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Article

Does technology help or hurt learning? Evidence from middle school and high school students

Marco Lu[1], Davis Mo[2], Fei Du[3]

[1] University Laboratory High School, Urbana, Illinois
[2] Concordia International School, Shanghai, China
[3] University of Illinois Urbana-Champaign, Champaign, Illinois

SUMMARY

In this study, we examined the effect of technology use on middle and high school students' learning effectiveness. Based on prior literature, we hypothesized that device use at school would increase students' learning effectiveness (H1), but that device use at home would decrease learning effectiveness (H2). To test our hypotheses, we conducted a survey of middle and high school students across different states in the United States. We measured the device use and learning effectiveness by asking participants to report their actual device use time both at school and at home and to rate the extent to which their learning met their expectations on a 7-point Likert-type scale. We found partial support for H1. While we did not find an overall positive relation between technology use at school and learning effectiveness, we found such effects among male students and middle school students. Consistent with H2, we found strong support for a negative effect of technology use at home on learning effectiveness. Further, this negative effect was exacerbated for female students and middle school students. Taken together, these results provide evidence suggesting that the effect of technology use on learning depends on where the device is used, the gender of students, and the grade in which students are in. Furthermore, we conducted additional analyses to shed light on how technology use benefits learning. Our results suggest that technology use improves learning mainly by facilitating collaboration, enabling more personalized learning, improving organization, allowing teachers to provide more timely feedback, and making learning more effective.

INTRODUCTION

Incorporating electronic devices into learning is increasingly popular in K-12 classrooms. A recent survey in 2019 showed that 49% of schools in their survey have implemented a 1:1 device program, and 20% of the schools allow students to bring their own devices ("BYOD") into the classroom (1). In the wake of the recent COVID-19 outbreak, online instruction and 1:1 computing opportunities are both increasingly frequent (2). The outbreak has led to much more widespread adoption of device use, through remote learning, which has made it more important to examine the impact of device use on students' learning effectiveness.

Some prior studies have examined the relationship between device use and student achievement in various subjects, such as math, science, and reading (3, 4). Most of these studies found that device use helps students perform better by increasing their motivation and engagement in reading within a stark experiment setting with a pre-designated task within a short period (5, 6), as opposed to real learning environments which might have ambiguous learning objectives or open-ended projects, over long periods of time. However, there has been an ongoing debate about the use of digital devices in and outside of the classroom. Commonly cited downsides of the use of digital devices in the classroom include distraction from schoolwork and less time for face-to-face social activities at school (3). In addition, prior studies on the effect of technology use on learning often fail to take into consideration that many parents allow children free reign of their device and the internet at home. Thus, these studies cannot comprehensively measure the effectiveness of device use for middle school and high school students. Technology use at home often plays a role as important as technology use at school since students spend much more time at home than at school. Homework is often as important as schoolwork in helping students remember and recall content (7). Further, if students have access to a device at home for homework, they will likely also have different devices with different capabilities (8).

In this study, we examined the effect of technology use on middle and high school students' learning experience. Our study attempted to overcome this limitation in prior research and simultaneously consider students' device use in the classroom and at home. Our main research question was "What is the effect of students' device use, both at home and in the classroom, on learning effectiveness?"

We hypothesized that device use in class improves learning effectiveness. Device use can increase learning effectiveness by facilitating information searches along with access to videos and images that could be a good supplement to teaching materials. Teachers will also be able to assign students to work on tasks with varying degrees of difficulty, thus allowing customizations in learning by enabling teachers to give timely feedback, as well as the advantage of real-time automatic grading provided by many educational apps. For example, Kahoot, a game-based learning platform which gamifies user-generated quizzes through a website, allows

teachers to know, in real time, how long students have spent answering each question and whether they were correct in answering such questions (9). On the other hand, students also have a variety of tools that can help them learn more effectively. Students can easily collaborate using tools such as Google Classroom or Google Docs. While students must participate by raising hands and speaking in front of the whole class in a traditional classroom, which could lead to anxiety, participating via device on web interfaces such as Padlet can be anonymous and alleviate students' anxiety. All of these tools help students self-pace their studies and have more decision autonomy over the learning interface, which reduces stress.

However, device use also comes with costs. When students are splitting attention between a device and the class material, the device can become distracting. Consistent with the attention splitting hypothesis, prior research has shown that there is a significant and negative association between device use and test performance (10). In addition, device use could potentially increase students' procrastination by providing frequent small gratifications, such as replying to emails and instant messages.

