

# Multitasking in the Virtual Classroom

Zoom-based Virtual Learning on Windows Notebooks  
and Chromebooks in K-12 Education



## Executive Summary

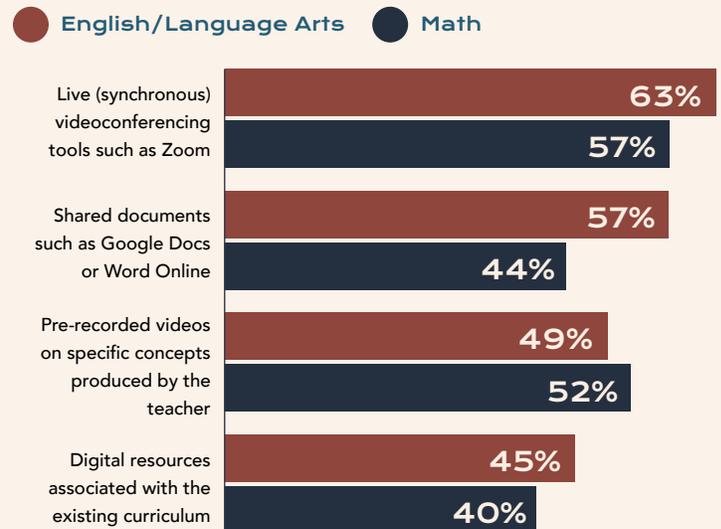
The use of laptops and other educational technologies by educators and students has exploded into mainstream adoption with 74% of U.S. schools in 2018 reporting at least 1 device per student.<sup>1</sup> The latest round of purchasing by schools will see that number grow even larger for the 2021-2022 school year. With responsive scheduling in schools coping with COVID-related issues for staff, students, and families, device availability and reliability are non-negotiables. To meet the needs of all stakeholders, states and districts are employing various approaches for teaching and learning that are both equitable and safe. Whether districts opt for face-to-face, virtual, or a hybrid (combination of face-to-face and virtual) approach, the goal—to use notebooks and other tools to better engage and connect students and improve learning outcomes—remains the same. Zoom\* reported in April 2020 that over 90,000 schools across 20 countries were using their service to help students continue their education remotely.<sup>2</sup>

**Live videoconferencing tools such as Zoom were seen as the most effective tools for teaching and learning both English/Language Arts and Math.<sup>3</sup>**

### Complex Demands of Multitasking

Just like in a classroom setting, a typical day of virtual learning requires students to use their devices to complete many simultaneous complex tasks. They often join a videoconference while having multiple web browser tabs open and applications running on their devices. Students rely heavily on video and livestreaming websites such as YouTube\* to engage with materials, both for their school-based work and for personal learning. Students also regularly engage with a learning management system, such as Google Classroom\* or Canvas\*, and work collaboratively in Google Docs\* or Microsoft OneDrive\* while connected to a videoconference on Zoom.

### Popularity of virtual learning tools



Source: EdWeek Research Center survey, 2020<sup>3</sup>

### Less Waiting, Fewer Disruptions, and More Time Learning

Devices with processors powered by Intel® technology create a more seamless teaching and learning experience by reducing disruptions and delays, making it easier to connect with others, and allowing students and educators to spend less time waiting for the processor to keep up with learning that requires multitasking.

**Notebooks with Intel® Core™ and Intel® