attainment value, $F(1, 96) = 59.55$, $p < 0.001$, partial $\eta^2 = 0.38$, utility value, $F(1, 96) = 62.94$, $p < 0.001$, partial $\eta^2 = 0.40$, and cost, $F(1, 96) = 9.99$, $p = 0.002$, partial $\eta^2 = 0.09$. Specifically, participants reported significantly lower expectancies for success, intrinsic value, attainment value, and utility value, and significantly higher cost for drawing compared to summarizing.

The main effects were partly qualified by unexpected significant group by learning strategy interactions for all five constructs ($F$'s $> 3.30$, $p$'s $< 0.05$). The pattern suggested that the interactions were driven by the summary group, which appeared to exhibit either a smaller difference between their beliefs about

TABLE 3 Post-test performance across groups.

| | Explanation test | | Transfer test | |
|---|---|---|---|---|
| Group | *M* | SD | *M* | SD |
| Summarize | 12.5 | 6.6 | 2.4 | 1.5 |
| Draw | 13.1 | 7.0 | 1.9 | 1.4 |
| Free choice | 12.2 | 7.3 | 2.4 | 1.3 |
| Forced choice | 12.7 | 7.0 | 2.4 | 1.5 |

drawing and their beliefs about summarizing. Follow-up paired-samples *t*-tests indicated the summary group reported significantly higher expectancies for success, $t\ (26) = 2.09$, $p = 0.023$, $d = 0.40$, attainment value, $t\ (26) = 2.11$, $p = 0.023$, $d = 0.41$, and utility value, $t\ (26) = 1.91$, $p = 0.034$, $d = 0.37$, for summarizing over drawing, but they showed no significant differences for intrinsic value, $t\ (26) = 0.09$, $p = 0.929$, or cost, $t\ (26) = 0.45$, $p = 0.330$. This suggests being instructed to summarize during the learning phase may have attenuated the beliefs of those in the summary group.

## Correlates of drawing frequency

Next, we examined whether students' prior use of drawing and their strategy-based motivation for drawing correlated with how frequently students chose to draw. Because drawing frequency was so low for the free choice group, this analysis only includes the forced choice group. The correlation coefficients were not statistically significant, likely due to restricted range and sample size, but all were in the expected direction: prior use of drawing ($r = 0.37$), expectancies for success ($r = 0.19$), intrinsic value ($r = 0.29$), attainment value ($r = 0.17$), utility value ($r = 0.18$) and perceived cost ($r = -0.23$). This pattern suggests participants in the forced choice group were more likely to choose to draw if they had more prior experience drawing, and if they perceived higher expectancies for success, higher values, and lower cost of drawing, consistent with Hypothesis 3.

## Post-test performance

Table 3 presents descriptive statistics for performance on the post-tests across the four groups. One-way ANOVA indicated no significant differences across groups on the explanation test, $F\ (3, 96) = 0.07$, $p = 0.978$, or the transfer test, $F\ (3, 96) = 0.75$, $p = 0.523$. This finding does not support Hypothesis 4. Next, we explored the relationship between drawing frequency and post-test performance among the forced choice group. There were small-to-moderate but non-significant correlations among drawing frequency and explanation test ($r = 0.33$) and transfer test ($r = 0.21$) performance, providing partial support for Hypothesis 5.

# Discussion

The findings provide insight into the factors contributing to students' use (or disuse) of drawing while learning from science texts. First, we confirmed that students across all groups reported greater prior use of summarizing than drawing. Second, when given the choice, students in the free choice and forced choice groups overwhelmingly chose to summarize rather than draw. Consistent with Hypothesis 1, students were more far more likely to chose to draw when the option of drawing was explicit (i.e., a forced choice between drawing and summarizing), but students still chose to summarize 84% of the time. This suggests students' low use of drawing reported in prior research (Fiorella and Mayer, 2017) is not merely explained by a lack of awareness that drawing was an option.

Consistent with Hypothesis 2, students reported lower strategy-based motivation for drawing compared to summarizing for all five constructs: expectancies for success, intrinsic value, attainment value, utility value, and cost. That is, students had lower expectations of success with drawing, perceived drawing as less valuable for supporting learning goals, and perceived higher costs of drawing in terms of the amount of time and effort it required. This pattern was unexpectedly weaker (but mostly still present) for the summary group, suggesting that being instructed to summarize may have attenuated their strategy-based motivation.[2] Consistent with Hypothesis 3, we found evidence that students with relatively more prior drawing experience and more favorable beliefs about drawing were more likely to choose to draw during learning. Of course, because drawing frequency was even lower than expected, the analysis was limited to the forced choice group, which still exhibited low drawing frequency. In fact, nearly half (44%) of participants in the forced choice group did not choose to draw even one time across the 10 parts of the lesson.

We did not find support for Hypothesis 4 that the draw group would outperform the other groups on the post-test measures. This is inconsistent with prior research comparing drawing and summarizing (Leopold and Leutner, 2012; Bobek and Tversky, 2016), though not all prior studies report benefits of drawing (see Fiorella and Zhang, 2018; Leutner and Schmeck, 2022). Drawing can sometimes create extraneous load in which students focus their attention on the mechanics of drawing or the aesthetics of their drawings (e.g., Leopold et al., 2013; Fiorella et al., 2024) instead of on their understanding of the conceptual information presented in the text. Students may also struggle to produce conceptually accurate drawings, which prior research suggests is important for supporting subsequent learning outcomes, including

2 Participants completed the strategy-based motivation questionnaires at the end of the experiment. This was done because we did not want the questionnaires to affect the strategies students subsequently chose during learning. It is possible that their experience during learning affected their responses on the strategy-based questionnaire; however, the same general pattern was consistent across groups.

performance on verbal comprehension and transfer tests (e.g., Schwamborn et al., 2010; Zhang and Fiorella, 2019). Thus, the null finding from the present study is important because it highlights the fact that generative learning activities like drawing are not always effective. Similarly, we found very limited evidence for Hypothesis 5 that drawing frequency was associated with better post-test performance. Again, this may have been in due to difficulties students had creating accurate drawings, as well as to very limited range in drawing frequency among the free choice and forced choice groups.