The costs of device use could be even higher in a home setting. While most laptops come with an easy solution for parents to set a hardline for screen time, parents usually do not know how to monitor what students do on their screens (11). Although the benefits of device use could be reduced in a home setting by, for example, video conferencing, interactive whiteboards, and classroom response systems which are most commonly used at school to facilitate group work among students (12), parents might not have sufficient technical knowledge or a set of protocols to enable the potential benefits of supervised device use at home, such as engagement, collaboration, or motivation. For example, when students watch videos on YouTube or message friends, it may be challenging for parents to tell whether students are watching videos or chatting with friends to complete assignments or group projects or just for fun. Such monitoring is relatively harder to enforce at home than in school because first, a teacher could have legitimate authority to designate students to work on the same task at the same time for a graded discussion or in-class quiz; secondly, parents' involvement in students' device use is usually perceived as intrusive by the students and may create tension and conflicts at home (13). The lack of ability for parents to understand what happens during students' home screen time means that parents cannot differentiate study time from idle time or game time, and thus cannot provide positive enforcement or structure to help students form good habits to manage screen time at home (13). Further, parents can also be too distracted to monitor students, and the inconsistency in parental monitoring can lead to more gaming and influence behavior by students (14, 15). Thus, distraction and procrastination could be more pronounced for device use at home. This leads to our two hypotheses.

Our first hypothesis predicts that device use at school increases students' learning effectiveness (which we will refer to as "H1"), and our second hypothesis predicts that device use at home decreases students' learning effectiveness (which we will refer to as "H2"). To test our hypotheses, we gathered data using an anonymous online survey among a random sample of middle school and high school students. To increase the chance of obtaining more accurate responses, we made the survey anonymous to reduce potential evaluation apprehension and social desirability bias. Because we were most interested in the relationship between technology use and learning experience of middle and high school students, we sent the survey to middle and high school students from two schools in the Midwest. We supplemented this initial sample with middle and high school students from various states across the United States that we were able to access through personal contacts.

We measured device use and learning effectiveness by asking participants to report their actual device use time, both at school and at home, and their learning effectiveness. Prior meta-analysis in education literature has suggested that the most frequently recurring words in defining learning effectiveness include learning outcomes, application to practice, perceived learning, skills or competency, attitude, satisfaction, skills acquired, and learning retention (16). Learning effectiveness could also be objectively assessed based on a measurement, such as a pre- and post-test (e.g., final exam), or a final letter grade (17). Learning effectiveness could also be subjectively assessed, based on a self-evaluation of whether the learning outcome met expectations. Our study takes a holistic view of learning effectiveness by using self-evaluation to measure learning effectiveness. Specifically, we defined learning effectiveness as the extent to which students' learning met their expectations. We also collected other variables for additional analyses, including student satisfaction with parental monitoring, student satisfaction with grades, most used websites for homework, and technology use by subject in order to find any relationship between these variables.

Our first hypothesis predicts that device use at school increases students' learning effectiveness (which we will refer to as "H1"), and our second hypothesis predicts that device use at home decreases students' learning effectiveness (which we will refer to as "H2"). We found partial support for H1. While we did not find an overall positive relationship between technology use at school and learning effectiveness, we found such effects among male students and middle school students. Consistent with H2, we found strong support for a negative effect of technology use at home and learning effectiveness. Furthermore, this negative effect was exacerbated for female students and middle school students. Taken together, these results showed that the effect of technology use on learning may depend on where the device is used, the gender of students, and the grade which students are in. We conducted additional analyses

to shed light on how technology use benefits learning. Our results suggest that technology use improves learning mainly by facilitating collaboration, enabling more personalized learning, improving organization, allowing teachers to provide more timely feedback, and making learning more enjoyable.

RESULTS

Descriptive Statistics

We first aimed to address the average device use time and the average learning effectiveness among the participants of our study. We accomplished this by examining descriptive statistics for our independent variables: amount of device use at school and amount of device use at home. We provide the percentage of respondents for each category of device use time at school and at home, respectively (**Table 1**). We provide descriptive statistics for our dependent variable, *Learning Effectiveness* (**Table 2**). We ask participants about the extent to which their learning met their expectations on a 7-point Likert-type scale, with 1 representing learning much less than expected and 7 representing learning much more than expected. We explicitly stated this in our survey question to make sure that students wouldn't misinterpret learning effectiveness. We found that, on average, students' learning effectiveness is 3.943 (median = 4) on a scale of 1 to 7, which suggests that, on average, students feel that they are learning slightly less than expected. In the following sections, we will report results on the relationship between our independent and dependent variables.

