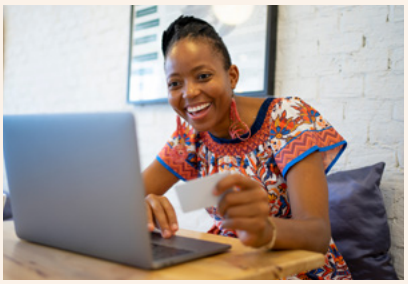
K-12 BLUEPRINT

Curriculum Platform Evaluation	Commissioned by Intel®
August 2020	Prepared by Clarity Innovations, Inc.

Planning for Virtual Learning

How Connectivity, Operating System, and Device Selection Effects Teaching and Learning Outcomes for Virtual and Blended Environments


Executive Summary

This evaluation report provides information to help school districts make informed choices in selecting the right devices to equitably support students and educators returning to school – virtually or in blended/hybrid learning environments – in the fall of 2020. Using authentic examples of curricular, pedagogical, and instructional practices, including applications, tools, and services students and educators regularly use, this study provides specific test results and recommendations for school and district leaders to help them make informed decisions to meet the needs of each student. The report highlights equity considerations including how rural, BIPOC, and students residing in high poverty areas are disproportionately affected by persistent periods of limited or no connectivity to the internet.

By exploring devices running the most common operating systems and typical software used in K-12 education, challenges including device storage and the functionality of applications when no internet connection is present must be addressed for virtual and online learning to be successful. While there is no one-size-fits-all solution, the key findings of this report will help school districts make the right choice to improve the process and practice of teaching and learning.

> **"Students who do not have home internet access...spend more time on their homework, have lower grade point averages, and have weaker digital skills, even after controlling for socioeconomic factors that potentially influence academic performance[1]."**

Digital Learning Tasks

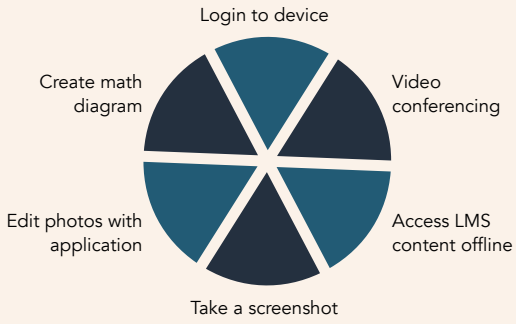


Chart 1: Example learning tasks tested in this study.

Offline Task Completion Rate

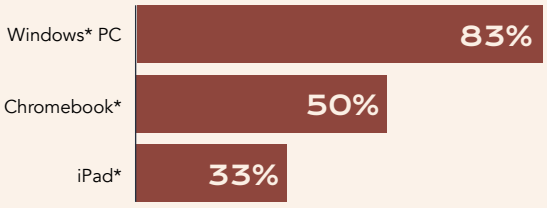


Chart 2: Success rate of each operating system completing digital learning tasks when not connected to the internet. See Appendix C for details.

[1] Source: Columbia Telecommunications Corporation, Mobile Broadband Service Is Not an Adequate Substitute for Wireline (Kensington, MD: Author, 2017).

8 Key Findings

1

Many common education apps and browser extensions have limited or no functionality – depending on operating system – when not connected to the internet.

2

All platforms require connectivity on first use of the device to provision applications and resources and federate login credentials.

3

Device storage is key to support devices that do not have a persistent, high-bandwidth connection to the internet. Expandable storage options including SD Cards and USB drives should be considered as a means to deliver curricular materials to students and will effect total cost of ownership.

4

Offline access to most learning management systems (LMS) is extremely limited or unavailable. Some LMS services, like Canvas*, allow users to download an entire module as an HTML or EPUB file which can be used as a work-around solution for students who lack connectivity.

5

Most of the evaluated curriculum from various publishers do not have digital applications or mobile access that support offline use, though many offer collections of materials (e.g., PDFs and video files) that can be downloaded and shared.

6

Adobe Flash* is still present in many K-12 resources and presents problems across many platforms (e.g., Apple* iPad* doesn't run Adobe Flash* applications). Flash* is scheduled to be deprecated by **Adobe*** in December 2020 and will no longer be available on **Chromebooks*** after January 2021.

7

Enabling and accessing files stored on Google Drive* for offline use is a complicated, **multi-step process** which includes using only the Chrome* browser, installing the offline extension, enabling offline access through the Chrome Management Console*, and making specific files available offline.

8

To support students with limited or no internet connectivity, educators and curriculum specialists must be mindful of file sizes and delivery methods for content shared with students and plan for how students can submit their work.

Storage Available for Curriculum and Student Work

	Total Storage	OS & System Requirements	Available Storage
Windows* 10-based device	128 GB	43.4 GB	84.6 GB
Chrome OS*based device	32 GB	14.8 GB	17.2 GB
iPad*	32 GB	7.3 GB	24.7 GB

Maximum Capacity for Curriculum

	Available Storage	Maximum Number of Lessons[9]	Maximum Number of Classes Supported[10]
Windows* 10-based device	84.6 GB	399	5.5
Chrome OS*-base device	17.2 GB	81	1.1
iPad*	24.7 GB	117	1.6

Choosing the Right Device for Virtual Learning

The Right Windows* Device for K-12 Education

The Right Chromebook* for Virtual Learning

Introduction

Back to School 2020–2021

As states and school districts plan for the upcoming school year while navigating the challenges presented by the COVID-19 pandemic, they are exploring various approaches for learning that are equitable and safe for all students and educators. Options largely include blended approaches and staggering schedules for in-person learning, as well as completely online offerings for families who desire it.

