Educational Psychology Review (2024) 36:78
https://doi.org/10.1007/s10648-024-09914-w

META-ANALYSIS

Typed Versus Handwritten Lecture Notes and College Student Achievement: A Meta-Analysis

Abraham E. Flanigan[1] · Jordan Wheeler[2] · Tiphaine Colliot[3] · Junrong Lu[2] · Kenneth A. Kiewra[2]

Accepted: 29 June 2024 / Published online: 12 July 2024

Abstract

Many college students prefer to type their lecture notes rather than write them by hand. As a result, the number of experimental and quasi-experimental studies comparing these two note-taking mediums has flourished over the past decade. The present meta-analytic research sought to uncover trends in the existing studies comparing achievement and note-taking outcomes among college students. Results from 24 separate studies across 21 articles revealed that taking and reviewing handwritten notes leads to higher achievement (Hedges' $g = 0.248$; $p < 0.001$), even though typing notes benefits note-taking volume (Hedges' $g = 0.919$; $p < 0.001$), among college students. Furthermore, our binomial effect size display shows that taking handwritten lecture notes is expected to produce higher course grades than typing notes among college students. We conclude that handwritten notes are more useful for studying and committing to memory than typed notes, ultimately contributing to higher achievement for college students.

Keywords Lecture note-taking · Note-taking medium · Laptop versus longhand note-taking · Typed versus handwritten note-taking

Introduction

Taking lecture notes is among college students' most common learning strategies (Morehead et al., 2019b; Witherby & Tauber, 2019). Lecture notes serve two primary functions for students: encoding and external storage (Di Vesta & Gray, 1972; Kiewra,

✉ Abraham E. Flanigan
aflanigan@georgiasouthern.edu

[1] College of Education, Georgia Southern University, Statesboro, GA 30460, USA

[2] Department of Educational Psychology, University of Nebraska-Lincoln, Lincoln, NE, USA

[3] Department of Cognitive Psychology, Université de Poitiers, Poitiers, France

1985). The process of taking notes, versus listening without note-taking, aids lecture learning (i.e., the encoding function) (Di Vesta & Gray, 1972; Kiewra, 1985). The product of taking notes is an external document of text and images that can be reviewed any time following the lecture to better commit noted information to memory (i.e., the external storage function) (Di Vesta & Gray, 1972; Kiewra et al., 1991). Although both functions aid learning, when the encoding and external-storage functions are compared, students who take and review their notes (external-storage function) tend to achieve more than those who take but do not review notes (encoding function) (Armbruster, 2000; Kiewra, 1985; Knight & McKelvie, 1986; Luo et al., 2018). Such findings indicate that the primary benefit of taking lecture notes emerges from the review of notes.

College students seem to inherently understand note-taking's beneficial functions, as most take and review lecture notes as their primary test preparation strategy (Blasiman et al., 2017; Morehead et al., 2019b; Witherby & Tauber, 2019). Traditionally, students have taken notes using the longhand, paper–pencil method. However, many college students now prefer to type lecture notes on laptop computers (Morehead et al., 2019b). Presently, 25–50% of college students prefer typing lecture notes over writing notes longhand (Crumb et al., 2022; Morehead et al., 2019b; Shell et al., 2021). Many do so, believing that typing notes makes it easier for them to learn (Morehead et al., 2019b). The growing popularity among college students of typing lecture notes has led to the "laptop versus longhand debate" (Mitchell & Zheng, 2019) and has spurred research into whether typing or handwriting notes is better for learning.

Several experiments (e.g., Bui et al., 2012; Crumb et al., 2022; Flanigan & Titsworth, 2020) and meta-analyses (e.g., Allen et al., 2020; Morehead et al., 2019a; Urry et al., 2021; Voyer et al., 2022) have compared the typing and longhand note-taking mediums in terms of note-taking and achievement outcomes, yet some scholars have concluded that it is too early to declare one note-taking medium better than the other (e.g., Morehead et al., 2019a; Urry et al., 2021; Voyer et al., 2022), largely due to inconsistent note-taking and achievement outcomes stemming from typing or writing lecture notes. For instance, Mueller and Oppenheimer (2014) found that students who typed notes tended to record the lecturer's words in a verbatim fashion. Longhand note-takers, meanwhile, tended to record the lecturer's words in a paraphrased fashion. Mueller and Oppenheimer concluded that verbatim note-taking led to shallower information processing than paraphrased note-taking and that these note-taking differences were largely responsible for the achievement advantages resident among longhand note-takers. Yet, Morehead et al. (2019b) found no relationship between the degree of verbatim note-taking and test performance, leading those researchers to conclude that the greater amount of verbatim overlap in typed notes is inconsequential for learning. When such contradictions arise across studies, it seems reasonable to show caution and not tout one note-taking medium over the other.

Trends in Existing Literature

Tables 1 and 2 provide visual representations of the inconsistent findings across studies comparing the learning outcomes among college students who record typed or handwritten lecture notes. As shown in Table 1, the note-taking medium does

not produce consistent achievement differences when learning assessments occur immediately following a lecture, regardless of the type of learning assessed or whether participants review their notes prior to testing. A comparison of the "Typed advantage" versus "Handwritten advantage" columns in Table 1 reveals that more studies have found achievement advantages associated with recording handwritten notes over typing notes. Yet, for practically all learning outcomes assessed, there are more studies that detected no achievement advantages for either note-taking medium. Table 2 shows similar patterns in studies using delayed learning assessments. Although more studies revealed handwritten advantages than typed advantages, there were studies that detected no achievement advantages for either note-taking medium.

Findings from Previous Meta-analyses

Inconsistent findings in the existing literature extend from individual studies overviewed in Tables 1 and 2 to wide-sweeping meta-analyses. Four known meta-analyses have uncovered mixed results regarding whether typing or writing lecture notes leads tohigher achievement. For instance, Lau (2022) compared the achievement of high school and college students across 36 experimental and quasi-experimental studies in 33 published and unpublished articles. Findings revealed a small positive effect on achievement—as measured by lecture posttest scores, course grades, and exam scores—associated with recording longhand notes. Similarly, Allen et al. (2020) found that typing lecture notes generally had a negative effect on achievement after reviewing the findings from 14 experimental, quasi-experimental, and survey-based studies. Yet, there is evidence that when notes are reviewed, the advantage of longhand note-taking goes away (Lau, 2022). Furthermore, other meta-analyses detected no discernible effect of the note-taking medium on achievement. The meta-analysis conducted by Voyer et al. (2022), based on the note-taking experiences of secondary and postsecondary students across 39 experimental studies, found that the note-taking medium has little influence on achievement. Moreover, Urry et al., (2021, p. 338) stated that students "may not need to ditch the laptop just yet" after finding that recording longhand notes had a negligible impact on total lecture quiz scores and on quiz items designed to assess factual recall and concept recognition in their review of eight replication studies of Mueller and Oppenheimer's (2014) seminal work.

It is plausible that inconsistent findings across these four meta-analyses stem from study inclusion differences. Although three of these meta-analyses included studies of secondary students (Lau, 2022; Urry et al., 2021; Voyer et al., 2022), one did not (Allen et al., 2020). Moreover, graduate students and online learners were also represented in the studies analyzed by Lau (2022) but were not represented in the other meta-analyses. Additionally, some meta-analyses included survey-based studies (e.g., Allen et al., 2020), whereas others excluded survey research (e.g., Lau, 2022; Voyer et al., 2022). Inconsistencies among the meta-analyses might also stem from the types of achievement measured. Some calculated achievement using course grades and exam scores (e.g., Allen et al., 2020), whereas others used lecture

Table 1 Note-taking medium achievement outcomes on immediate tests without and with review