Technology and Learning Effectiveness

First, we wanted to determine how technology impacted the learning of the subjects. The regression results suggest that the overall effect of device use at school on learning effectiveness is insignificant. Although the coefficient on device use at school is positive (0.217), suggesting a positive relationship between the two variables, the coefficient is statistically insignificant with a *p*-value of 0.18 (**Figure 1A**). To shed more light on this result, we partitioned our sample by gender to see whether the effect of technology use at school on learning varies by gender. We found that the effect of technology use at school on learning was more pronounced for male students (coefficient = 0.57, *p*-value = 0.028) (**Figure 1B**) than for female students (coefficient = 0.14, *p*-value = 0.55) (**Figure 1C**). While the effect of technology use at school on learning was not significant for female students, it was significantly positive for male students.

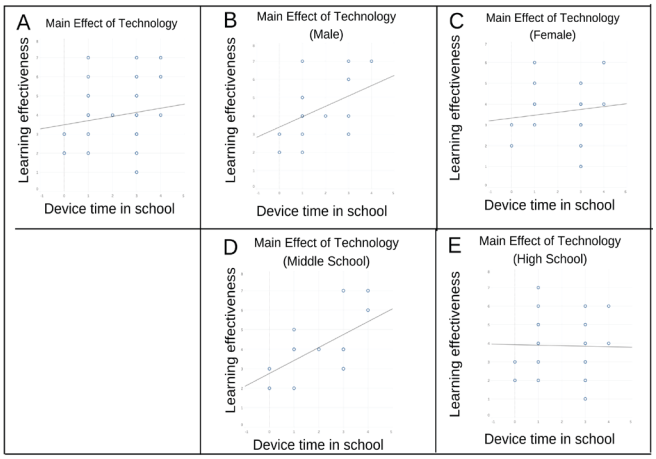

Figure 1. Relationship between device use at school and learning effectiveness. Scatterplot showing the result of regressing learning effectiveness on device use at school, in full sample (1A), for male students (1B), for female students (1C), for middle school students (1D), and for high school students (1E), respectively.

Percentage of respondents for each category of device use time at school and at home

Device at home	*Frequency*	*Percent*	*Device at school*	*Frequency*	*Percent*
Zero use	0	0%	Zero use	1	2%
< 1 hour	0	0%	< 1 hour	3	65%
1-3 hours	10	19%	1-3 hours	19	5%
3-5 hours	17	*31%*	3-5 hours	25	19%
5+ hours	27	50%	5+ hours	5	9%
Depends	0	0%	Depends	1	2%

Table 1. Demographics of survey respondents.

Descriptive of dependent variable: To what extent did your learning meet your expectations?

	Percentiles	*Smallest*	Obs.	54
1%	1	1	Mean	3.91
25%	3		Std. Dev.	1.43
50%	4		Variance	2.05
75%	5	*Largest*	Skewness	0.24
99%	7	*7*	Kurtosis	2.85

Table 2. Percentage of students for each category of device use time for independent variables: *Device use at school* and *Device use at home*.

Performing an intergroup analysis based on grade also yielded interesting differences across grades. We found that the effect of technology use at school on learning was more pronounced for middle school students (6th, 7th, and 8th grades) (coefficient = 0.66, *p*-value = 0.016) (**Figure 1D**) than for high school students (9th, 10th, 11th, and 12th grades) (coefficient = -0.027, *p*-value = 0.89) (**Figure 1E**). Collectively, these results provide partial support for H1, which stated that device use in school increases learning effectiveness. Although we did not find an overall positive relationship between technology use at school and learning effectiveness, we found such effects among male students and middle school students.