Specifically, many school districts are offering one or more of the following options:

Brick-to-Click— a district resumes traditional in-person classes with the flexibility to quickly pivot to distance education in the event of a COVID-19 outbreak;

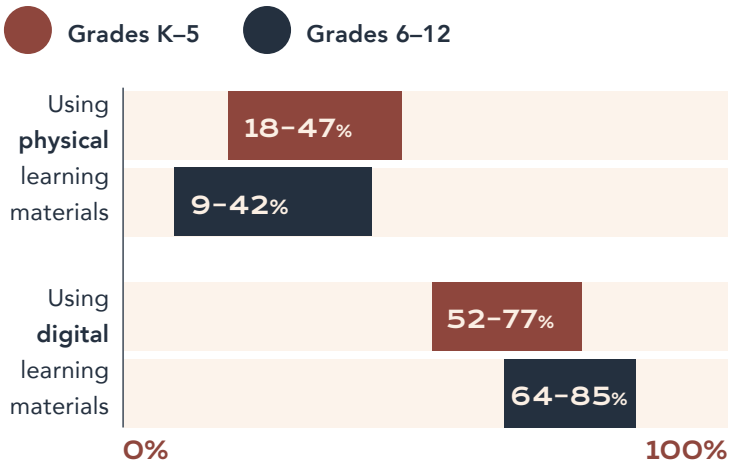
Click-to-Brick— a district begins with online learning and resumes in-person classes when it is safe to do so;

Blended/Hybrid Learning— a district uses a combination of learning that takes place in-person and online both synchronously and asynchronously; and,

Virtual Online Learning— a district uses a system-based approach to move all learning experiences and services online[2].

With approaches that include both in-person and virtual learning, districts and schools are also exploring how instructional activities can be designed equitably, with considerations for things such as how learning materials are distributed across grades K-5 and 6-12. In a recent study conducted by the American Institutes for Research*, school districts surveyed – both low poverty and high poverty identified districts – reported interesting results when considering methods for distributing learning materials. Of 269 districts for grades K-5, 18%-47% report that they will have some version of physical material distribution (e.g. paper packets sent home for students) and 52%-77% will distribute learning materials digitally. The results for the 282 districts surveyed about grades 6-12 show similar results for using and distributing physical materials for learning with 9%-42% reporting that they will offer this option. However, 64%-85% of districts note that they will distribute learning materials digitally for these grades 6-12 students, a markedly higher number than reported for elementary students[3]. Results like these clearly illustrate that districts are relying heavily on digital solutions for both blended and completely virtual learning experiences.

Reported distribution methods for learning materials



Source: American Institutes for Research

[2] Source: Pandemic Planning for Distance Learning: Scenarios and Considerations from New America
[3] Source: National Survey on Public Education's Coronavirus Pandemic Response from The American Institutes for Research

Challenges in Moving to Virtual and Online Learning

In developing their plans for the school year, states and districts are facing many challenges including public health, funding, connectivity, and equity.

Specifically, these challenges include:

- Ensuring all students have access to devices and the internet when learning virtually;
- Ensuring IT departments can support BYOD;
- Ensuring that students at risk for lack of connectivity (e.g., rural, highly mobile, low SES, etc.) have the ability to fully participate in virtual and blended learning models;
- Ensuring students with special needs and/or English language learners are supported in alignment with their needs;
- Ensuring educators are equipped with technology and skills to teach in virtual and blended/hybrid environments; and,
- Supporting school leaders in observing and coaching their educators virtually.

Funding the Shift to Virtual

In addition to health and safety challenges that the coming school year brings, funding poses a significant issue for many districts. The Coronavirus Aid, Relief, and Economic Security (CARES) Act, signed into law by President Trump on March 27, 2020, provides funding and flexibilities for states to respond to the COVID-19 emergency in K-12 schools. CARES Act funding supports students with allotments specifically for schools, provided directly to governors for spending, and funding for projects and microgrants[4].

COVID-19 Funding to Support Students

- $ 13.2 billion for K-12 schools
- $ 3 billion for governors to spend
- $ 154 million for Bureau of Indian Affairs
- $ 100 million for Project SERV grants
- $ 180 million to "Rethink K-12 School Models" microgrants

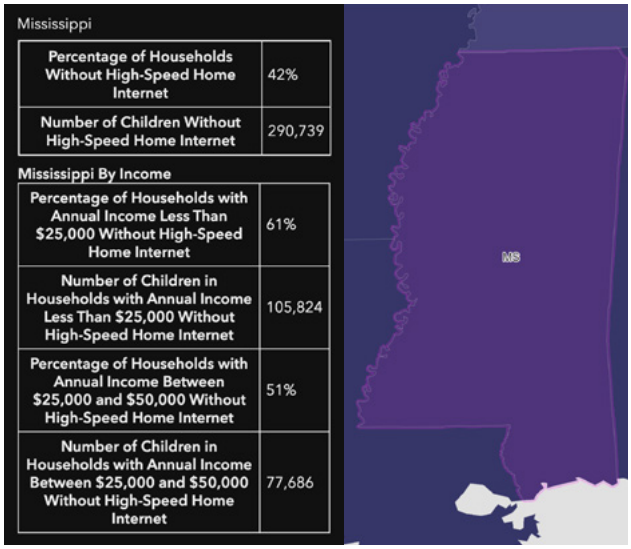
Allowable Activities for CARES Act Funding

Areas	Activities	Examples
• Any activities authorized by ESSA, IDEA, the Adult Education and Family Literacy Act, The Perkins Act, and the McKinney-Vento Homeless Act • Activities to address the unique needs of low-income students, children with disabilities, English-language learners, racial and ethnic minorities, and students experiencing homelessness	• Resources for principals and school leaders to meet the needs of their schools • Designing and implementing procedures and systems to improve preparedness and response efforts • Training and professional learning on sanitation and minimizing infectious diseases • Purchasing supplies to clean and sanitize	• Planning for and coordinating during long-term closures, such as providing meals to students, providing online learning to all students and providing guidance on carrying out IDEA (Individuals with Disabilities Education Act) requirements • Purchasing education technology for all students • Providing mental health services • Planning and implementing summer learning and after school programs • Continuing to employ existing staff • Other activities to maintain operations and continue services

[4] Source: **FutureEd**

Across the country, 15 to 16 million public school students live in households without persistent internet access or computing devices to facilitate distance learning

Virtual teaching and learning also presents challenges around connectivity. Many students, and some educators, lack regular access to reliable internet or devices that provide a reliable online experience. Intermittent and persistent periods of no connectivity also make it hard to communicate information to and garner feedback from all families. A recent study finds that across the country, 15 to 16 million public school students live in households without persistent internet access or computing devices to facilitate distance learning. The same analysis also reveals that almost 10% of public school teachers are also affected by limited connectivity making it difficult to conduct virtual classes[5].