	No review			Review allowed		
	Typed advantage	Handwritten advantage	No advantage	Typed advantage	Handwritten advantage	No advantage
Total posttest score	Bui et al. (2012) and Schoen (2012)	Duran and Frederick (2013)	Beck et al. (2014) Eason (2017), Gür (2021), Luo et al. (2018), Shell et al. (2021), Wei et al. (2014), and Wilson et al. (2023)		Kodaira (2017) and Luo et al. (2018)	Flanigan and Titsworth (2020) and Kirkland (2016)
Fact item score		Mitchell and Zheng (2019) and Morehead et al. (2019a) (Experiment 1)	Mueller and Oppenheimer (2014) (Experiment 1), Mueller and Oppenheimer (2014) (Experiment 2), Urry et al. (2021), Wiechmann et al. (2022), and Wilson et al. (2023)		Kodaira (2017)	Flanigan and Titsworth (2020), Kirkland (2016), and Morehead et al. (2019a) (Experiment 2)
Concept item score		Mueller and Oppenheimer (2014) (Experiment 1) and Mueller and Oppenheimer (2014) (Experiment 2)	Mitchell and Zheng (2019), Morehead et al. (2019a) (Experiment 1), Urry et al. (2021), Wiechmann et al. (2022), and Wilson et al. (2023)		Kodaira (2017)	Flanigan and Titsworth (2020), Kirkland (2016), and Morehead et al. (2019a) (Experiment 2)
Selected-response item score		Blankenship (2016), Chiaraluce (2019), and Duran and Frederick (2013)	Beck et al. (2014), Shell et al. (2021), and Wei et al. (2014)			Flanigan and Titsworth (2020) and Kirkland (2016)

Table 1 (continued)

	No review			Review allowed		
	Typed advantage	Handwritten advantage	No advantage	Typed advantage	Handwritten advantage	No advantage
Written-response item score	Bui et al. (2012)	Mitchell and Zheng (2019), Morehead et al. (2019a) (Experiment 1), Mueller and Oppenheimer (2014 (Experiment 1), and Mueller and Oppenheimer (2014) (Experiment 2)	Blankenship (2016), Mitchell and Zheng (2019), Morehead et al. (2019a) (Experiment 1), Mueller and Oppenheimer (2014) (Experiment 1), Mueller and Oppenheimer (2014) (Experiment 2), Urry et al. (2021), Wiechmann et al. (2022), and Wilson et al., (2023			Morehead et al. (2019a) (Experiment 2)
Free recall item score	Bui et al. (2012)					

Table 2 Note-taking medium achievement outcomes on delayed tests without and with review

	No review			Review allowed		
	Typed advantage	Handwritten advantage	No advantage	Typed advantage	Handwritten advantage	No advantage
Total posttest score		Gür (2021)	Beck et al. (2014), Eason (2017), and Wilson et al. (2023)		Crumb et al. (2022) and Flanigan et al. (2023)	Quade (1996) and Shi et al. (2022)
Fact item score			Morehead et al. (2019a) (Experiment 1) and Wilson et al. (2023)		Flanigan et al. (2023) and Mueller and Oppenheimer (2014) (Experiment 3)	Crumb et al. (2022), Morehead et al. (2019a) (Experiment 2), and Quade (1996)
Concept learning score			Artz et al. (2020), Morehead et al. (2019a) (Experiment 1), and Wilson et al. (2023)		Crumb et al. (2022), Flanigan et al. (2023), and Mueller and Oppenheimer (2014) (Experiment 3)	Morehead et al. (2019a) (Experiment 2) and Quade (1996)
Selected-response item score			Artz et al. (2020), Beck et al. (2014), and Morehead et al. (2019a) (Experiment 1)		Flanigan et al. (2023)	Quade (1996)
Written-response item score			Wilson et al. (2023)		Crumb et al. (2022) and Mueller and Oppenheimer (2014) (Experiment 3)	Crumb et al. (2022), Morehead et al. (2019a) (Experiment 2), and Quade (1996)
Free recall item score						
Course quizzes/exams			Artz et al. (2020)		Pettit-O'Malley et al. (2017)	Pettit-O'Malley et al. (2017)

posttests (e.g., Urry et al., 2021). Such differences in inclusions and outcomes perhaps led to the different findings and conclusions about the relative achievement advantages of typing versus writing lecture notes.

The Present Research

The present research aims to untangle the existing literature and offer a more definitive account as to whether typing or writing notes better aids note-taking and achievement among college students. To this end, two separate meta-analyses were conducted: one for the note-taking medium's achievement effect and one for the note-taking medium's note-taking effect.

Studies Included in the Meta-analyses

The following subsections describe the inclusion criteria and search procedures used to locate relevant studies for the meta-analyses.

Inclusion Criteria

Although no restrictions were placed on the year of publication, country of origin, or field of study when screening studies, they had to meet six screening criteria for inclusion in the meta-analyses. Published and unpublished studies meeting these criteria were included. First, the studies had to compare how recording typed (e.g., laptop, desktop computer, tablet) versus handwritten lecture notes affected note-taking and/or achievement outcomes. Acceptable achievement outcomes were scores on immediate or delayed lecture-related posttests, course exam or quiz grades, and final course grades. Second, participants needed to be college students. Third, the instructional materials must have been either a live classroom lecture or a pre-recorded video lecture in a laboratory setting. Studies including remote learners were not included. Fourth, only experimental and quasi-experimental studies were included. No survey-based or observational studies were included. Fifth, lectures needed to pertain to college-level topics; studies whose instruction focused on list learning or other non-meaningful learning outcomes (e.g., Aragón-Mendizábal et al., 2016) were excluded. Sixth, studies needed to have measured a direct effect between handwritten and typed note-taking and provided adequate information and data about the measured effects, such as test statistics that compare handwritten versus typed note-taking or descriptive statistics that included information such as sample sizes, mean scores, and standard deviations for both note-medium groups.

Search Procedures

Studies were identified in two ways. First, relevant studies were located through repeated searches in the Academic Search Premier, ERIC, Google Scholar, ProQuest Dissertations and Theses, and PsychINFO databases from January 2023 through April 2023 and again in January 2024 while the original version of this manuscript

was revised. Search terms used to identify relevant articles were: laptop versus longhand note taking; typed versus handwritten lecture notes; paper versus computer note taking; computers and lecture notes; and note-taking method and learning. The search continued until no new articles were found. This search process resulted in the identification of 20 relevant studies across 17 articles. Second, the reference lists of existing meta-analyses (i.e., Allen et al., 2020; Lau, 2022; Urry et al., 2021; Voyer et al., 2022) were combed to search for relevant studies missed while searching databases. This reference list search resulted in the identification of 4 more relevant studies across 4 articles. In total, our search procedures identified 21 articles containing 24 quasi-experimental ($n=2$) and experimental ($n=22$) studies that included 3005 participants. Both published ($n=18$) and unpublished ($n=6$) studies were included in the analysis to reduce the potential for publication bias to influence our findings. Among these 24 studies, 20 were conducted as original studies, and four were replications of Mueller and Oppenheimer's (2014) work. Ultimately, our meta-analysis of the note-taking medium's achievement effect included a total sample of $k=49$ effect sizes across all 24 different studies. Our meta-analysis of the note-taking medium's note-taking effect included a total sample of $k=15$ effect sizes from 12 different studies. Table 3 overviews the 24 studies included in our analyses.

Moderator Variable Collected

Multiple variables were collected from each study included in our analysis, including moderator variables and effect sizes. The moderator variables included assessment timing, review, and achievement type. The assessment timing moderator categorized studies as immediate ($k=29$) or delayed ($k=20$), where immediate included any study that assessed achievement within an hour after the note-taking session and delayed included all other studies. The review moderator categorized studies into three groups: yes ($k=9$), no ($k=34$), or optional ($k=6$). "Yes" indicates that participants were provided a formal review period; "no" indicates that participants were not allowed to review notes; and "optional" indicates that a formal review period was not provided but that participants were not restricted from reviewing. The achievement-type moderator categorized studies into three types: total achievement ($k=22$), factual item achievement ($k=15$), and conceptual item achievement ($k=12$).

Coding Validity

To ensure the validity of coded variables and results, we independently processed the articles and recorded moderator variables and effects for each study.