On the other hand, based on a regression of learning effectiveness on device use at home, we found that device use at home had a negative relationship to learning effectiveness, with a negative coefficient of -0.42 (*p*-value = 0.09) (**Figure 2A**). This result supports H2. When we divided by gender, we found that the negative effect of device use at home on learning was less pronounced for male students, as the p-value was not statistically significant (coefficient = -0.26, *p*-value = 0.5) (**Figure 2B**). By contrast, female students were much more negatively impacted by the use of devices at home, with their trend line having a steeper negative slope (coefficient = -0.77, *p*-value =0.017). (**Figure 2C**). Another subgroup analysis based on grade shows no significant difference between the middle schoolers and higher schoolers. The coefficient for middle schoolers is -0.59 (*p* = 0.17) (**Figure 2D**), and the coefficient for high schoolers is -0.28 (*p* = 0.39) (**Figure 2E**). Collectively, these results provide partial support for H2, which stated that device use at home decreases learning effectiveness. We found an overall negative relationship between technology use at home and learning effectiveness, and we also found that such effects were more pronounced among female students and middle school students. results on the relationship between our independent and dependent variables.

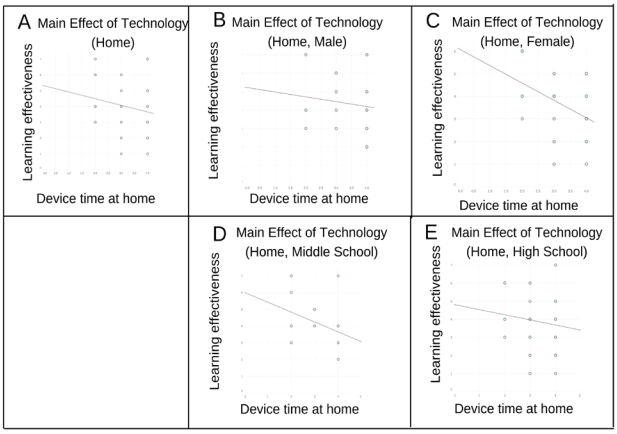

Figure 2. Relationship between device use at home and learning effectiveness. Scatterplot showing the result of regressing learning effectiveness on device use at home, in full sample (A), for male students (B), for female students (C), for middle school students (D), and for high school students (E), respectively.

Parental Monitoring and Learning Effectiveness

In addition to testing our main hypotheses regarding the consequences of device use, we also analyzed the consequences of parental monitoring of middle and high school students' device use. On one hand, parental monitoring of students' device use may prevent excessive device use for entertainment and promote more effective use of the device for learning. On the other hand, excessive parental monitoring may signal distrust of the students' ability to use devices responsibly and cause stress.

The first relationship we examined was between the amount of parental monitoring of device time and the learning quality of the participants. To measure parental monitoring of students' device use, we used the following item on the survey: "To what extent are your parents aware of your device leisure time?". This measure was obtained on a 5-point Likert-type scale with 1 corresponding to "They do not know much about my technology use" and 5 corresponding to "I am transparent with my technology use." We used this variable as the independent variable. We used learning effectiveness as the dependent variable in this analysis. Overall, we found an insignificant relationship between parental monitoring of students' device use and students' learning effectiveness, with a *p*-value of 0.357 (**Figure 3**).

Benefits of Technology Use in School and Learning Effectiveness

In addition, we measured the benefits of technology use for learning with several questions in the survey. Of note, 52 out of 54 respondents answered these questions. Results show that technology had six noticeably pronounced benefits, meaning that a majority of respondents selected "Agree" or "Strongly Agree" for those benefits (**Table 3**). These benefits included: (1) boosts to collaboration, selected by 86% of the respondents; (2) the ability to tailor learning to individual student's needs, selected by 81%

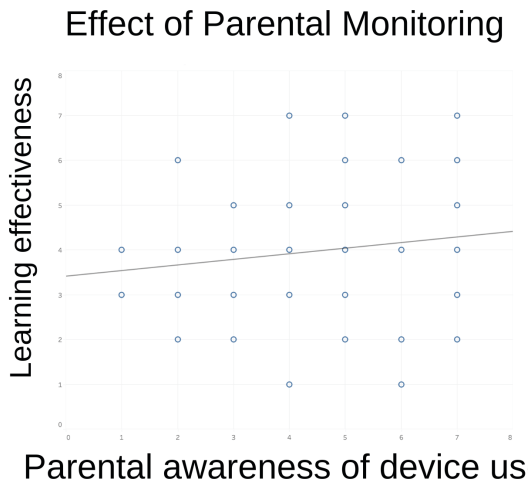

Figure 3. Relationship between parental awareness of device use and learning effectiveness. Scatterplot showing the result of regressing learning effectiveness on parental monitoring of device use.

