Do hotspots improve student performance? Evidence from a small-scale randomized controlled trial
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Abstract
Much has been made about the “homework gap” that exists between students who have access to the Internet and those that do not. Policy-makers increasingly recognize the connectivity aspect of this issue but typically fail to acknowledge the importance of computer ownership. We use a small-scale randomized controlled trial \((n=18)\) to test whether the provision of Internet access by itself — or in conjunction with a laptop computer — improves educational outcomes of alternative high-school students in the U.S. Our results suggest that the combination of Internet access and computer ownership is more effective than Internet access alone for positive educational outcomes.

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Introduction
Before (and during) the COVID-19 pandemic, communities and schools have recognized that students without Internet access at home are at a disadvantage. However, an overlooked aspect of this disparity is that many students also lack a desktop or laptop computer at home. Disconnected students likely benefit if they are given free Internet; however, their school performance may still suffer if they are limited to completing assignments on a smartphone. This project randomly assigned 18 disconnected students into three groups — Internet, Internet + laptop, and control — and followed their educational outcomes pre- and post-intervention. We find evidence that providing both Internet access and a computer results in improved academic attainment, but providing only Internet access does not. This is an important finding since most policies to date have focused explicitly on the Internet provision component.

The homework gap
As the Internet has become pervasive across most aspects of American life, much has been made of the “homework gap” between school-aged children who have access to the Internet at home and those that do not (McLaughlin, 2016; Meyer, 2016; Wong, 2018; Moore, et al., 2018; Santillana, et al., 2020). As of 2017, 14 percent of school-age children lacked any type of Internet access at home, with higher rates for non-metropolitan, African-American, and low-income households (18 percent, 19 percent, and 28 percent, respectively) (National Center for Education Statistics [NCES], 2021). This disparity has led to concerns that students without home access will fall behind their peers and, over the long term, exacerbate existing economic gaps across these categories. The recent COVID-19 pandemic has brought...
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This topic to the front of the national news (Lee, 2020; Vogels, 2020). While the Internet-related portion of this gap is increasingly acknowledged by policy-makers (King, 2015; Consortium of School Networking [CoSN], 2018; Fazlullah and Ong, 2019), an important but less recognized counterpart is that 15 percent of households also lack desktop or laptop computers (National Center for Education Statistics [NCES], 2021). Thirty-five percent of U.S. teens acknowledge sometimes doing their homework on a smartphone (Anderson and Perrin, 2018), and recent data suggests that low-income students are much more likely to do their schoolwork on a smartphone than their higher-income counterparts (Vogels, 2020). The limitations of completing schoolwork on such a device vary by context — for example, compiling a report or building a presentation are much more difficult on a smartphone than is conducting Internet research or viewing educational videos. Even at the college level, only limited guidance on optimizing mobile device use is available for most course design instruments (Baldwin and Ching, 2020). Regardless, the lack of computer access is an important consideration in the homework gap discussion. Some school systems have dealt with this problem by offering “one-to-one” programs providing laptops to every enrolled student; however the cost of such programs has limited their implementation in districts with fewer resources. Recent research has shown that roughly half of all schools have a one-to-one program as of 2019; up from 26 percent in 2016 (Mouhanna, 2019). A meta-analysis on these programs found positive average effect sizes for English, writing, mathematics, and science (Zheng, et al., 2016).

Recent work in this area has suggested that wireless solutions to the homework gap have promise (Reisdorf, et al., 2019). This is consistent with recent trends showing shifts to wireless connections for the population as a whole (Manlove and Whitacre, 2019). These solutions include loaning out hotspots (devices that use a local cellular network to emit a wi-fi signal) to students without a connection of their own. Some public libraries offer this service to their patrons (Inklebarger, 2015; Schrubbe, 2017). K-12 libraries have been slower to adopt but examples exist and were growing even prior to the COVID-19 pandemic (Willert, 2016; Tate, 2018). Such efforts increased dramatically during the pandemic when nearly all U.S. school systems were forced to transition to remote learning (Freedberg, 2020; Reilly, 2020). The Coronavirus Aid, Relief, and Economic Security (CARES) Act passed in March 2020 provided US$13.2 billion for K-12 funding, with some of the funds passed down to schools being used to distribute hotspots to students lacking a connection (Jordan, 2021). As such programs gain momentum, a useful question is whether the provision of hotspots by itself leads to improved student performance in households without Internet access. If the devices are used solely in conjunction with smartphones, their impact on school performance may be limited. Alternatively, partnering the hotspot with a loaned laptop computer may result in significantly better school outcomes. The lack of home-based Internet or computers can be dramatic in some instances — a 2018 survey found that 12 percent of teachers said that the majority of their students (61 percent to 100 percent) do not have home access to the Internet or to a computer (Fazlullah and Ong, 2019). Testing how such students respond to different types of technology access (i.e., Internet alone vs. Internet + computer) is an important component of this discussion.