Effect Size Measures

Because studies included in the meta-analysis used different measures for reporting the effects of handwritten versus typed notes on achievement and on the number of words and ideas recorded, all effects were first converted to a Cohen's d effect size measure. Specifically, when means and standard deviations of note-taking groups

Table 3 Summary of Studies Included in the Meta-Analyses

Author(s)	Year	Study type	Design	Sample size	Sample	Publication status	Typing device
Artz et al	2020	Experimental	Within	230	Undergraduate	Published	Laptop
Beck	2014	Experimental	Between	21	Undergraduate	Unpublished	Laptop
Blankenship	2016	Experimental	Between	200	Undergraduate	Unpublished	Not stated
Bui et al	2012	Experimental	Between	80	Undergraduate	Published	Desktop
Chiaraluce	2019	Experimental	Between	88	Undergraduate	Unpublished	Laptop
Crumb et al	2022	Experimental	Between	80	Undergraduate	Published	Laptop
Duran and Frederick	2013	Experimental	Between	72	Undergraduate	Published	Laptop
Eason	2017	Experimental	Mixed	72	Undergraduate	Unpublished	Desktop
Flanigan and Titsworth	2020	Experimental	Between	100	Undergraduate	Published	Laptop
Flanigan et al	2023	Experimental	Between	189	Undergraduate	Published	Desktop
Gür	2021	Quasi	Mixed	116	Undergraduate	Published	Not stated
Kirkland	2016	Experimental	Between	109	Undergraduate	Unpublished	Desktop
Kodaira	2017	Experimental	Between	90	Undergraduate	Unpublished	Laptop
Luo et al	2018	Experimental	Between	126	Undergraduate	Published	Laptop
Mitchell and Zheng	2019	Quasi	Between	295	Undergraduate	Published	Laptop
Morehead et al. (study 1)	2019	Experimental	Between	193	Undergraduate	Published	Laptop
Morehead et al. (study 2)	2019	Experimental	Between	222	Undergraduate	Published	Laptop
Mueller and Oppenheimer (study 1)	2014	Experimental	Between	67	Undergraduate	Published	Laptop
Mueller and Oppenheimer (study 2)	2014	Experimental	Between	151	Undergraduate	Published	Laptop
Mueller and Oppenheimer (study 3)	2014	Experimental	Between	109	Undergraduate	Published	Laptop
Quade	1996	Experimental	Between	112	Undergraduate	Published	Desktop
Shell et al	2021	Experimental	Between	97	Undergraduate	Published	Laptop
Shi et al	2022	Experimental	Between	42	Undergraduate	Published	Laptop
Urry et al	2021	Experimental	Between	145	Undergraduate	Published	Laptop

were provided, Cohen's d was calculated directly using Cohen's (1988) formula. When test statistics (e.g., *t*, *F*, *Mann-Whitney U*) were provided, Cohen's d was calculated using an approximation offered by Lipsey and Wilson (2001). Once Cohen's d effect size was computed for each study, effect sizes were adjusted to correct for small samples using the Hedges' *g* effect size measure (Hedges, 1981). In addition to converting all effects to a Hedges' *g* effect size measure, we ensured that a positive Hedges' *g* indicated that the handwritten note-taking method was more effective than the typed note-taking method.

Results

All data analyses were conducted using *R* (Version 4.2.1; R Core Team, 2021), a statistical software. Additionally, *metafor* (Viechtbauer & Viechtbauer, 2015) and *meta* (Balduzzi et al., 2019), two commonly used meta-analysis packages for R, were used to conduct and verify meta-analysis results.

Meta-analysis 1: Handwritten Versus Typed Note-taking Achievement Effects

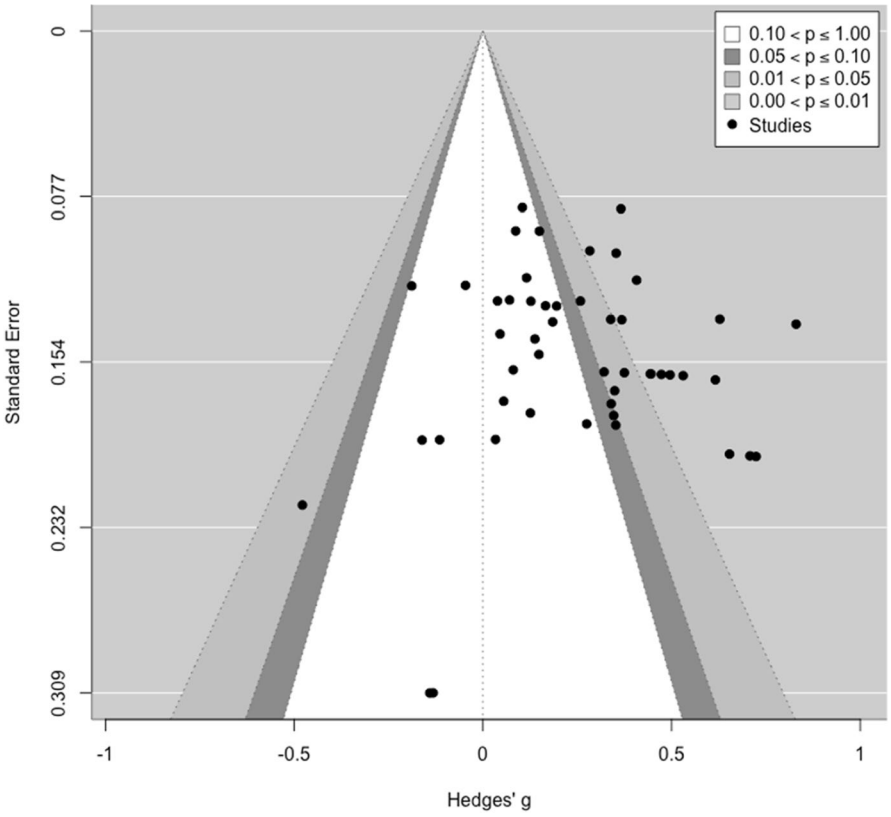
The first meta-analysis investigated and compared the effect that handwritten and typed notes have on achievement. The standardized effect sizes used in this meta-analysis represent the standardized measure for achievement differences between handwritten and typed notes. A positive standardized effect size indicates that students who handwrote notes had higher achievement than students who typed notes, whereas a negative standardized effect size indicates that students who handwrote notes had lower achievement than students who typed notes.

Test for Heterogeneity

A test for heterogeneity was performed to determine whether fixed-effects or random-effects models were appropriate for this meta-analysis. The heterogeneity test for handwritten versus typed note-taking on achievement indicated that a random-effects analysis should be conducted, $Q(48) = 128.95, p < .001, I^2 = 64.39\%$.

Overall Results

The overall analysis indicated a mean effect size of $0.248, p < .001[95\%\text{CI} : 0.181, 0.315]$, which was statistically significant. This finding indicates that the overall sample of studies found that handwritten note-taking had a positive effect on achievement, meaning that handwriting notes produced higher achievement than typing notes. Figure 1 displays a funnel plot for the standardized effect sizes (Hedges' *g*) and their standard error for all 49 effect sizes used in the meta-analysis. As shown in Fig. 1, most studies included in this meta-analysis found an achievement benefit for students who took handwritten notes.

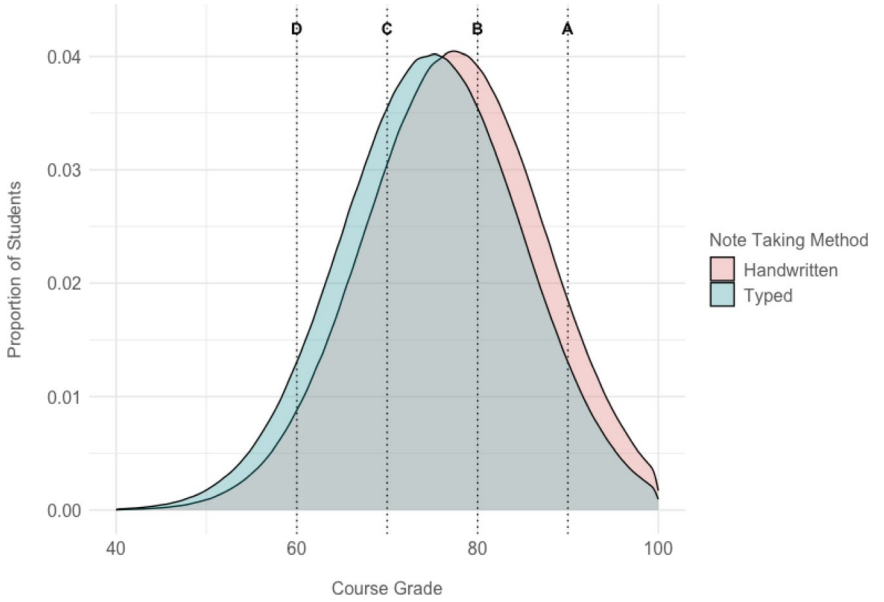


Note. A positive standardized effect size indicates that students who handwrote their notes had higher achievement than those who typed their notes.