Source: **Students of Color Caught in the Homework Gap from Future Ready Schools**

Maintaining Equity for All Students

In addition to navigating the challenges posed in developing virtual approaches for teaching and learning for the upcoming school year, states and districts must take into account numerous equity considerations -- creating conditions where every student and educator has what they need to be successful. Remote learning experiences have highlighted the effects that student mobility has on learning, disrupting access to technology, and creating gaps in access. Students experiencing homelessness, foster students, students in transient home situations (e.g., moving between family members' and friends' homes), and children living in rural and remote areas all have significant challenges with persistent to reliable internet access (or any connectivity at all).

Closures of both public and private facilities (e.g., libraries, restaurants, and schools) have greatly reduced the number of locations that students without reliable access to the internet can get online. While mobile hotspots, tethering to phones, and LTE-enabled notebooks can provide respite for connectivity challenges for students who reside in areas with a strong connection, these solutions frequently have additional costs or slower throughput, making activities like video conferencing, downloading learning materials, and viewing videos more unreliable. There are also equity issues around the accessibility of at home learning technologies for students with special needs that states and districts must consider when working to use technology and other tools to better engage and connect students and improve learning outcomes.

[5] Source: **Closing the K–12 Digital Divide in the Age of Distance Learning from Common Sense Media**

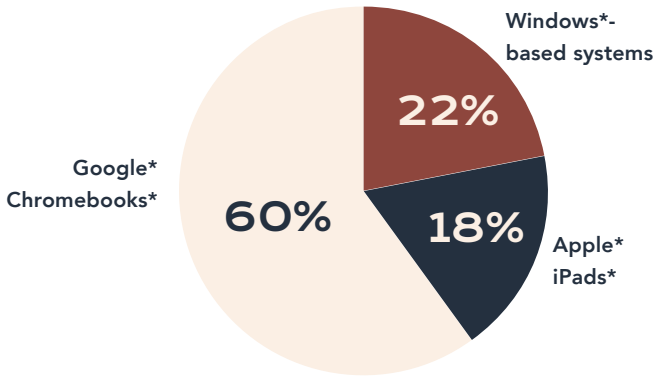
Device and Curriculum Considerations for Back to School 2020

Common Platforms for U.S. Education

In the K-12 education ecosystem, there are three main platforms used for both blended and virtual teaching and learning – Windows* 10 from Microsoft*, iPadOS* from Apple*, and Chrome OS* from Google*. According to the latest data from **Futuresource Consulting**, Windows*-based systems account for about 22% of the market while Apple*'s iPads* account for about 18%. Chromebooks* from Google* account for the majority of device sales in U.S. K-12 education used in approximately 60% of the market. Other options including Android* tablets, macOS* notebooks, and Linux*-based devices, but account for a relatively small percentage of the market.

Device sales in U.S. K-12 education

Source: Futuresource Consulting*



Devices Tested in this Study

In determining which devices to test, schools have to be attuned to many factors including cost, durability, manageability (especially in a virtual learning setting), and integration into their existing infrastructure. Keeping those considerations in mind, we identified three devices to evaluate their ability to support offline virtual learning environments. These include an Intel® Core™ i3-based device running Windows* 10, an Intel® Celeron® N4020-based device using Chrome* OS, and an Apple* A10 Fusion-based iPad* enabled for Wi-Fi and cellular usage using iPadOS*[6].

	**Windows* 10 PC** 10th Gen Intel® Core™ i3 128 GB storage **$ 399***
	**Chrome* OS Chromebook*** Intel® Celeron® N4020 32 GB storage **$ 325***
	**iPad* (7th generation)** Apple* A10 Fusion 32 GB storage **$ 459 plus monthly LTE charges***

Table 1: Devices tested for this report
*Retail price at the time of purchase and testing

[6] Complete details on device specifications and configuration are available in Appendix A.

Storage and Bandwidth Requirements

Virtual learning requires student devices that have ample storage for downloading course materials. In a typical virtual lesson for a middle or high school course, students might be asked to download and engage with two or more PDF documents, one five-minute uncompressed teacher created video or screencast, and one compressed ten-minute video from a source like Khan Academy*. For just this one lesson, at least 212 MB of storage may be required to download and save these resources. Multiply this one lesson by a typical six-course load for middle and high school students, with two teachers assigning lessons like this just once a week for the school year, and students will use 15.2 GB of storage on their devices. At three lessons of this nature a week, that amount increases to 22.9 GB of storage space used[7]!

Considering the amount of storage space students need to simply download required learning resources, not taking into account storage needed to save their own work, the Windows* PC allows for ample space, with 85 GB of available storage. The Chromebook* has 17 GB of available storage and the iPad* offers 25 GB of space. This means students using these devices will likely run out of available space to store learning resources and their own work before the conclusion of the school year without some means to easily manage files and storage space on their devices. Access to learning resources also depends on the ability of curriculum and content to be offered in downloadable or offline formats and whether or not learning tasks require additional applications, tools, or software to complete. External storage solutions such as SD Cards or USB drives are a relatively affordable way that schools can prepare and deliver curriculum to students without relying on connectivity. But, managing the preparation, pickup, and return of external storage devices (with student-completed work) may prove to be another challenge unto itself.