This paper describes a small-scale randomized controlled trial designed to empirically test this premise. Eighteen high school students without Internet access at home were randomly selected into three groups: one receiving hotspots, one receiving hotspots and laptops, and one control. Participants were followed for one full semester and compared in terms of credits completed, grade point average, and number of days absent. The results suggest that only the group receiving both hotspots and a laptop had meaningful improvements in school performance from the prior semester.

The digital divide and computer gap in context

The American education system is increasingly embracing the power of the Internet. Seven out of ten teachers report assigning homework that requires Internet access (Steyer and Johnson, 2018). Ninety percent of high-school students report being assigned online-based homework at least once a month and 50 percent of all students report being assigned this type of homework almost daily (Anderson and Perrin, 2018). Despite the necessity of Internet access to complete schoolwork, students lack equal access to the Internet. This is particularly true for students that reside in rural communities, are African-American, or live in low-income households (National Center for Education Statistics [NCES], 2021). Nearly one third of students living in low-income households (US$30,000 or less annually) do not have Internet access, compared to only six percent of students living in high-income households (US$75,000 or more annually) (Anderson and Perrin, 2018). In 2015, only 64 percent of non-metropolitan households had a broadband subscription compared to 74 percent of metropolitan households (Lee and Whitacre, 2017). Without a high speed Internet connection, households are disadvantaged compared to those with connection (Horrigan and Duggan, 2015). There is evidence that home Internet access can result in higher reading comprehension, standardized test scores, and overall GPA for low-income students (Jackson, et al., 2006). Another study found that these results are even stronger the longer the students have Internet access (Jackson, et al., 2007). One study that provided Internet-enabled tablets to fifth graders noted improved communications between student and teacher as well as improved math scores (Kajeet, 2015).
In addition to a lack of Internet access, students also face a computer ownership gap. In fact, one recent survey of nearly 1,000 households with children in Austin, Texas found that 20 percent of parents were concerned with a lack of access to computers while only 12 percent were concerned about the lack of Internet access (Santillana, et al., 2020). This gap is highly correlated to home income levels, with only 58 percent of households making less than US$10,000 having a desktop, laptop, or notebook at home — much lower than the 94 percent of households with more than US$75,000 in income (KewalRamani, et al., 2017). There are also racial and geographic components to this gap. Almost one quarter of African American students report not being able to complete homework due to a lack of computer access, and almost half of all students in low-income households rely on cell-phones to complete homework (Anderson and Perrin, 2018). Location also affects computer ownership rates with 24 percent of rural students having only one device capable of connecting to the Internet, while just nine percent of suburban students had a single connection (Moore, et al., 2018). Of the students who have only a single connection, most rely solely on a smartphone (Moore, et al., 2018). By only accessing the Internet via smartphones, users are often completing tasks that are meant for the larger screen size of computers (Anderson and Kumar, 2019). This drawback was also noted by teachers attempting to implement mobile learning into their classrooms (Bai, 2019). Students are often forced to ask their teachers for special accommodations or rely on the technological resources of their peers to complete homework requiring a computer (Wong, 2018; Melia, et al., 2019). Recent research has found that high-school students dependent on cell phones for home Internet access performed significantly lower on school-related outcomes such as homework completion, grade point average, and standardized testing (Hampton, et al., 2020). These results held after controlling for demographic characteristics such as race and income. To address the computer gap, many schools have implemented one-to-one laptop programs where each student is provided a laptop. However, there is still debate if these programs actually decrease the inequalities that students face (Zheng, et al., 2016) — and, as noted earlier, the cost of implementing such a program is a difficult obstacle to overcome. One rural school that implemented a one-to-one program in 2012 found that 70 percent of their students did not have Internet access at home (Curry, et al., 2019).