Fig. 1 Funnel plot depicting Hedges' *g* and precision in assessing achievement: handwritten vs. typed note-taking

Binomial Effect Size Display

To better understand the practical significance of the overall effect of handwritten note-taking compared to typed note-taking on achievement outcomes, consider the binomial effect size display (BESD; Rosenthal, 1991) in Fig. 2. The BESD expresses how the overall effect size (Hedges' $g = 0.248$) would impact student performance in a typical course setting. Consider a course where the average percent grade is 75% with a standard deviation of 10%. The BESD shown in Fig. 2 depicts the expected proportion of students who record handwritten or typed notes achieving each letter grade. In this hypothetical case, 9.5% of students who took handwritten notes would be expected to achieve an A grade, whereas only 6.0% of students who typed their notes would be expected to achieve an A. Conversely, a smaller proportion of



	F (0, 60)	D (60, 70)	C (70, 80)	B (80, 90)	A (90, 100)
Handwritten	4.0%	19.0%	37.5%	30.0%	9.5%
Typed	7.0%	24.5%	38.5%	24.0%	6.0%

Note. The above BESD shows the impact of note taking method for a course that had an average score of 75 with a standard deviation of 10. The percentages provided in the table show the expected percentage of students for each letter grade category.

Fig. 2 Binomial effect size display (BESD) for the impact of note-taking method on course grades

students who took handwritten notes would be expected to achieve a D or F (19.0 and 4.0%, respectively) than students who typed their notes (24.5 and 7.0%, respectively).

Moderator Analyses

Two moderator analyses were used to investigate potential sources of heterogeneity among the studies included in the meta-analysis: a subgroup analysis and a meta-regression analysis. Subgroup analyses investigate within-moderator differences by comparing effect sizes between subgroups of studies. In the present study, effect sizes were divided into subgroups based on the three moderator variables explained above: assessment timing, review, and achievement type. Meta-regression analyses investigate between-moderator effects by treating the moderator variables as independent variables and the effect size as the dependent variable. In the present study, meta-regression analysis measures the impact of the three moderator variables (assessment timing, review, and achievement) on the effect sizes of the handwritten note-taking method on achievement.

Table 4 Mixed effects subgroup analysis (moderator analysis) on standardized effect sizes of achievement: handwritten vs. typed note-taking

Moderator	Category	k	Hedges' *g*	95% CI
Assessment timing	Immediate	29	0.229	[0.146, 0.312]
	Delayed	20	0.276	[0.161, 0.392]
Review	No	34	0.208	[0.124, 0.292]
	Optional	6	0.195	[0.067, 0.323]
	Yes	9	0.421	[0.287, 0.554]
Achievement type	Overall	22	0.271	[0.151, 0.390]
	Factual	15	0.246	[0.151, 0.339]
	Concept	12	0.199	[0.068, 0.330]

Table 5 Multiple meta-regression on standardized effect sizes of achievement: handwritten vs. typed note-taking

Moderator	Coefficient	Standard error	*Z*-value	*p* value
Intercept	0.246	0.062	3.964	< 0.001*
Assessment timing[a]				
Delayed	0.001	0.072	0.011	0.992
Review[b]				
Optional	−0.021	0.105	−0.198	0.843
Yes	0.230	0.094	2.454	0.014*
Achievement type[c]				
Factual	−0.040	0.081	−0.499	0.618
Concept	−0.099	0.086	−1.152	0.249

[a]Immediate testing is the reference group

[b]No review is the reference group

[c]Overall score is the reference group

Table 4 displays the results of the moderator subgroup analysis for each of the three moderator variables, and Table 5 displays the results of the meta-regression analysis with the three moderator variables as independent variables and effect size as the dependent variable. The following three sections provide a detailed analysis and interpretation of the results presented in Tables 4 and 5, focusing on the influence of each moderator variable on the effect size of the handwritten note-taking method on achievement.

Assessment Timing

The assessment timing moderator was used to investigate whether the timing of the achievement test affected the overall effectiveness of the note-taking medium. Studies were divided into two subgroups: immediate assessment (within one hour of the note-taking session) and delayed assessment (at least one hour after the note-taking session). As shown in Table 4, the immediate assessment subgroup had a Hedges' g of 0.229[95%CI : 0.146, 0.312], and the delayed assessment subgroup

had a Hedges' g of 0.276[95% CI : 0.161, 0.392]. The subgroup analysis indicated no significant difference in effect sizes between the immediate and delayed testing subgroups, $Q(1) = 0.43, p = 0.511$. Furthermore, the meta-analysis regression, shown in Table 5, indicated that the assessment timing moderator variable did not significantly influence the overall effect size, $\beta_{\text{Delayed}} = 0.001, p = 0.992$. These results suggest that the benefits of handwritten note-taking on achievement outcomes remain consistent, regardless of whether the assessment is administered immediately after the note-taking session or after a delay. In other words, the timing of the assessment does not appear to moderate the effectiveness of handwritten note-taking on achievement outcomes.

Review

The review moderator was used to investigate whether allowing students to review notes before achievement assessment affects the overall effectiveness of the note-taking medium. Studies were divided into three subgroups: yes (students were provided a formal review period), no (students were not provided a formal review period), and optional (students were not provided a formal review period but were not restricted from reviewing). As shown in Table 4, the review subgroup had a Hedges' g of 0.421[95%CI : 0.287, 0.554], the no review subgroup had a Hedges' g of 0.208[95%CI : 0.124, 0.292], and the optional review subgroup had a Hedges' g of 0.195[95%CI : 0.067, 0.323]. The subgroup analysis indicated a significant difference in effect sizes among the review subgroups, $Q(2) = 7.94, p = 0.019$. Additionally, the meta-analysis regression, shown in Table 5, indicated that the review moderator variable significantly influences the overall effect size, $\beta_{\text{Optional}} = -0.021, p = 0.843$ and $\beta_{\text{Yes}} = 0.230, p = 0.014$. These results suggest that the benefits of handwritten note-taking on achievement outcomes are significantly influenced by whether students are provided with an opportunity to review their notes before the assessment. The findings indicate that providing a formal review period can enhance the positive effects of handwritten note-taking on achievement outcomes.

Achievement Type

The achievement type moderator was used to investigate whether the type of achievement test affects the overall effectiveness of the note-taking method. Studies were divided into three subgroups: total (student achievement was determined by all items on the assessment), factual (student achievement was determined by only the factual items on the assessment), and conceptual (student achievement was determined by only the conceptual items on the assessment). As shown in Table 4, the total achievement subgroup had a Hedges' g of 0.271[95% CI : 0.151, 0.390], the factual achievement subgroup had a Hedges' g of 0.246[95%CI : 0.151, 0.339], and the conceptual achievement subgroup had a Hedges' g of 0.199[95%CI : 0.068, 0.330]. The subgroup analysis indicated no significant difference in effect sizes among the

achievement type subgroups, $Q(2) = 0.63, p = 0.730$. Additionally, the meta-analysis regression, shown in Table 5, indicated that the achievement type moderator variable did not significantly influence the overall effect size, $\beta_{\text{Factual}} = -0.040, p = 0.618$ and $\beta_{\text{Conceptual}} = -0.099, p = 0.249$. These results suggest that the benefits of handwritten note-taking on achievement outcomes remain consistent, regardless of the type of achievement test. In other words, whether the assessment consists of factual items, conceptual items, or a combination of both does not appear to moderate the effectiveness of handwritten note-taking on achievement outcomes.