Response of respondents regarding the benefits of technology

To what extent do you agree with the following statements?		Strong agree	Agree	Neither Disagree or Agree	Disagree	Strongly Disagree
Technology is helpful in school because it can be tailored to my needs.	#	17	25	9	1	0
	%	33%	48%	17%	2%	0%
Technology makes learning more enjoyable.	#	11	21	14	6	0
	%	21%	40%	27%	12%	0%
Technology helps decrease stress.	#	7	16	19	10	0
	%	13%	31%	37%	19%	0%
Technology helps me collaborate.	#	22	23	5	2	0
	%	42%	44%	10%	4%	0%
Technology helps me be more organized.	#	12	24	12	4	0
	%	23%	46%	23%	8%	0%
Technology helps motivate me to put in more effort.	#	6	5	22	18	1
	%	12%	10%	42%	35%	2%
Technology makes it hard for me to focus.	#	3	21	13	11	4
	%	6%	40%	25%	21%	8%
Technology makes me stay up later than my parents encourage me to.	#	18	8	15	9	2
	%	35%	15%	29%	17%	4%
Technology makes me more interested in learning on my own.	#	8	20	18	6	0
	%	15%	38%	35%	12%	0%

Table 3. Descriptive statistics for dependent variable: *Learning effectiveness*.

of the respondents; (3) making students more organized, selected by 69% of the respondents; (4) allowing more timely feedback from teachers, selected by 67% of the respondents; (5) making learning more enjoyable, selected by 61% of the respondents; and (6) the encouragement of self-study, selected by 53% of the respondents (**Table 3**). We found that the potential benefits of technology use in terms of reducing stress and enhancing motivation of students were notably less pronounced, with only 44% and 22% of the respondents selecting "Agree" or "Strongly Agree," respectively (**Table 3**). Regarding the downsides of technology use, we found that 46% of the respondents found technology distracting, and almost half of the respondent (50% of the respondents) found that technology use made them stay up late (**Table 3**).

DISCUSSION

Additional Analyses on the Relationship between the Benefits of Technology Use and Learning Effectiveness

Taken together, these results helped open the black box of how technology use benefits learning. These results suggest that technology use improves learning mainly through the following channels: facilitating collaboration, enabling more personalized learning, improving organization, allowing teachers to provide more timely feedback, and making learning more enjoyable. We acknowledge that we used a convenience sample, so the results of our study may not generalize to other samples of the population.

We conducted additional regression analyses to examine the relationship between the benefits of technology use discussed above and students' learning effectiveness. For example, we regressed learning effectiveness on the extent to which technology use facilitates collaboration. Untabulated results from these regression analyses support a positive relationship between these benefits and learning effectiveness. One potential limitation of this analysis is that the regression results for the various benefits of technology use are largely similar to each other. However, this could also be caused by the fact that independent variables in these regressions were placed quite near each other in the survey instrument we used, leading participants to answer similarly in those questions. This effect is known as straightlining in survey research, which is the tendency for respondents to give the same response to a series of grouped questions (17). We acknowledge this as a limitation in our survey. The best way to prevent this in the future, as well as other elements of bias in any given answer, would be to randomize the order in which questions were presented to the participants. This would help eliminate not only straightlining, but also weed out any potential priming bias. Another method that can be used to improve survey design and mitigate straightlining in the future is to phrase the questions differently. For example, some items can be phrased in a positive way and other items can be phrased in a negative way. Researchers can then validate respondents' answers to these questions to see whether the responses are consistent.

Contributions to Prior Literature

Results of our study contribute to the debate about the effect of technology use on learning in the prior literature in several ways. First, we extend prior literature by documenting that the effect of technology use on learning may depend on contextual factors including whether the device is used at school or at home, the gender of students, and the grade which students are in. These results provide a more nuanced view of the impact of technology use on middle and high school students and help us understand the mixed findings in prior literature. Secondly, we contribute to the prior literature by shedding light on the mechanisms through which technology use helps or hurts learning. Specifically, our results suggest that technology use improves learning primarily through the following channels: facilitating collaboration, enabling more personalized learning, improving organization, allowing teachers to provide more timely feedback, and making learning more enjoyable. We also document the two major costs of technology use for middle and high school students: distraction and reduced sleep. Future research can build on our study to examine how schools and parents can manage middle and high school students' technology use to maximize the benefits of technology use and mitigate the potential negative impact.