Computer ownership does show promise in increasing various academic performance measures. Early studies of home-based computer use by students raised questions about the equity issues involved (Downes, 1996). Simple comparisons of school achievement show higher scores across all categories (reading, math, and science) for students who use a computer at home versus those that do not (KewalRamani, et al., 2017); however, this analysis does not account for self-selection and has no relevant counterfactuals. A quasi-experimental comparison of sixth grade mathematics classrooms that employ one-to-one laptop programs versus classrooms without laptop programs showed that students in the laptop classrooms outperformed the non-laptop students on quarterly mathematics exams (Clariana, 2009). Another analysis compared students within the same school district by comparing students enrolled in the schools laptop program versus those not enrolled in the program. The authors found evidence that suggest enrollment in the laptop program increased mathematics and language arts scores and also increased overall cumulative GPA (Gulck and Demirtas, 2005). One program that provided computers to families in low socio-economic areas of Australia noted the ways that K-12 students used them for school activities (Yelland and Neal, 2013). Additional studies have demonstrated that computer availability matters for older students as well. In a randomized controlled trial field experiment, researchers provided college-age students with a laptop to use at their own discretion (Fairlie and London, 2011). The results of this trial found statistically significant evidence that computer ownership increased educational outcomes — a result that held even with regression-adjusted estimates controlling for individual student characteristics. Interestingly, the study also found that the increase in educational outcome was higher for students who lived farther away from campus; however, this was not consistent across each measure of educational outcome considered (Fairlie and London, 2011).

The current literature provides evidence that both increased Internet access and computer ownership have the potential to limit the effects of the homework gap and increase student performance. These studies focus on Internet access and computer ownership separately, without consideration for the interaction between the two. To our knowledge, there are currently no empirical studies that test whether the provision of both Internet and computer is measurably better than providing only one. The aim of this project is to complete a randomized controlled trial that performs such a test. In particular, we are interested in whether Internet provision by itself is enough to elicit improvements in student achievement, or if both Internet and computer access are required.

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**Methodology**

This project approached an alternative high school in one mid-sized Midwestern city in the United States during the...
Fall of 2017. The alternative high school was selected after the local traditional public high school chose not to participate. An alternative high school is one that has non-traditional curriculum and methods. The school we chose did not have formal semester-long classes but instead allowed students to work on a particular subject as long as they needed before taking a formal test assessing their knowledge of the subject. As a result, students varied in the number of credit hours they earned each semester. They earned grades based on their performance on the subject tests and exercises leading up to it. Notably, no standardized tests were given at this school, and as such we did not include them in our analysis. For these reasons, we are up front that our results are likely not generalizable to traditional high school students. The faculty and staff of the high school helped us recruit students who indicated that they lacked both a wired Internet connection and a laptop/desktop computer at home, without consideration for any other demographics. We provided those students with a summary of the project, a consent form, and preliminary surveys to be completed by the student and their guardian. The survey contained information regarding the socioeconomic characteristics of the household (income levels, race, number of household members, single-parent status, parental education levels), and both guardians and students signed consent forms permitting us to access the students’ school records for the previous and forthcoming semester. Students also agreed to complete short surveys about their Internet use during the semester. A total of 18 students completed all required forms. All were aged 16–18 and were approximately one to two years away from graduation. Oklahoma State University’s Institutional Review Board (IRB) approved the protocol for the study.

Hotspots and monthly data plans were purchased from PCs for People, which provides low-cost Internet access to non-profit and low-income individuals. These hotspots used a cellular network that had good connectivity in the school’s city and surrounding areas. The devices were filtered for pornography (via the manufacturer) at the request of the school principal, but provided unlimited data access each month. This was important, because while each student had their own smartphone, data limitations often prevented them from using it for educational or entertainment purposes. While researchers could see the total amount of data used by each hotspot per month, they did not have access to the individual Web sites visited. Participants were informed of what Internet data would be available to the researchers prior to signing the informed consent form. Lightly used laptops were provided from Oklahoma State University, which came with Microsoft Office and an Internet browser installed. Participants acknowledged that they would return both the hotspot and the laptop upon completion of the project (after one semester of use).