Taken together, the results complement related research on the use of drawing during mathematics problem solving (e.g., Uesaka and Manalo, 2012; Schukajlow et al., 2022). Students often do not draw spontaneously when learning from science texts, likely due to relatively low prior experience and strategy-based motivation for drawing compared to a more commonly used strategy like summarizing. Although prior research has linked drawing to better learning outcomes, we did not observe this relationship in the present study.

## Limitations and future directions

One limitation of the study is that it was conducted online via Zoom due to data collection restrictions imposed by the COVID-19 pandemic. This limited our sample size and the authenticity of the learning context. For example, motivation among participants might have been particularly low in this setting, possibly exaggerating students' tendencies to use more familiar or relatively passive learning strategies. Furthermore, the online setting made it difficult to control the implementation of the strategy instructions. Although we included checks in our experimental design, and we collected pictures of the notes they created during learning, these steps still had limitations. For example, while we could determine how frequently students attempted to create a drawing, it was not possible to clearly determine the accuracy and comprehensiveness of each of their drawings. Based on prior research (e.g., Schwamborn et al., 2010; Zhang and Fiorella, 2019), it is possible that the draw group did not outperform the other conditions on the post-test because they struggled to generate accurate drawings. However, this explanation is speculative because we could not directly confirm students' drawing accuracy with the current data. Future research should replicate and extend these findings within a more controlled setting.

An alternative explanation is that the drawing group might have been disadvantaged by the nature of the outcome measures. The explanation and transfer tests required learners to explain concepts verbally rather than depict ideas visually. Although prior research suggests drawing accuracy generally predicts performance on verbal measures of comprehension (Schwamborn et al., 2010; Zhang and Fiorella, 2019), it is possible that any benefits of drawing would be more pronounced on assessments that explicitly require students to draw the structures of the respiratory system. Thus, future research should incorporate a wider range of assessment types to better isolate any unique benefits of drawing compared to other strategies like summarizing.

Another limitation is that drawing frequency was even lower than expected among the free choice and forced choice groups. Of course, this was partly the purpose of the experiment, but the very low drawing frequency (particularly among the free choice group) created a restriction of range (i.e., many students did not draw at all), making it difficult to examine relationships among drawing frequency, beliefs about drawing, and learning outcomes. Future research should investigate other types of note-taking instructions and/or include larger samples to more closely investigate individual differences among the relatively small subset of students who choose to draw spontaneously. Specifically, one criticism of the present study is that instructing students in the free choice group to "make notes" may have biased them to take verbal notes. We acknowledge that students may have interpreted the instructions this way, though this also reinforces the idea that students do not typically consider drawing and other forms of visualizing as forms of "making notes." It is possible that other types of instructions may have helped students be more open to drawing, but students in the present study still rarely chose to draw even when given an explicit forced choice between summarizing and drawing.

Future research should also consider students' use of drawing with other types of learning materials. The present study provided students with a science text that did not include any provided visuals. This was intentional because existing research suggests one of the key benefits of drawing is that it requires students to use their existing knowledge to generate their own visual representation rather than rely on a provided visual (e.g., Leutner and Schmeck, 2022; Fiorella, 2023). Nonetheless, in many learning contexts (e.g., watching instructional videos, consulting Internet resources), students are commonly provided with instructional visuals, and the presence of such visuals may influence whether and how students choose to draw. A related consideration is the nature of the content described in the text. The potential utility of drawing may be limited to learning about physical systems like the human respiratory system in the present study. Other visualizing strategies, such as creating matrix tables, graphic organizers, or concepts maps may be more appropriate for depicting more abstract ideas (e.g., Adesope et al., 2022).

Finally, future research should examine interventions designed to increase students' motivation to draw. The results from the present study suggest that a lack of prior experience and confidence drawing may be important factors driving students' strategy-based motivation. Students might be more willing to draw if they viewed examples or instructor modeling of how to draw and/or opportunities for scaffolded practice and feedback drawing. Some of these guidance methods have already been examined in prior research (e.g., see Fiorella and Zhang, 2018), but researchers have yet to systematically examine how explicit instruction on how to draw affects students' beliefs about drawing and their subsequent spontaneous use of drawing in new learning situations. Overall, the present study suggests students are unlikely to use drawing if they do not already have positive beliefs about their ability to draw effectively and its potential value as a learning tool.

## Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

## Ethics statement

The studies involving humans were approved by Institutional Review Board, University of Georgia. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

## Author contributions

LE: Writing – review & editing, Conceptualization, Investigation, Methodology. LF: Writing – original draft, Writing – review & editing, Funding acquisition, Methodology, Resources, Supervision.

## Funding

The author(s) declare that financial support was received for the research, authorship, and/or publication of this article. This research was supported by grants from the National Science Foundation awarded to LF (1955348 and 2055117).

## Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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## Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2024.1365202/full#supplementary-material

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