Estimated File Sizes per Lesson

PDFs (2)	3 MB
5-minute, uncompressed teacher created video	200 MB
10-minute compressed instructional video	8.8 MB
Total	**211.8 MB**

Storage Available for Curriculum and Student Work[8]

	Total Storage	OS & System Requirements	Available Storage
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Chrome OS*based device	32 GB	14.8 GB	17.2 GB
iPad*	32 GB	7.3 GB	24.7 GB

Maximum Capacity for Curriculum

	Available Storage	Maximum Number of Lessons[9]	Maximum Number of Classes Supported[10]
Windows* 10-based device	84.6 GB	399	5.5
Chrome OS*-base device	17.2 GB	81	1.1
iPad*	24.7 GB	117	1.6

[7] For additional details on device storage, see Appendix B.
[8] Results determined by device testing, July 2020.
[9] Assumes an average lesson size of 211.8 MB as described above.
[10] Assumes 2 lessons per week for a 36 week school year.

Virtual Teaching and Learning Workload Scenarios

The following sections outline typical K–12 virtual teaching and learning scenarios that compare the learning experience for students using the three featured operating systems -- both online and offline. Using authentic examples of curriculum materials and pedagogical approaches, the findings evaluate and provide guidance and better understanding for how well these devices and platforms will perform. For test results, see Appendix C.

Educator Scenario

Collaborative Lesson Design in Professional Learning Communities (PLCs)

At a Glance

Use Case: Educator

Educators use video conferencing tools to work together virtually in their PLC. They use student work samples and data to brainstorm, plan, and design lessons within a new unit of study. After their video call, educators work individually on the learning experiences for their assigned lesson within the unit, creating content such as videos, and then assign and schedule activities in their LMS.

Applications and Tools

- Zoom*
- Google Drive*
- Google Docs*
- Google Sheets*
- Google Slides*
- Google Classroom*
- Native video and screen recording device applications
- Screencastify*
- Screen Recorder Lite*
- Capture*

As the new school year gets underway, educators are eagerly attending PLC planning sessions with their grade level and/or department colleagues. These meetings center around student success and how to better use data to inform practice when designing learning experiences. As schedules for the school year are changing week to week, educators use Zoom* video conferencing software to connect when they can't physically be in the same room. Zoom* also provides a call in number so anyone with limited or intermittent connectivity can still join the meeting and participate in breakout rooms via phone audio only.

During the Zoom* meeting, a group of educators utilize shared folders in Google Drive* to access student work samples including documents and presentations. These folders also contain Google* sheets with sample data to help them identify areas of needs. The host can share their screen, while everyone opens the work samples and data and follows along using Google's* commenting feature to add notes, thoughts, and discussion along the way. Since the district has allowed offline access to Google Drive*educators may also join the conversation later by accessing the latest version of student work and data offline adding their own comments which will sync as soon as connectivity resumes.

Each of the educators work on designing one lesson in a four part unit. These lessons contain resources and tools including HMH* curriculum and various media such as, video, teacher created screencasts, online multimedia texts, and audio recordings. For those who choose to work both online and offline, all of the curriculum and media can be downloaded ahead of time and saved on the device so it can still be accessed with limited or no connectivity. To create videos for their students, they choose to utilize native video recording device applications and screencasting tools such as Screencastify*, Screen Recorder Lite*, and Capture* which can be used both online and offline.

Before ending the meeting, educators construct a brief outline of what each of the four lessons will contain and use Google Keep* to create a shared to-do list of action items and their proposed timeline. This application allows educators to share a note, which is updated in real-time as edits are made or action items are marked completed. If educators are working offline, they can update the note in Google Keep* and it will sync automatically as internet connectivity resumes.

After the meeting ends, the host shares the video file of the recording with the other members of the team by adding it to the shared folder in Google Drive* and emailing the provided video link to everyone. While the educators are working on individual lessons, they stay connected to each other by using shared folders, documents, and slides in Google Drive*. This gives everyone the ability to offer comments, thoughts, and feedback along the way, and ensures that each of the four lessons in the unit align with each other. Educators who choose to work offline, for instance outside where connectivity is limited, save their work in the folder in Google Drive which is synced and available for others once internet access resumes. After the lessons are created, educators use their LMS, Google Classroom*, to assign students various projects and assignments from the corresponding lessons using both the assign now and schedule for later features.

Evaluation Highlights

In this learning scenario, testing revealed that when recording a three minute video using each device's native camera or video recording tool, file sizes varied across devices. The Chromebook* produced a 42.1 MB mkv file, while the PC and iPad created much larger video files, a 174 MB mp4 file on the PC and a 171.9 MB mov file on the iPad. And, in a time when so much content is delivered via videos, the PC has the potential of producing higher quality content, offering more control and device options than the Chromebook* or iPad*. However, the large size of these videos over the course of the school year could cause educators or students to run out of storage on their devices if they need to download the videos for offline access. The PC had options for recording videos at a lower quality (to create a smaller file size), while both the Chromebook* and the iPad* video recording tools did not provide this option.

Testing results also provided interesting data when working through the scenario with no internet connectivity. That is, there are significant differences in terms of functionality depending on which device and which operating system a student or educator is using. Across all devices, access to curriculum materials and the LMS was unavailable offline. In order to participate in a video call, call in details for a phone must be provided or shared in advance. Offline access to Google Drive* varied among devices. All three operating systems allow offline access when this feature is enabled through the Chrome* Management console and users work through a few steps in their own accounts.

Making It Work Offline

	Windows* 10	Chrome* OS	iPadOS*
Video conferencing with Zoom*	• Provide users a call in number ahead of time	• Provide users a call in number ahead of time	• Provide users a call in number ahead of time
Accessing Google Drive*	• Use Chrome* Browser • Install Google Docs* Offline Chrome Extension • Enable Offline access in Google Drive* settings • Make specific files available offline • Turn on offline preview		• Use Google Drive* application • Mark individual files as available offline

High School Scenario
Digital Content Creation

At a Glance

Use Case: High school student

During their unit on the **Unsung Heroes of Mississippi**, English I students explore the use of rhetorical devices in online text sets including speeches, poems, videos, and image galleries. Using tools for taking screenshots and photo manipulation, students find real world examples of rhetorical devices in popular media, edit and annotate the media to point out the devices, and then submit their finished work in their LMS.