Upon receipt of all forms and surveys, we randomly assigned the 18 students into the three study groups. Although this is a small number for a quantitative study, it did allow for even distribution across the categories of the randomized controlled trial. Table 1 shows the distribution of the socioeconomic characteristics across the groups. Despite the small sample size, the groups are quite similar across nearly all characteristics. While the control group has a higher percentage of single-parent households and slightly lower income levels, none of the means are statistically different from one another. This may be due to the small number of observations in each group (6). In particular, with such a small sub-sample even a single student could have a sizable impact on differences between groups. The only significant differences that exist are for parental education, where the control group exhibits a lower level than the hotspot-only group; and the number of household members, where the hotspot group is higher than the hotspot + laptop group. The remaining similarities across several categories ease concerns that any differences in outcome measures across groups might be due to underlying background characteristics. It is worth noting, however, that failing to reject our null hypothesis of no differences between groups is different from proving that they are statistically identical. This is particularly important given our small sample size, which makes it difficult to achieve statistically significant differences.

<table>
<thead>
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<th>Table 1: Demographic characteristics across randomized groups.</th>
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<td>Note: C, H, and HL denote statistically significant differences between the Control, Hotspot, and Hotspot + Laptop groups at the p &lt; 0.05 level.</td>
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<tr>
<td>Percentage female</td>
</tr>
<tr>
<td>Household income</td>
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<tr>
<td>Percentage &lt;US$10,000</td>
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<td>Percentage US$10,000–</td>
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The hotspots and laptops were provided to the students in January of 2018, to be used for the duration of the spring 2018 semester. While teachers were aware of the project, we did not meet with them and to the best of our knowledge they did not change their teaching approach from previous semesters. An Internet-based follow-up survey to all participants (including the control group) was sent out via e-mail and text messages in March 2018 (Appendix). The survey asked questions about homework habits and Internet use, including their opinion on the usefulness of laptops versus smartphones for homework purposes. The response rate for the survey was 100 percent after reminders via text message and school officials. Outside of this survey, students were not contacted until the final week of the semester (May 2018). At this point, a reminder was sent out to all participating students that received hotspots or laptops to return them. Project leaders met with all students individually upon device return, and asked concluding questions about their experience. Approximately one month following the students’ last day of school (June 2018), project leaders met with school officials to gather student performance and attendance data from the fall 2017 (pre) and spring 2018 (experiment) semesters. We were again able to gather data on 100 percent of participants. Simple t-tests were used to compare differences across categories, including the pre- and during-experiment periods.

## Results

### Student Internet use and perceptions of devices

The results of the follow-up survey sent to all participants approximately 1.5 months after the devices were distributed are displayed in Figures 1–4. In Figures 1 and 2, the category selected by the respondent was converted to a point estimate by using the midpoint of that category (for example, 1.5 when the category ranged from 1-2). Categories with no upper limit were coded as one unit above the endpoint (for example, 11 when the category was 10+). Figure 1 demonstrates that while the total hours per week spent doing homework was similar (5.3–6.3 hours) across all three groups, the Internet was accessed for homework purposes significantly less often in the control group (only twice per week, compared to nearly six for the hotspot + laptop group). Internet use for homework for the Hotspot-only group was also higher than the control (four times vs. two), but this difference was not statistically significant (p=0.19). General Internet use was also notably lower for the control group, at one hour per day; groups receiving hotspots reported between two and three hours of daily use. This reflects the limited Internet access available to the control group, since all participating households attested that they lacked a wired residential connection. Figure 2 compares...
the percentage of time spent on different categories of Internet use. The percentage of Internet time spent on homework is noticeably higher for the hotspot + laptop group (55 percent vs. 30 percent in the control group). We note that the Hotspot + Laptop group was not statistically different from the Hotspot-only group, although it was very close ($p = 0.056$).

**Figure 1:** Student time spent on homework, Internet, and school-related Internet use; by randomized group.
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Figure 2: Student usage of Internet time, by randomized group.

Figure 3 presents student responses to two statements about Internet use and schoolwork, using a 1–5 Likert scale. All groups agree with the statement that Internet use improves their school performance, although the control group had less strenuous agreement when compared to the other two categories. The hotspot + laptop group disagreed with the statement that smartphones were just as useful as laptops for schoolwork, suggesting that the provision of laptops allowed students to see their benefit firsthand. The opinions of the hotspot + laptop group were measurably different from those for the control group on this question. Along this vein, Figure 4 shows that the hotspot + laptop students were much more likely to use laptops as part of their schoolwork when compared to the other two groups.

H1, H2, and C denote a group that is statistically significantly different from the Hotspot, Hotspot + Laptop, and Control groups (at the p<0.05 level), respectively.
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Figure 3: Student Internet/smartphone use perception, by randomized group.

H, HL, and C denote a group that is statistically significantly different from the Hotspot, Hotspot + Laptop, and Control groups (at the $p<0.05$ level), respectively.
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Figure 4: Student types of device used for schoolwork, by randomized group.

**Student performance/attendance outcomes**

The findings from the initial follow-up survey suggested that the loaned devices (hotspots and/or laptops) were having an effect on the way the students approached their schoolwork. However, a comprehensive evaluation of their impact on school performance could only be accomplished following the completion of the semester. Importantly, student data was gathered from the prior semester (Fall 2017) as well, so that each student was compared against their own baseline accomplishments. Figures 5–7 show the results for three outcome measures: (1) number of credits earned; (2) grade point average (GPA) on a four-point scale; and, (3) days absent during the five-month semester. Recall that this alternative school allowed students to work at their own pace, taking exams for course credit when they felt they were ready. As such, each student had a different curriculum than their classmates — adding another concern to the small size of each sub-group. Figure 5 shows that the only group to increase the number of credits obtained during the experiment period (Spring 2018) was the hotspot + laptop participants. This group showed a sizable jump of credits earned per semester, from 4.8 to 8.0. The number of credits earned remained about the same for the hotspot-only group (6.2 to 6.0) while the control group showed a non-statistically significant decrease (from 8.0 to 6.2). Figure 6 further shows that although none of experiment-period GPAs were statistically different from the prior period, only the hotspot + laptop group moved in the positive direction (from 2.7 to 3.0). GPAs in the hotspot-only group were very similar across semesters (3.3 to 3.2) while the control group saw a slight decline (3.0 to 2.8). Figure 7 indicates that all groups suffered from an increased number of days absent during the Spring 2018 semester (over a 40 percent increase on average). Such a high number of absences — and shifts in absence levels across semesters — are not uncommon in alternative high school students (Fuller and Sabatino, 1996). Notably, however, the increase in absences was relatively limited for the hotspot + laptops group (19 days higher in Spring vs. Fall) in comparison to the hotspot only (40 more missed days in Spring) and control (42 more missed days in Spring) groups. Only the hotspot group showed a
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A statistically significant increase over time ($p = 0.0338$). The control group showed a larger difference in number of days, but was not significant due to a high degree of variation in the responses ($p = 0.0640$).

**Figure 5:** School credits earned before and during experiment, by randomized group.
Figure 6: Grade point average (GPA) before and during experiment, by randomized group.
Finally, we compared the change in pre- and during-experiment values for the three outcome measures across the three randomized groups. Table 2 displays the results, and shows that only the number of credits earned was significantly different for the hotspot + laptop when compared to the control group. None of the other simple differences were statistically higher or lower across groups.

Table 2: Outcome measure summary and comparison across randomized groups.

<table>
<thead>
<tr>
<th></th>
<th>Pre</th>
<th>During</th>
<th>Difference</th>
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<tbody>
<tr>
<td>Credits earned</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hotspots</td>
<td>6.2</td>
<td>6.0</td>
<td>-0.2</td>
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Note: * denotes statistically significant difference across pre- and during-time period at the $p<0.05$ level; C and HL denote a statistically significant group difference when compared to the Control and Hotspot + Laptop group (at the $p<0.05$ level), respectively.

Figure 7: School absences (number of days) before and during experiment, by randomized group.
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<table>
<thead>
<tr>
<th></th>
<th>Hotspots + Laptops</th>
<th>Control</th>
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<tbody>
<tr>
<td>Grade point average (four-point scale)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hotspots</td>
<td>3.3</td>
<td>3.1</td>
</tr>
<tr>
<td>Hotspots + Laptops</td>
<td>2.7</td>
<td>2.8</td>
</tr>
<tr>
<td>Control</td>
<td>3.1</td>
<td>2.8</td>
</tr>
<tr>
<td>Days absent</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hotspots</td>
<td>58.3</td>
<td>73.8</td>
</tr>
<tr>
<td>Hotspots + Laptops</td>
<td>75.7</td>
<td>116.0</td>
</tr>
<tr>
<td>Control</td>
<td>73.8</td>
<td>116.0</td>
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</table>

Discussion and conclusion

The results of this small randomized controlled trial suggest that simply providing alternative high-school students with Internet access is not enough to have a meaningful impact on student performance over the course of a semester. Rather, a combination of Internet access (hotspots) and tools to take advantage of that access (laptops) are more effective at generating improvements in scholastic achievement. The group assigned both of these devices was the only one to show measurable increases in the number of credits earned, and to display a positive trend in GPA (although not statistically significant). We also highlight the significantly higher proportion of Internet time spent on homework for this group (Figure 2); those in the hotspot-only group spent roughly the same percentage of Internet time devoted to homework as did the control (around 30 percent). Recall that the guardians of these students all attested that they did not have a fixed broadband connection at home; however simply providing them with a comparable Internet alternative was not enough to increase their Internet time spent on homework. The mobile network used regularly provided speeds of 10 megabits per second (MBPS) download and one MBPS upload in the study area. This is slower than the current U.S. Federal Communications Commission (FCC) definition of broadband (25 MBPS down, three MBPS up), but no students noted that their device use was limited by speed availability. As a corollary to this, we obtained the total amount of data consumed on the Internet across the two groups provided with hotspots after the project was over. The average per-month consumption was 212 megabytes (MB) for the hotspot group, and 190 MB for the hotspot + laptop group. While these were somewhat skewed by several “very high” data consumers in each group, the higher average usage in the hotspot-only group may suggest that the devices were being used more for videos or entertainment (which typically require more data than simple Web searches or basic research) than for school-oriented purposes.

This study is clearly limited by the very small sample size, with only six observations in each group. Individual circumstances can play an outsized role in such small samples, such as the increased number of school absences that affected many in our study and the group differences in pre-treatment school performance metrics in Table 2. Undoubtedly, such conditions would also impact school results. Unfortunately, we do not have enough observations to run a regression analysis to control for these factors as some prior studies do (Fairlie and London, 2011). However, statistical significance can be difficult to obtain in small samples, and its presence across several survey responses and one main outcome measure suggests that students receiving both hotspots and laptops view — and use — the Internet differently. Our individual student results show that all six of the hotspot + laptop recipients improved the number of credit hours earned during our experiment; this was true for only three students in the hotspot group and just one in the control group. The fact that the improvement occurred across a range of student ability levels is also noteworthy: students earning a low, moderate, and high number of credit hours prior to the experiment all experienced progress when they had access to both types of devices. Our study is also limited due to a lack of insight into students at the school without an Internet connection at home but who chose not to sign up to participate in the project. The characteristics of these students may be different from those who did participate, and our results are only
representative of the group that joined the study. Further, although our randomization process did effectively allocate the percentage of students in single-parent households across categories (Table 1), we did not explicitly ask questions regarding parental involvement. Castro, et al. (2015) note that the strongest associations between parental involvement and student outcomes are in families with high academic expectations, which is not likely in this instance given the alternative school’s use of self-paced study and lack of required standardized test scores. Regardless, parental involvement is an important consideration for student outcomes that should be controlled for in future studies.

We caution that because our sample is comprised of alternative school students, the results may not apply to traditional public schools. Alternative school students generally enroll because something about a traditional school environment did not work for them. Smaller class sizes, a wider variety of teaching methods, and flexible graduation requirements are often noted as reasons for choosing an alternative school (Fuller and Sabatino, 1996; Dugger and Dugger, 1998). Stewart (2008) finds that structural differences in schools do have some effect on student performance, although these effects are relatively small compared to individual factors. The differences between alternative and traditional schools may be important for how students respond to technology access; the results here suggest that the availability of both the Internet and a smartphone alternative are important for positive student outcomes for those learning in a non-traditional environment. Future research should attempt to both increase the sample size and replicate this result in a traditional high school atmosphere. We also note that while there was significant overlap and a clear “core curriculum” across the three groups in terms of the types of credits earned during the semester of the experiment, students were free to choose from a variety of courses offered by the school. The core curriculum included classes in English, math, social studies, and science. Examples of courses outside this core included those in languages and visual arts. Several classes only showed up in one of the three randomized groups, and while they may have had different degrees of difficulty, their small number (five percent of all 121 credits earned) limits concern about how this might skew the results.

We did have an opportunity to sit with each study participant and review the project upon its completion (i.e., when devices were turned back in). These one-on-one sessions allowed for a free discussion of any issues that arose during the study. The students were generally very appreciative of the devices loaned to them, and several remarked that they felt that their schoolwork improved because of the devices. Participants receiving laptops noted taking pride in them, and all were all returned in good condition. No issues were reported with lost or stolen devices; many students indicated that the devices were widely used by others in their household. We also did not receive any comments about cyberbullying, although most students acknowledged participating in various forms of social media. Students reported connecting up to five devices at one time to a single hotspot; and none indicated that their usage was affected by slow download or upload speeds.

As Internet use permeates through nearly all aspects of society, the “homework gap” will continue to be an important policy issue for the foreseeable future. Different approaches for solving this problem have been suggested, including identifying community homework hotspots where students can congregate, installing wi-fi on school buses, or even building private networks (Consortium of School Networking [CoSN], 2018). The results here imply that viewing the homework gap as solely one of Internet access is too simplistic: access to digital technology such as laptops or desktops is also a crucial component. This finding is in agreement with other recent research documenting that cell phone-only access results in lower school performance for high school students (Hampton, et al., 2020), and recent survey results from Austin, Texas showing that more parents/guardians were concerned about the lack of computer access than were concerned about Internet access (Santillana, et al., 2020). Thus, programs focusing solely on the Internet provision problem may not achieve the degree of equality they seek. Rather, such efforts should be combined with programs to increase laptop or desktop availability. This could be via a district-level one-to-one program or by working with a local non-profit to distribute low or no-cost computers to students in need. One such program emphasizing this combination is the wireless provider Kajeet; they offer a variety of school connectivity alternatives including hotspots and a one-to-one laptop component. However, such programs can be costly with hotspots averaging US$90 plus US$20/month for data, and laptops averaging US$150 (Kajeet, 2019). This would work out to nearly US$500 per student per year, a prohibitive amount for many school districts. Kajeet has its own grant program, however relatively few are awarded (only five grants were awarded nationally during the initial cohort in 2017 and 15 in 2018). Other low-cost providers also exist. A good example is PCs for People and Mobile Beacon’s “Bridging the Gap” program that recognizes the importance of both the Internet and digital tools to use it effectively (PCs for People, 2019). Neal (2016) notes the existence of several federal funding programs that can be used to initiate these types of efforts, including Title I and School Improvement Grants from the U.S. Department of Education.

In conclusion, recent policy papers on the homework gap focus almost explicitly on the broadband access portion of the issue (Fazlullah and Ong, 2019; Consortium of School Networking [CoSN], 2018). The recent COVID-19 pandemic has highlighted the importance of digital learning, and future research will focus heavily on the lessons
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learned during this time. This study argues that future policies geared towards bridging the homework gap should recognize that computer or laptop access to supplement Internet connectivity is an important component that is often overlooked. This randomized controlled trial, though small in size, offers evidence that the provision of both Internet and laptop computers results in better school outcomes than simply providing Internet access alone. Although there are notable limitations to the analysis, this study offers some preliminary evidence about the necessity of computers as part of the homework gap solution, and sets the stage for additional research on this topic. 

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Appendix: Student survey on home Internet use

Home Internet Use Survey (Student Version)

Student’s name: __________________________ Date: _____________

The questions below refer to the last 4 weeks. Give your best estimate of the averages over that time.

1. On average, how many hours per week did you spend doing your homework?
   - None
   - 1-2
   - 3-6
   - 7-10
   - More than 10

2. During the last week, how many times did you access the Internet specifically for homework or other school-related activities? (Include access from any location)
   - None
   - 1-2
   - 3-6
   - 7-10
   - More than 10

3. Where are you most likely to be when you are connected to the Internet?
   - My house
   - Library/school
   - Friend/relative’s house
   - Business with free Wi-Fi (McDonald’s)
   - Some other place

4. What device do you tend to use the most for school-related Internet searches and assignments?
   - __________________________
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Editorial history

Received 1 December 2020; revised 18 March 2021; accepted 15 June 2021.

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Do hotspots improve student performance? Evidence from a small-scale randomized controlled trial by Brian Whitacre and Amanda Higgins. 
First Monday, volume 26, number 7 (July 2021). 
doi: http://dx.doi.org/10.5210/fm.v26i7.11467