Practical Implications

As we observe the increasing presence of technology use both at home and in middle schools and high schools, results of our study have significant practical implications and contribute to the ongoing debate about the pros and cons of technology use for learning. The results documented in our study can provide valuable input for students, parents, teachers, and school administrators. Specifically, our results show that technology use at school has a greater effectiveness for males in comparison to females, and that technology use has a greater effectiveness for middle schoolers in comparison to high schoolers. We also found that technology use at home generally reduces learning effectiveness, and the negative effects on learning effectiveness are primarily driven by female students. While technology use at home does not appear to have a negative effect of learning for male students, it does have a negative effect on female students. We conjecture that these results could be due to a gender-based discrepancy in the amount of time spent on social media on these devices at home (18). These results suggest that limiting technology use at home for female students could benefit their overall learning. Furthermore, our results shed light on how technology use benefits learning. Our results that technology use can lead to distraction and sleep deprivation for middle and high school students highlight two aspects that require the attention of teachers, school administrators, and parents. Overall, these results can help students, parents, and teachers develop a more complete understanding of the pros and cons of technology use for learning and hence help them navigate learning in the digital age with more wisdom.

MATERIALS AND METHODS

Participants

We recruited participants from a private middle school (grades 6-8) and a public high school (grades 8-12) in a Midwest state, as well as from various public and private schools in other states across the U.S. The age of the participants ranged between 12 and 18. After obtaining permission from the students' parents, we administered the survey online. We received a total of 54 responses, including 27 from the two schools in the Midwest, and 27 from the latter pool. We acknowledge that we used a convenience sample, so the results of our study may not generalize to other samples of the population.We provide demographics for our sample (**Table 4**).

In the survey, we asked participants about their technology use at school and at home, perceived benefits and costs of technology use, and learning effectiveness, among other things.

Materials

We sent the preliminary draft of the survey to various anonymous middle school and high school teachers and students for feedback, and they responded with suggested additions and changes to the survey. We revised the survey instrument based on several rounds of feedback from middle and high school teachers and students. We used Google Forms for the survey. The final survey included three parts: (1) The consent form; (2) Specific questions about technology use at home and at school, perceived benefits and costs of technology use, and learning effectiveness; and (3) Demographic questions and general questions on schoolwork, homework, and parental monitoring.

Demographic Characteristics of the 54 Survey Respondents

Gender	*Frequency*	*Percent*	*Race*	*Frequency*	*Percent*
Male	25	46%	2 or more races	6	11%
Female	29	54%	Asian	35	65%
			Hispanic/Latino	2	4%
Grade	*Frequency*	*Percent*	White	10	19%
Middle school	22	41%	Not disclosed	1	2%
High school	32	49%			

Table 4. The number and percentage of students who (strongly) agree or (strongly) disagree with each of the benefits and costs of technology.

Specifically, we measured technology use with the following questions on the survey "On average, how much time do you spend using technology in school (at home) each day?". This question was evaluated with an interval scale between 1 and 4 with 1 corresponding to "less than 1 hour", 2 corresponding to "1-3 hours", 3 corresponding to "3-5 hours", and 4 corresponding to "> 5 hours." A higher number indicates more device time, and we used this variable as the independent variable. We measured learning effectiveness with the following survey item: "To what extent did your learning meet your expectations?" This measure was evaluated with a 7-point Likert-type scale and was used as the dependent variable. This means that our measure of learning effectiveness was dependent on student expectations of their learning.

Procedure

We first emailed the parents of all the students in the two schools in the Midwest, and to various other parents across the country with whom the authors have personal contact to obtain parental permission for their children's participation in the survey. After obtaining consent from the parents, we sent the survey in the form of a Google Form to their children. We distributed our survey on May 6, 2020, when most of the respondents had been participating in remote learning for one to two months. We received responses between May 26, 2020, and June 24, 2020.

We analyzed the data using Excel and Tableau. We first saved the raw data from Google Survey in Excel, and then exported the Excel spreadsheet into Tableau for all statistical analyses. For descriptive statistics, we checked the distribution of these variables and provided mean and standard deviations. For hypotheses tests, we used regression plots to visualize our results because both the independent variable (device use) and dependent variable (learning effectiveness) are continuous in most of our analyses. Specifically, we used Ordinary Least Squares (OLS) regressions and reported two-tailed *p*-values.

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