Applications and Tools

- Zoom*
- Canvas*
- Chrome* web browser
- Edge* web browser
- HMH* curriculum applications
- Native video and screen capture device applications (e.g., Windows* Snip and Sketch)
- Screenshot Capture & Editor*
- ShareX*
- Adobe Photoshop*
- Adobe Photoshop Express*
- Polarr*
- Google Drive*

As a part of their exploration of rhetoric and rhetorical devices, students engage in an English Language Arts unit about some of Mississippi's unsung heroes. Using multimedia texts, students read, view, and hear the voices of change makers who helped to alter history.

To begin the day's lesson, students log into their devices, access their calendars, and use a shared link to join a quick Zoom* video conference check-in and reflection with the class. For students with intermittent internet connectivity that might make connecting via video difficult, or no access to the internet at all, there is a call-in number provided. Students who will have no internet access at the time of the video conference were able to previously download a set of reflection questions from their teacher that they can use to reflect on their own while others are on the video call.

After completing their check-in and reflection, students begin work on the day's assignments. They navigate to their LMS, Canvas*, click on the course, and open the module for the new unit. Students locate day 1 and click the content to open the assignment. In addition to written directions, their teacher has provided a short tutorial video that they can view for more scaffolding on the texts they will engage with and the assignment they will complete. Canvas* provides functionality for students with intermittent or no internet access to download and save the course module and materials on their devices ahead of time, so that they can have access to their assignment that day.

Students are asked to engage with rhetorical devices using a text set including a video of a speech accessible from the HMH* app on their devices, a poem from the **Project Gutenberg** website, and a set of historical advertisements accessed from the **Library of Congress** database. Accessing these resources is

as simple as logging into the app and navigating to websites using the Chrome* or Edge* browser on their devices. Students who might have limited internet access that day are encouraged ahead of time to download a copy of the speech from the app and use a keyboard shortcut to save the web pages containing the poem and advertisements for offline viewing.

After students have read and reflected on the text set, it's their turn to find real-world examples of rhetorical devices in popular media, including the news, advertisements, song lyrics, and social media posts. Capturing examples of these texts on their devices is simple using the device's native screen capture tool such as Windows* Snip and Sketch or screenshot applications such as Screenshot Capture & Editor* and ShareX*. Students then use more powerful digital creation and editing tools such as Adobe Photoshop* or Photoshop Express* to edit and annotate the examples they find to point out uses of common rhetorical devices. They are also provided with the Polarr* application which works both online and offline, so internet access won't limit students' ability to complete this creative assignment. Once they have their examples annotated, students either submit their assignments online through Canvas* or work offline and add it to a Google Drive* folder shared with their teacher.

Evaluation Highlights

In this learning scenario, testing revealed that most of the tasks were easy to complete across operating systems with reliable internet connectivity. When testing each device's ability to successfully log into the LMS, Canvas*, review an assignment and related materials, and then submit work, the PC and the Chromebook* completed each task seamlessly. While the Canvas* application on the iPad* was easy to log into and navigate to view assignments, it did not allow access to the built in feature of adding media (e.g., audio and video recordings) to an assignment submission from within the application because the recorder runs on Adobe Flash*.

When testing this scenario completely offline, many of the learning tasks were impossible to complete. As with the previous scenario, video conferencing, accessing the LMS, Canvas*, and accessing curriculum materials did not work. Taking screenshots of media and editing that media, however, did work offline across operating systems. Screenshots were simple using both applications and the native or built in tools on both the Intel-based PC and the Chromebook*. The iPad*'s screenshot tool worked well, while the photo editing app had extremely limited functionality offline.

Making It Work Offline

	Windows* 10	Chrome* OS	iPadOS*
Accessing assignments in Canvas*	• Canvas is not available offline; however, if a school has allowed offline access, a student should be able to download some content. • Content will not be interactive (e.g. quizzes, discussions, etc.). • Downloading is available in epub or html formats.		
Taking screenshots and editing media	• Native device tools worked best to avoid limited functionality with offline applications		
	• Windows* Snip & Sketch*	• Keyboard shortcut on Chrome* OS	• Native screenshot tool on iPadOS*

Upper Elementary Scenario

3D Modeling of Geometry Concepts

At a Glance

Use Case: Upper elementary or middle school student

For a culminating project in their unit on **visual math**, 7th grade Introduction to Geometry students are challenged with the real world application of using two and three-dimensional shapes to create a 3D model of a living space. Choosing from one of three challenges, students begin by using applications to brainstorm a design for their model and then access a 3D modeling application to make their design come to life. Before showcasing their models in a multimedia presentation shared during a video conference, students use commenting features within the presentation tool to give each other helpful feedback and make revisions.

Applications and Tools

- Google Meet*
- Google Classroom*
- Gliffy Diagrams*
- Draw.io*
- Google Drawings*
- Tinkercad*
- Google Slides*
- Microsoft PowerPoint*

During their unit on visual math, students have worked on exploring and solving mathematical problems involving area, volume, and surface area of two and three-dimensional objects composed of triangles, quadrilaterals, polygons, cubes, and right prisms. As a culminating project, they will complete the task of designing a living space for a group of people in one of three challenges offered by their teacher. This project asks students to use 3D modeling tools to demonstrate their knowledge and make math visual.

To begin their project, students log into their devices and access their Math class in Google Classroom*. Using the invite link their teacher provided in an announcement, students join a short video call on Google Meet*. During this call their teacher shares their screen, explaining the project requirements and then streams a quick YouTube* video on how to use simple 3D modeling software. Since some students may have limited or no internet access at the time of the scheduled call, the teacher makes a screencast instructional video of the same information available for students to download ahead of time and adds it to a shared Google Drive* folder for offline access.