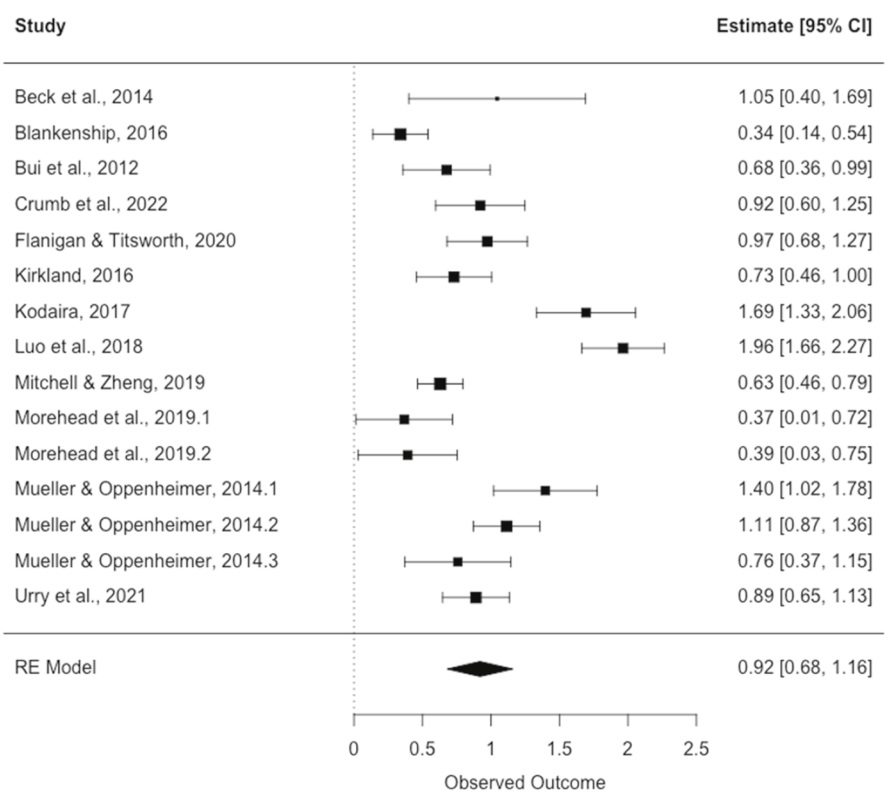
Publication Bias

The studies included in the meta-analysis were further investigated for publication bias. As shown in Fig. 1, the distribution of effect sizes and their precisions do not suggest asymmetry, which suggests the absence of publication bias. The studies were further analyzed for publication bias using Egger's regression test (Egger et al., 1997). Results from this test were not statistically significant, $t(47) = 0.550, p = 0.585$, indicating the absence of publication bias. Additionally, 7 of the 49 effect sizes reported in this meta-analysis came from unpublished work. Therefore, the publication status of the effect sizes was used as a moderator to determine whether publication status (published or unpublished) affected effect size magnitudes. No significant difference was found between published and unpublished effect sizes, $Q(1) = 1.831, p = 0.176$. Based on the funnel plot in Fig. 1, Egger's regression test, and the moderator analysis of publication status, it appears that there was no publication bias in the studies used for this meta-analysis.

Meta-analysis 2: Typed Versus Handwritten Note-taking Note Quantity Effects

The second meta-analysis compared the effect that handwritten and typed note-taking mediums had on the number of words and ideas recorded during lectures. The standardized effect sizes used in this meta-analysis represent the standardized measure for the difference in the number of words and ideas recorded in typed versus handwritten notes. A positive standardized effect size indicates that students who typed notes recorded more words and ideas than students who handwrote notes, whereas a negative standardized effect size indicates that students who typed notes recorded fewer words and ideas than students who took handwritten notes.

Figure 3 displays a forest plot that includes the effect sizes and their 95% confidence intervals for all 15 studies that were included in this meta-analysis. Based on the forest plot, all 15 studies had statistically significant positive effect sizes, demonstrating a consistent trend across the studies. Furthermore, the overall mean effect size was statistically significant $(0.919, p < 0.001[95\%\text{CI} : 0.679, 1.160])$. These results indicate that typed notes contain more words and ideas than handwritten notes.



Note. A positive standardized effect size indicates that students who typed their notes recorded a larger number of words compared to those who handwrote their notes.

Fig. 3 Forest plot comparing the standardized effect sizes of word count: typed vs. handwritten note-taking

Discussion

Although some scholars contend that it is too early to declare whether typing or writing lecture notes is better for learning (Morehead et al., 2019a; Urry et al., 2021; Voyer et al., 2022), the present meta-analysis suggests otherwise. Namely, our findings indicate that although typing leads to a greater quantity of noted ideas, recording and reviewing handwritten notes leads to higher achievement among college students. All the studies included in our meta-analyses were based on student note-taking and achievement within a single lecture. Yet, as the BESD in Fig. 2 shows that when the learning effects of note-taking medium are considered across the length of a semester-long course, meaningful differences in expected final course grades emerge—with college students who record handwritten notes expected to earn more As and Bs than those who type their notes, who, in turn, are expected to earn more Cs, Ds, and Fs. The trends shown in Fig. 2 provide a visual representation

of the cascading learning benefits that appear to stem from recording handwritten notes in college courses.

Comparison with Previous Meta-analyses

Table 6 overviews the overall achievement-related effect size statistics calculated in the present and prior meta-analyses comparing typed versus handwritten note-taking. The present study is among three (i.e., Allen et al., 2020; Authors, under review; Lau, 2022) of the five studies included in Table 6 that detected statistically significant achievement advantages stemming from recording handwritten lecture notes. Although the directionality of the overall meta-analytic achievement analyses of the other two studies included in Table 6 (i.e., Urry et al., 2021; Voyer et al., 2022) also favored handwritten notes, those analyses did not achieve statistical significance. Curiously, Lau (2022) found that the achievement advantage for handwritten notes disappeared after notes were reviewed, whereas our analysis revealed that note review increased the achievement benefits of handwritten notes. Although tentative, an explanation for the conflicting findings drawn from Lau's meta-analysis and ours might simply be due to the different student populations included in these analyses. For instance, some studies included in the present analysis showing an advantage for longhand note-takers who review notes (e.g., Flanigan et al., 2023) were not included in the analyses Lau (2022) conducted. Furthermore, Lau's (2022) conclusions were influenced by the achievement of secondary school students, whose achievement was unaccounted for in the present analysis. Perhaps reviewing notes somehow closes the achievement gap between secondary students who record and review handwritten versus typed notes.

Regarding note-taking quantity across note-taking mediums, our findings align with those of Urry et al. (2021), who found that recording handwritten notes had a large, negative effect on the number of words contained in lecture notes (Hodge's $g = -0.91$ [95% CI: $-1.18, -0.65$]). It seems that students who type their notes record more words in notes than students who handwrite notes. Yet, there is no evidence across the existing meta-analyses that the advantages in note-taking volume enjoyed by students who type their notes give those students any achievement advantages over students who record handwritten notes, even when those notes are reviewed before testing.

Table 6 Overall achievement-related effect sizes from present and previous meta-analyses

	Effect size statistics		95% CI
	Number of ES	Hedges' *g*	
Authors (under review)	49	+0.248	[0.181, 0.315]
Allen et al. (2020)	24	+0.250	[0.127, 0.371]
Lau (2022)	76	+0.144	[0.023, 0.265]
Urry et al. (2021)	22	+0.040	[−0.13, 0.20]
Voyer et al. (2022)	73	+0.008	[−0.16, 0.18]

Note. A positive Hedges' *g* indicates that handwritten notes were more effective than typed notes on overall achievement

Interpretation of Present Achievement Findings

As to why handwriting notes is superior to typing them, we offer three explanations. The first is that handwriting notes produce deeper processing than typing notes. Longhand notes tend to capture lecture ideas in a paraphrased and personalized style meaningful to the note-taker, whereas typed notes tend to capture lecture ideas in a verbatim, almost thoughtless way. Scholars have used the depth of processing framework (Craik & Lockhart, 1972) to explain how paraphrasing notes is indicative of deeper, more meaningful processing of lecture information (Luo et al., 2018), whereas typing notes that are verbatim is indicative of a shallower, less meaningful processing of lecture information (Mueller & Oppenheimer, 2014). Although typing leads to a greater quantity of recorded ideas than writing does, the shallow, verbatim nature of typing notes seems to hinder their external storage value, thereby rendering typed notes less useful during review than handwritten notes.

The second explanation is that handwritten notes contain more lecture images than typed notes. In studies measuring the number of images recorded in notes, college students typing notes recorded zero lecture images, whereas longhand notetakers recorded multiple images (Flanigan & Titsworth, 2020; Flanigan et al., 2023; Luo et al., 2018). According to dual-coding theory (Clark & Paivio, 1991), learning occurs best when information is coded both verbally and visually. Moreover, Mayer and Gallini (1990) contend that an image is worth 10,000 words.

The third explanation is actually a counterargument. One might conjecture that typed notes are superior to handwritten notes because typed notes tend to be more complete (e.g., Bui et al., 2012; Crumb et al., 2022; Luo et al., 2018), and the more complete notes are, the more they boost achievement (Flanigan & Titsworth, 2020; Morehead et al., 2019a; Mueller & Oppenheimer, 2014). However, despite typed notes proving more complete than handwritten notes in the present review, both note-taking mediums contain similar amounts of lecture ideas later covered on assessments (Morehead et al., 2019a), thereby negating the quantity advantage of typed notes. Thus, the argument that typed notes are superior because they are more complete than handwritten notes does not hold.

In conclusion, although longhand notes might be less wordy than typed notes, the former contain just as many test-relevant ideas and more images and reflect deeper processing because of their more personal and paraphrased style. Each aspect seems to enhance the external storage function of handwritten notes relative to typed notes among college students.

Accessibility Considerations and Note-taking Medium

No studies included in our meta-analysis—or in any other known meta-analyses on note-taking medium—accounted for the needs of students with disabilities. As such, the findings and implications drawn from the research could be unintentionally influenced by ableist assumptions. Course policies and classroom instructional practices should account for the needs of students with disabilities.

Handwriting or typing lecture notes might not be an option for some students, whether their disabilities are physical or cognitive in nature. Other students might require note-taking assistance, such as having another student record notes for them or instructors providing notes for them. As a result, it would be inappropriate for readers to transfer the findings from our research to inform their course policies and instructional practices for working with students with disabilities.

Literature Limitations and Future Research Avenues

The present research investigated the note-taking medium's achievement and note-taking effects among college students. However, if the effects of the note-taking medium differ based on the student population under study, then the existing differences across the known meta-analyses highlight the need for future research examining the interplay among note-taking medium, note-taking outcomes, and achievement within specific populations of students (e.g., elementary, middle grades, secondary, and college students). Such investigations could help resolve the achievement discrepancies that exist across some of the meta-analyses included in Table 6.

Furthermore, while reviewing the 24 studies included in our analyses, several limitations were noted that, if remedied by future research, could provide deeper clarity on the note-taking medium's effects on achievement and note-taking outcomes. Four such limitations are discussed.

Documentation of Lecture Content

Only nine of the studies included in our analysis reported the number of lecture ideas students recorded in notes (e.g., Bui et al., 2012; Flanigan et al., 2023; Luo et al., 2018; Morehead et al., 2019a; Quade, 1996), and just three reported how many lecture images were recorded (Flanigan & Titsworth, 2020; Flanigan et al., 2023; Luo et al., 2018). We believe that all note-taking studies should certainly examine the notes recorded. Neglecting to do so obscures treatment effects and neglects to ascertain note-taking's true achievement effect.

Even when researchers document the contents of student notes, they often do so without reporting the number of ideas or images originally presented during the lecture. Knowing, for example, that students recorded an average of 34 lecture ideas is inconsequential without knowing the number of lecture ideas presented. Yet, most of the studies reviewed ($n = 15$) did not indicate the total number of ideas or images presented during lectures. This shortcoming makes it impossible to fully assess note completeness. The existing literature that does report the total number of ideas and images presented during lectures suggests that college students record a small fraction of lecture-presented ideas (about 30%) (Flanigan & Titsworth, 2020; Flanigan et al., 2023; Luo et al., 2018) and images (about 10–20%) (Flanigan & Titsworth, 2020; Flanigan et al., 2023; Luo et al., 2018). This information suggests that researchers must continue to find ways to boost student note-taking, regardless of

whether notes are typed or handwritten. Instructional strategies like providing spoken organizational lecture cues (Titsworth, 2001, 2004; Titsworth & Kiewra, 2004), providing students with matrices and other graphic organizers to record and organize notes (Bui & McDaniel, 2015; Kiewra et al., 1995), and focusing student attention by asking pre-questions (Rickards & McCormick, 1988) are some instructional strategies known to increase note-taking and achievement among students recording handwritten notes. These and other instructional strategies seem ripe for investigation as to whether they differentially impact typed versus handwritten note-taking.

That said, an accounting of lecture ideas and images is especially important when comparing note-taking mediums. For instance, given that computer users tend to struggle with re-creating lecture images in their notes (Flanigan et al., 2023; Luo et al., 2018; Mosleh et al., 2016; Reimer et al., 2009), it is plausible that the utility of typing lecture notes might vary for lectures containing few or many images. For instance, a student typing notes on a laptop might struggle to recreate presented graphs, figures, or images during a biology lecture but easily capture most text-based ideas during a psychology lecture. Yet, most studies fail to report the number of images contained in lessons or recorded in notes (e.g., Mueller & Oppenheimer, 2014; Shell et al., 2021; Urry et al., 2021). Researchers should reveal the total number of ideas and images presented during a lesson and the numbers recorded in notes to fully gauge the impacts of typed versus handwritten notes.

Accounting for Revision

Note-taking has recently been conceptualized as a three-stage process of recording–revising–reviewing (Luo et al., 2016), but only one known study (Flanigan et al., 2023) incorporated the revision stage into the investigation of note-taking mediums. Findings revealed that longhand note-takers used revision pauses embedded in an ongoing lecture to add more ideas and images to notes than did computer note-takers, which subsequently contributed to higher scores for longhand note-takers on a delayed posttest. All other known studies comparing typed versus handwritten lecture notes conceptualized note-taking as either a one-stage (recording only) or two-stage (recording and reviewing) process. Doing so results in an incomplete accounting of the note-taking process. A complete accounting of all three phases in the note-taking process seems to favor longhand note-takers (Flanigan et al., 2023). Future note-medium studies might include and investigate note-taking's revision process.

Student Characteristics

Little is known about the characteristics of students who choose to record typed or handwritten lecture notes in real-world classrooms or how these characteristics influence their note-taking behaviors and achievement. Scant findings indicate that college students who prefer to type rather than handwrite lecture notes rate

their note-taking skills as "poor" and do not believe that taking notes is "very useful" for doing well in their courses (Artz et al., 2020). Furthermore, given the multitude of distractions available to students who type notes on laptops, Artz et al. (2020) postulated that the choice to type lecture notes is driven more by students' susceptibility to digital distractions than by an underlying motivation to take better notes. Moreover, such characteristics might drive students to use one note-taking medium over the other, and those characteristics might be more consequential for note-taking and achievement than for the mediums themselves. Future research should investigate the interplay between student characteristics (e.g., note-taking skill, motivation, self-regulation) and their preferred note-taking mediums to determine the extent to which these characteristics affect note-taking and achievement.

Lecture Supplements

Lecture supplements, such as note-taking frameworks or printed PowerPoint slides, are occasionally given to college students to boost note-taking and achievement (Morehead et al., 2019b; Witherby & Tauber, 2019). Oddly, none of the note-taking medium studies in our analysis investigated how the availability of lecture supplements influences the achievement and note-taking effects of the note-taking medium. Further research should determine how various lecture supplements affect note-taking behaviors and achievement among students who type or handwrite notes.

Conclusion

The increasing popularity among college students of typing lecture notes has led to numerous studies comparing the note-taking and achievement effects of typed versus handwritten lecture notes. Many college students are motivated to type their lecture notes, believing that typing notes makes it easier for them to learn (Morehead et al., 2019b). Yet, our findings do not support this belief. Rather, findings from the 24 studies included in our analyses indicated that recording and reviewing handwritten lecture notes leads to higher achievement among college students. Although those working in K-12 settings or with students with disabilities or special needs should be cautious in applying our findings in those situations, we believe our findings tilt the ongoing "laptop versus longhand" debate (Mitchell & Zheng, 2019) in support of longhand note-taking and that college students should be advised to record notes longhand.

Declarations

Conflict of Interest The authors declare no conflict of interest.

References

Allen, M., LeFebvre, L., LeFebvre, L., & Bourhis, J. (2020). Is the pencil mightier than the keyboard? A meta-analysis comparing the method of notetaking outcomes. *Southern Communication Journal, 85*(3), 143–154. https://doi.org/10.1080/1041794X.2020.1764613

Aragón-Mendizábal, E., Delgado-Casas, C., Navarro-Guzmán, J.-I., Menacho-Jiménez, I., & Romero-Oliva, M.-F. (2016). A comparative study of handwriting and computer typing in note-taking by university students. *Comunicar, 24*(48), 101–107. https://doi.org/10.3916/C48-2016-10

Armbruster, B. B. (2000). Taking notes from lectures. In R. F. Flippo & D. C. Caverly (Eds.), *Handbook of college reading and study strategy research* (pp. 175–199). Lawrence Erlbaum Associates Publishers.

Artz, B., Johnson, M., Robson, D., & Taengnoi, S. (2020). Taking notes in the digital age: Evidence from classroom random control trials. *The Journal of Economic Education, 51*(2), 103–115. https://doi.org/10.1080/00220485.2020.1731386

Balduzzi, S., Rücker, G., & Schwarzer, G. (2019). How to perform a meta-analysis with R: A practical tutorial. *BMJ Mental Health, 22*, 153–160.

Barrett, M. E., Swan, A. B., Mamikonian, A., Ghajoyan, I., Kramarova, O., & Youmans, R. J. (2014). Technology in note taking and assessment: The effects of congruence on student performance. *International Journal of Instruction, 7*(1), 49–58.

Beck, K. M., Hartley, J. S., Hustedde, S. L., & Felsberg, T. C. (2014). Note taking effectiveness in the modern classroom. *The Compass, 1*(1), 9.

Blankenship, M. W. (2016). *Comparing note taking and test performance in methods and modes of note taking conditions* [unpublished dissertation]. Ball State University.

Blasiman, R. N., Dunlosky, J., & Rawson, K. A. (2017). The what, how much, and when of study strategies: Comparing intended versus actual study behavior. *Memory, 25*(6), 784–792. https://doi.org/10.1080/09658211.2016.1221974

Bui, D. C., & McDaniel, M. A. (2015). Enhancing learning during lecture note-taking using outlines and illustrative diagrams. *Journal of Applied Research in Memory and Cognition, 4*(2), 129–135. https://doi.org/10.1016/j.jarmac.2015.03.002

Bui, D. C., Myerson, J., & Hale, S. (2012). Note-taking with computers: Exploring alternative strategies for improved recall. *Journal of Educational Psychology, 105*(2), 299–309. https://doi.org/10.1037/a0030367

Chiaraluce, B. (2019). *Effects of distraction on memory while handwriting or typing* [unpublished thesis]. Southern Connecticut State University.

Clark, J. M., & Paivio, A. (1991). Dual coding theory and education. *Educational Psychology Review, 3*, 149–210. https://doi.org/10.1007/BF01320076

Cohen, J. (2013). *Statistical power analysis for the behavioral sciences*. Academic Press.

Craik, F. I., & Lockhart, R. S. (1972). Levels of processing: A framework for memory research. *Journal of Verbal Learning and Verbal Behavior, 11*(6), 671–684. https://doi.org/10.1016/S0022-5371(72)80001-X

Crawford, C. C. (1925). The correlation between college lecture notes and quiz papers. *The Journal of Educational Research, 12*, 282–290. https://doi.org/10.1080/00220671.1925.10879600

Crumb, R. M., Hildebrandt, R., & Sutton, T. M. (2022). The value of handwritten notes: A failure to find state-dependent effects when using a laptop to take notes and complete a quiz. *Teaching of Psychology, 49*(1), 7–13. https://doi.org/10.1177/0098628320979895

Di Vesta, F. J., & Gray, S. G. (1972). Listening and note taking. *Journal of Educational Psychology, 63*(1), 8–14. https://doi.org/10.1037/h0032243

Duran, K. S., & Frederick, C. M. (2013). Information comprehension: Handwritten vs. typed notes. Retrieved from *Undergraduate Research Journal for the Human Sciences*, *12*(1).

Eason, T. (2017). *Various methods of note-taking and how they compare in terms of information retention* [unpublished thesis]. East Carolina University.

Egger, M., Smith, G. D., Schneider, M., & Minder, C. (1997). Bias in meta-analysis detected by a simple, graphical test. *BMJ, 315*(7109), 629–634.

Flanigan, A. E., & Titsworth, S. (2020). The impact of digital distraction on lecture note taking and student learning. *Instructional Science, 48*(5), 495–524. https://doi.org/10.1007/s11251-020-09517-2

Flanigan, A. E., Kiewra, K. A., Lu, J., & Dzhuraev, D. (2023). Computer versus longhand note taking: Influence of revision. *Instructional Science, 51*(2), 251–284. https://doi.org/10.1007/s11251-022-09605-5

Gür, T. (2021). The effect of verbatim and generative notes taken by hand and keyboard at university level on success and persistence. *Education Quarterly Reviews, 4*(4), 132–141. https://doi.org/10.31014/aior.1993.04.03.325

Hedges, L. V. (1981). Distribution theory for Glass's estimator of effect size and related estimators. *Journal of Educational Statistics, 6*(2), 107–128.

Kiewra, K. A. (1985). Investigating notetaking and review: A depth of processing alternative. *Educational Psychologist, 20*, 23–32. https://doi.org/10.1207/s15326985ep2001_4

Kiewra, K. A., & Fletcher, H. J. (1984). The relationship between levels of note-taking and achievement. *Human Learning: Journal of Practical Research & Applications, 3*(4), 273–280.

Kiewra, K. A., DuBois, N. F., Christian, D., McShane, A., Meyerhoffer, M., & Roskelley, D. (1991). Note-taking functions and techniques. *Journal of Educational Psychology, 83*(2), 240–245. https://doi.org/10.1037/0022-0663.83.2.240

Kiewra, K. A., Benton, S. L., Kim, S. I., Risch, N., & Christensen, M. (1995). Effects of note-taking format and study technique on recall and relational performance. *Contemporary Educational Psychology, 20*(2), 172–187. https://doi.org/10.1006/ceps.1995.1011

Kim, I., Kim, R., Kim, H., Kim, D., Han, K., Lee, P. H., & Lee, U. (2019). Understanding smartphone usage in college classrooms: A long-term measurement study. *Computers & Education, 141*, 103611. https://doi.org/10.1016/j.compedu.2019.103611

Kirkland, K. M. (2016). *The effect of note taking media and preference on the cognitive processes involved in learning* [Undergraduate honors thesis]. https://scholar.colorado.edu/honr_theses/1244. Accessed 15 June 2023.

Knight, L. J., & McKelvie, S. J. (1986). Effects of attendance, note-taking, and review on memory for a lecture: Encoding vs. external storage functions of notes. *Canadian Journal of Behavioural Science, 18*(1), 52–61. https://doi.org/10.1037/h0079957

Kodaira, Y. (2017). *An investigation of cognitive processes associated with notetaking and notes-review* [unpublished dissertation]. Columbia University.

Kornhauser, Z. G. C., Paul, A. L., & Siedlecki, K. L. (2016). An examination of students' use of technology for non-academic purposes in the college classroom. *Journal of Teaching and Learning with Technology, 5*(1), 1–15. https://doi.org/10.14434/jotlt.v5n1.13781

Lau, T. S. (2022). *The effect of typewriting vs. handwriting lecture notes on learning: a systematic review and meta-analysis* [unpublished dissertation]. The University of Louisville.

le Roux, D. B., & Parry, D. A. (2018). In-lecture media use and academic performance: Investigating demographic and intentional moderators. *South African Computer Journal*, *30*(1), 87–107. https://hdl.handle.net/10520/EJC-1076e4c0d3

Lipsey, M. W., & Wilson, D. B. (2001). *Practical meta-analysis*. SAGE Publications, Inc.

Luo, L., Kiewra, K. A., & Samuelson, L. (2016). Revising lecture notes: How revision, pauses, and partners affect note taking and achievement. *Instructional Science, 44*(1), 45–67. https://doi.org/10.1007/s11251-016-9370-4

Luo, L., Kiewra, K. A., Flanigan, A. E., & Peteranetz, M. S. (2018). Laptop versus longhand note taking: Effects on lecture notes and achievement. *Instructional Science, 46*(6), 947–971. https://doi.org/10.1007/s11251-018-9458-0

Mayer, R. E., & Gallini, J. K. (1990). When is an illustration worth ten thousand words? *Journal of Educational Psychology, 82*(4), 715–726. https://doi.org/10.1037/0022-0663.82.4.715

McCoy, B. R. (2020). Gen Z and digital distractions in the classroom: Student classroom use of digital devices for non-class related purposes. *Journal of Media Education, 11*(2), 5–23.

Mitchell, A., & Zheng, L. (2019). Examining longhand vs. laptop debate: A replication study. *AIS Transactions on Replication Research, 5*(9), 1–15. https://doi.org/10.17705/1atrr.00041

Morehead, K., Dunlosky, J., & Rawson, K. A. (2019a). How much mightier is the pen than the keyboard for note-taking? A replication and extension of Mueller and Oppenheimer (2014). *Educational Psychology Review, 31*, 753–780. https://doi.org/10.1007/s10648-019-09468-2

Morehead, K., Dunlosky, J., Rawson, K. A., Blasiman, R., & Hollis, R. B. (2019b). Note-taking habits of 21st century college students: Implications for student learning, memory, and achievement. *Memory, 27*(6), 807–819. https://doi.org/10.1080/09658211.2019.1569694

Mosleh, M. A., Baba, M. S., Malek, S., & Alhussein, M. A. (2016). Challenges of digital note taking. In H. Sulaiman, M. Othman, M. Othman, Y. Rahim, & N. Pee (Eds.), *Advanced Computer and Communication Engineering Technology* (pp. 211–231). Springer.

Mueller, P. A., & Oppenheimer, D. M. (2014). The pen is mightier than the keyboard: Advantages of longhand over laptop note taking. *Psychological Science, 25*(6), 1159–1168. https://doi.org/10.1177/0956797614524581

O'Donnell, A., & Dansereau, D. F. (1993). Learning from lectures: Effects of cooperative review. *The Journal of Experimental Education, 61*(2), 116–125. https://doi.org/10.1080/00220973.1993.9943856

Pettit-O'Malley, K. L., Liesz, T. J., & Sisodiya, S. R. (2017). The relative efficacy of handwritten versus electronic student classroom notes. *Business Education Innovation Journal, 9*(2), 110–120.

Quade, A. Q. (1996). An assessment of retention and depth of processing associated with notetaking using traditional pencil and paper and an on-line notepad during computer-delivered instruction. In M. R. Simonson, M. Hays, & S. Hall (Eds.), *Proceedings of Selected Research and Development Presentations at the 1996 Convention of the Association for Educational Communications and Technology* (pp. 559–570). Retrieved from http://files.eric.ed.gov/fulltext/ED397772.pdf. Accessed 15 June 2023.

R Core Team. (2021). *R: A language and environment for statistical computing*. R Foundation for Statistical Computing. https://www.R-project.org/. Accessed 10 Oct 2023.

Ragan, E. D., Jennings, S. R., Massey, J. D., & Doolittle, P. E. (2014). Unregulated use of laptops over time in large lecture halls. *Computers & Education, 78*, 78–86. https://doi.org/10.1016/j.compedu.2014.05.002

Ravizza, S. M., Uitvlugt, M. G., & Fenn, K. M. (2017). Logged in and zoned out: How laptop internet use relates to classroom learning. *Psychological Science, 28*(2), 171–180. https://doi.org/10.1177/0956797616677314

Reimer, Y. J., Brimhall, E., Cao, C., & O'Reilly, K. (2009). Empirical user studies inform the design of an e-notetaking and information assimilation system for students in higher education. *Computers & Education, 52*(4), 893–913. https://doi.org/10.1016/j.compedu.2008.12.013

Rickards, J. P., & McCormick, C. B. (1988). Effect of interspersed conceptual prequestions on note-taking in listening comprehension. *Journal of Educational Psychology, 80*(4), 592–594. https://doi.org/10.1037/0022-0663.80.4.592

Rosenthal, R. (1991). Effect sizes: Pearson's correlation, its display via the BESD, and alternative indices. *American Psychologist, 46*(10), 1086–1087.

Schoen, I. (2012). *Effects of method and context of note-taking on memory: Handwriting versus typing in lecture and textbook-reading contexts* [unpublished thesis]. Pitzer College.

Shell, M. D., Strouth, M., & Reynolds, A. M. (2021). Make a note of It: Comparison in longhand, keyboard, and stylus note-taking techniques. *Learning Assistance Review, 26*(2), 1–21.

Shi, Y., Yang, H., Yang, Z., Liu, W., Wu, D., & Yang, H. H. (2022). Examining the effects of note-taking styles on college students' learning achievement and cognitive load. *Australasian Journal of Educational Technology, 38*(5), 1–11. https://doi.org/10.14742/ajet.6688

Titsworth, B. S. (2001). The effects of teacher immediacy, use of organizational lecture cues, and students' notetaking on cognitive learning. *Communication Education, 50*(4), 283–297. https://doi.org/10.1080/03634520109379256

Titsworth, B. S. (2004). Students' note taking: The effects of teacher immediacy and clarity. *Communication Education, 53*, 305–320. https://doi.org/10.1080/0363452032000305922

Titsworth, B. S., & Kiewra, K. A. (2004). Spoken organizational lecture cues and student notetaking as facilitators of student learning. *Contemporary Educational Psychology, 29*(4), 447–461. https://doi.org/10.1016/j.cedpsych.2003.12.001

Tulving, E., & Thomson, D. M. (1973). Encoding specificity and retrieval processes in episodic memory. *Psychological Review, 80*(5), 352–373. https://doi.org/10.1037/h0020071

Urry, H. L., Crittle, C. S., Floerke, V. A., Leonard, M. Z., Perry III, C. S., Akdilek, N., ... & Zarrow, J. E. (2021). Don't ditch the laptop just yet: A direct replication of Mueller and Oppenheimer's (2014) study 1 plus mini meta-analyses across similar studies. *Psychological Science*, *32*(3), 326–339. https://doi.org/10.1177/0956797620965544

Viechtbauer, W., & Viechtbauer, M. W. (2015). Package 'metafor'. *The Comprehensive R Archive Network. Package 'metafor'*. http://cran.r-project.org/web/packages/metafor/metafor.pdf. Accessed 10 Oct 2023.

Voyer, D., Ronis, S. T., & Byers, N. (2022). The effect of notetaking method on academic performance: A systematic review and meta-analysis. *Contemporary Educational Psychology, 68*, 102025. https://doi.org/10.1016/j.cedpsych.2021.102025

Wei, F. Y. F., Wang, Y. K., & Fass, W. (2014). An experimental study of online chatting and notetaking techniques on college students' cognitive learning from a lecture. *Computers in Human Behavior, 34*, 148–156. https://doi.org/10.1016/j.chb.2014.01.019

Wiechmann, W., Edwards, R., Low, C., Wray, A., Boysen-Osborn, M., & Toohey, S. (2022). No difference in factual or conceptual recall comprehension for tablet, laptop, and handwritten note-taking by medical students in the United States: A survey-based observational study. *Journal of Educational Evaluation for Health Professions, 19*(8), 1–7. https://doi.org/10.3352/jeehp.2022.19.8

Wilson, J. T., Miller-Goldwater, H. E., Porter, B. M., & Bauer, P. J. (2023). Learning neuroscience: Investigating influences of notetaking materials and individual differences. *Learning and Individual Differences, 101*, 102243. https://doi.org/10.1016/j.lindif.2022.102243

Witherby, A. E., & Tauber, S. K. (2019). The current status of students' note-taking: Why and how do students take notes? *Journal of Applied Research in Memory and Cognition, 8*(2), 139–153. https://doi.org/10.1016/j.jarmac.2019.04.002