After the video call, students navigate back to Google Classroom* to access all the assignment materials. There is a direction sheet including tools and apps they can use to create 3D models, an infographic explaining the three challenges they can choose from, and a rubric for their final project. To brainstorm visual representations of their designs using two and three-dimensional shapes, students are encouraged to use diagramming applications on their devices, such as Gliffy Diagrams*, Draw.io*, or Google Drawings*, all of which are available online and offline. After brainstorming their designs, students use Tinkercad* to create their model of the living space. Students with intermittent or no connectivity are encouraged to

download all of the apps ahead of time and explore their offline use while completing the project.

Once they have the 3D visuals of their designed living space, they create a multimedia presentation to explain the thinking processes they used. Using presentation applications such as Google Slides* or Microsoft PowerPoint*, students are able to create a narrative of their work, exploring how they used both two and three-dimensional shapes to design a solution for their chosen challenge. Each of these applications allows students to work both online and offline, with syncing available once internet access resumes.

Once they've put the final touches on their presentations, students add them to a shared Google Drive* folder where they are available for online and offline viewing from their classmates. Students are paired to work through their presentations and give each other feedback based on the project rubric. Using Google's* commenting features, they can ask clarifying questions, point out parts that are awesome, and remind each other where gaps might exist. Students who are working offline, are still able to participate in the feedback loop as their comments will sync when internet access resumes. Once all of the feedback has be incorporated, students navigate back to Google Classroom* and submit their assignments to their teacher.

Evaluation Highlights

In this learning scenario, testing revealed that each device was able to successfully complete all the tasks while connected to reliable internet.

Testing results provided interesting data when working through the scenario with no internet connectivity. As with the other scenarios, access to video conferencing and the LMS, Google Classroom*, were not possible while offline. All of the applications tested to create math drawings and visualizations of the design of their 3D models worked on the PC without issue when not connected to the internet. One application, Draw.io*, while successful on the PC, was unavailable offline on the Chromebook*. Of the two iPad* applications used to create math visualizations, one, Flowdia* worked offline, and the other, Lucid Charts* had no offline access. There was no access to Tinkercad* offline, making creating 3D models impossible offline on these devices.

Making It Work Offline

	Windows* 10	Chrome* OS	iPadOS*
Accessing curriculum and learning task materials and resources	• Downloading files on devices with more than 128 GB minimizes time students spend managing offline file access.	• External storage devices preloaded with materials and resources minimizes effort students spend with offline access.	• Downloading files on devices with more than 128 GB is costly, but minimizes time students spend managing offline file access.

Planning for Success

Device Performance Outcomes

Across the three learning scenarios tested, when connected to reliable internet, all three platforms were able to successfully complete most tasks using native tools, installed software, or downloaded applications. Results varied with no internet access, with the Windows* 10 PC -- an Intel® Core™ i3-based device -- proving to offer the most seamless learning experience. Both the Chromebook* and the iPad* had limited success, relying heavily on installed applications that offered no offline access.

To create equitable blended/hybrid or virtual learning experiences for students, districts and schools must consider equipping them with what they need, in their personalized situations, to be successful. In order to future-proof their purchases, it is important to ensure that devices will work for both near and long-term needs such as the demands of skills for innovation: simulation, modeling, computational thinking, and visualization, as well as social and emotional learning and collaboration. For educator and administrator devices, it may be worth considering Windows*-based devices with Intel® Core™ i5 or Intel® Core™ i7 processors as these devices include additional hardware- and software-based security options -- the Intel vPro® solution and Intel® Active Management Technology -- which can further protect the devices, sensitive student and staff data, and allow for device management.

As noted in a recent Intel® commissioned study[11], Intel®-based Windows* devices provide more powerful processors that support improved multitasking capabilities and reduce student and educator wait time. The same is true for Intel®-based Chromebooks*, which outperform those powered by AMD* and MediaTek* processors[12]. Improved processor speeds ensure that students who are multitasking during learning experiences, downloading materials and resources, and streaming media will have a more seamless experience both online and offline. In addition, Intel® Core™-based devices with a Windows* 10 operating system offer more storage, allowing students with intermittent and persistent periods of no internet access to download and store learning resources on their devices, rather than having to navigate a multi-step process for making individual files available offline.

[11] Source: **The Right Windows* Device for Teaching and Learning**
[12] Source: **The Right Chromebook for Teaching and Learning**

Considerations and Recommendations for Districts and Schools

Based on the evaluation results of this study, it is clear that educators need consistent and reliable internet connectivity to successfully plan and implement both blended and virtual learning experiences for students. Whether they are accessing curriculum materials online or through textbook publisher applications, or assigning and scheduling assignments for students in a LMS, intermittent and persistent periods of limited or no internet access make common tasks next to impossible. Educators must also be aware of file sizes when developing content for teaching and learning. Content such as custom-created videos that need to be downloaded or streamed can result in large file sizes that load or download slowly due to syncing and bandwidth issues, or take up large amounts of storage space on student devices.

Students can also experience issues when accessing curriculum materials. Students with persistent periods of no internet connectivity will not be able to access curriculum materials through LMS or publisher applications or websites as they require connectivity to log in, search for their institution, and access courses.

For students who need to work offline, storing learning materials on a device requires large amounts of internal storage. Districts and schools should consider options such as:

- Devices with 128 GB or more of storage to help minimize the amount of time students spend managing offline-accessible files;
- External storage devices such as SD Cards that can be preloaded with curriculum materials and content;
- Devices with a minimum of 8 GB system memory to support multitasking and video playback whether offline or connected;
- LTE-enabled devices or mobile hotspots to provide connectivity for learning experiences that do not demand significant amounts of data exchange for students who live in areas with good telecommunications coverage; and,
- Using native, built-in device applications, tools such as keyboard shortcuts, and installed software rather than downloadable applications for completing simple tasks.

> "the findings of this study are clear: Windows*-based PCs with ample storage capacity can help solve many of the challenges that persistent lack of internet connectivity creates for both students and educators."

When planning approaches for the 2020-2021 school year, districts may want to consider the specific recommendations for creating equitable learning experiences for both educators and students described in this paper. To support virtual learning – especially when students have persistent periods with either intermittent or no internet access – all purchased devices should have a minimum of 128 GB of internal storage, such as the Intel® Core™ i3-based PC tested in this study. In addition, external storage options, such as SD Cards and USB flash drives, can be purchased and used with both PCs and Chromebooks* and iPad*.

District IT departments may also consider utilizing configuration services from resellers to save internal capacity by preventing staff from having to touch and configure each individual device. Such services offer pre-loaded applications and content, saving significant amounts of time when getting devices into students' hands.

Overall, the findings of this study are clear: Windows*-based PCs with ample storage capacity can help solve many of the challenges that persistent lack of internet connectivity creates for both students and educators. While other platforms, including Chromebooks* and iPads*, do offer some offline capability there are significant gaps in functionality that districts need to be aware of when making their device purchases for the 2020-2021 school year during this unprecedented time.

Appendices

A. Detailed Device Specifications

Device	ASUS* VivoBook* 15	HP* Chromebook* X360	Apple* iPad*
Model Number	F512J	1A767UT#ABA	iPad* 10.2" (7th generation)
Operating System	Windows* 10 Pro 64-bit	Chrome OS v 83.x	iPadOS v 13.5.1
Processor	**10th Gen Intel® Core™ i3-1005G1**	**Intel® Celeron® N4020**	**Apple* A10 Fusion 64-bit**
Processor Frequency	3.4 GHz	1.1 GHz	n/a
Storage	128 GB	32 GB	32 GB
Memory	8 GB	4 GB	n/a
Battery Capacity	32 Whr	60 Whr	32.4 Whr
Display Size	15.6" Touchscreen 1920x1080	11.6" Touchscreen 1366x768	10.2" Touchscreen 2160x1620
Graphics	Intel UHD Graphics	Intel UHD Graphics	Integrated
Camera	Integrated Webcam	Integrated Webcam	Integrated Webcam
Audio	Stereo speakers	Stereo speakers	Stereo speakers
Networking	802.11ac	802.11ac	Wi-Fi + Cellular 802.11ac
USB / ports	USB 3.2 Type-C, USB 3.2 Type-A, USB 2.0, HDMI	4x USB	1x lightning port, 1x audio combo jack
Bluetooth	Bluetooth® 4.2	Bluetooth® 4.2	Bluetooth® 4.2
Price at Time of Purchase	$399	$325	$ 459 + monthly LTE charges
Dimensions	14.1x9.1x.8	11.6 x 8 x .82	9.8 x 6.8 x .29 in
Weight	3.75 pounds	3.2 pounds	1.09 pounds

B. Device Storage Requirements

	ASUS* VivoBook* 15	HP* Chromebook* x360	iPad* 10.2"
Storage	128 GB	32 GB	32 GB
OS Requirements	**15 GB**	**4 GB**	**5 GB**
Other Requirements (GB)†	28.4	10.8	2.3
Available (GB)†	**28.4**	**17.2**	**24.7**
Available (MB)†	84600	17200	16467
Max # PDFs	84600	11467	16467
Max # Uncompressed Videos	282	57	82
Max # Compressed Videos	9614	1955	124
Max # Movies	56	11	16
Max # Lessons	399	81	117
# Classes (~2 lessons/wk) per School year	**5.5**	1.1	1.6

	Average File Sizes
Lesson Plan PDF (MB)	1.5
Full-length movie (GB)	1.5
5-minute uncompressed video (MB)	**200**
10-minute compressed video (MB)	8.8

Based on sampling content from multiple curriculum providers
See **Tool Studio** for details

Estimated Files Per Lesson	Number	Size (MB)
PDFs	2	3
5-minute uncompressed, teacher created video	1	200
10-minute compressed video	1	8.8
Total		**211.8**

Assumes one lesson prepared by an educator that includes 2 PDFs from HMH, a compressed video, and one self-generated, uncompressed video

† Includes software installed by the manufacturer with no additional configuration changes
‡ As determined based on new, out-of-the box testing

School-year Usage			
Middle or High School	2 lessons/wk	36 weeks	15250 MB
	3 lessons/wk	36 weeks	22874 MB

Assuming a student has a typical class load of ~6 courses and only 2 teachers assign lessons as described above (e.g., ~211MB each) per week

Initial iPad Storage Use†	
System	5GB
Other	2.3GB

iPadOS > Settings > General > iPad Storage

Initial Windows Storage Use‡	
Used Space	31.2GB
Free Space	86.1GB

OS (C:) Properties

Initial Chromebook Storage Use‡	
In Use	14.8GB
Available	17.2GB
My Files	260KB
Browsing Data	242MB
System	14.1GB
Apps	415MB

Chrome://settings/device/storage management

† Includes software installed by the manufacturer with no additional configuration changes
‡ As determined based on new, out-of-the box testing

C. Testing Results for Each Scenario

Educator Scenario (1 of 3)	Connected			Not Connected		
Task & Steps	**Windows***	**Chromebook***	**iPad***	**Windows***	**Chromebook***	**iPad***
Device log in 1. Log into device	✓	✓	✓	✓	✓	✓
Video conferencing 1. Open Zoom* 2. Log into application 3. Start video call	✓	✓	✓	No offline access, call in is only option (call in details must be shared in advance)	No offline access, call in is only option (call in details must be shared in advance)	No offline access, call in is only option (call in details must be shared in advance)
Access curriculum 1. Log into curriculum app or web application 2. Access curriculum, download materials, get links, and review student facing content	✓	✓	✓	No offline access	No offline access	No offline access

Table continues on next page

Educator Scenario (2 of 3)	Connected			Not Connected		
Task & Steps	**Windows***	**Chromebook***	**iPad***	**Windows***	**Chromebook***	**iPad***
Create assignment 1. Navigate to Google Drive* 2. Access the shared unit folder 3. Click new and choose Google Documents* or Google Slides* 4. Name file 5. Edit and create assignment using HMH* curriculum and/or websites and other media 6. Open Screencastify* or iXplain* 7. Create screencast for directions and notes 8. Save screencast in unit folder	✓	✓	✓	Once offline access is configured in Google Drive*, files can be accessed if made available offline, and new files can be created Screencast can be created offline, saved to device while offline	Once offline access is configured in Google Drive*, files can be accessed, and created Screencast can be created offline, cannot be saved to drive until device is back online, option to download to device is available	Created a Google* Doc titled New doc; doc wouldn't appear when folder was opened When opening already created docs, got message that doc will be made available offline but doc wouldn't open When opening pdf, got message that the iPad* was offline iPad* offline capabilities, when connected you can go into each individual file (not at the folder level) in the Drive* app and mark them as available offline — there doesn't seem to be any global way to do this from the app iPad* native Screen Record feature is limited and doesn't allow for drawing on the screen, webcam inclusion, etc. Opened Google Drive* > Test folder and uploaded screen recording; screencast wouldn't upload, got a waiting message

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Educator Scenario (3 of 3)

	Connected			Not Connected		
Task & Steps	**Windows***	**Chromebook***	**iPad***	**Windows***	**Chromebook***	**iPad***
Make to-do list 1. Open Google Keep* 2. Add items to shared note	✓	✓	✓	Google Keep* not available offline	Can be created while offline, but not shared until online	Can be created while offline, but not shared until online
Assign students work in LMS (Google Classroom* and Canvas*) 1. Log into LMS 2. Click to create a new assignment 3. Create an assignment with attached screencast to assign immediately to students 4. Create an assignment with attached screencast and schedule to assign it to students next week	✓	✓	✓	No offline access	No offline access	No offline access
Record Video 1. Open native camera app on device 2. Record 3 minute video explaining lesson 3. Save video	✓ 3 min video file size: 174 MB (.mp4)	✓ 3 min video file size: 42.1 MV (.mkv)	✓ 3 min video file size: 171.9 MB (.mov)	✓	✓	✓

High School Scenario (1 of 2)	Connected			Not Connected		
Task & Steps	**Windows***	**Chromebook***	**iPad***	**Windows***	**Chromebook***	**iPad***
Device log in 1. Log into device	✓	✓	✓	✓	✓	✓
Video conferencing 1. Open Zoom* 2. Log into application 3. Start video call	✓	✓	✓	No offline access, call in is only option (call in details must be shared in advance)	No offline access, call in is only option (call in details must be shared in advance)	No offline access, call in is only option (call in details must be shared in advance)
Review and complete assignment in LMS 1. Navigate to Canvas* 2. Log into LMS 3. Click to view module and then assignment 4. Edit and complete assignment using options to include multimedia 5. Submit assignment	✓	✓	When adding media during assignment submission, the Canvas* video/ audio recorder won't load because it runs on Adobe Flash*	No offline access No Canvas* app for Windows*	No offline access through web browser If a student has connected to the Canvas* student app while online, module content can be accessed offline. Any embedded content, such as videos, cannot be viewed while offline. Student cannot submit assignments while offline. "Submission Failed" message.	No offline access through web browser When app is fully logged out before trying to access offline you are able to enter name of institution, but the next page never loads When app isn't logged out before trying to access offline, you can get to the main dashboard page but you get an error message when you try to access a particular course
Curriculum access 1. Log into curriculum app or web application (HMH* iRead* and others) 2. Access curriculum and media assigned by teacher	✓	✓	✓	No offline access	No offline access	No offline access

Table continues on next page

High School Scenario (2 of 2)

Task & Steps	Connected			Not Connected		
	Windows*	Chromebook*	iPad*	Windows*	Chromebook*	iPad*
Taking screenshot of media 1. Open screenshot app 2. Take screenshot 3. Save image on device	✓	✓	✓	✓	Screenshot Capture & Editor* app is supposed to be available offline, but it doesn't actually appear to work. Extension says a screenshot will open in a new tab after completion, but it never takes the screenshot or opens a new tab. The app only takes screenshots of a webpage, so not useful if a student is viewing a PDF or some other app not in a browser	✓
Editing media 1. Open photo editing apps (Polarr*, Adobe Photoshop Express*) 2. Add shapes and text to photo 3. Save image on device	✓	✓	✓	✓	✓	Limited functionality offline: tried to add shapes, text, filters, etc.; got message that the app is unable to load content because it's not connected to the internet.

Upper Elementary Scenario

	Connected			Not Connected		
Task & Steps	**Windows***	**Chromebook***	**iPad***	**Windows***	**Chromebook***	**iPad***
Device log in 1. Log into device	✓	✓	✓	✓	✓	✓
Video conferencing 1. Open Google Meet* 2. Log into application 3. Start video call	✓	✓	✓	No offline access, call in is only option (call in details must be shared in advance)	No offline access, call in is only option (call in details must be shared in advance)	No offline access, call in is only option (call in details must be shared in advance)
Review and complete assignment in LMS 1. Navigate to Google Classroom* 2. Log into LMS 3. Click to view assignment 4. Edit and complete assignment using options to include multimedia 5. Submit assignment	✓	✓	✓	No offline access to Google Classroom*	No offline access to Google Classroom*	No offline access to Google Classroom*
Create math diagrams 1. "Open diagram app (Gliffy*, Google Drawings*, Draw.io*, Flowdia*, and Lucid Charts*) 2. Create sample diagram 3. Save diagram 4. Download diagram on device"	✓	✓	✓	✓	Gliffy* and Google Drawings* works offline Draw.io* has no offline access	Flowdia* works offline Cannot create blank diagram with Lucid Charts* offline
Create 3D model 1. Open Tinkercad* web application 2. Create sample 3D model using two and three-dimensional shapes 3. Save model 4. Download to device	✓	✓	✓	No offline access to Tinkercad*	No offline access to Tinkercad*	No offline access to Tinkercad*

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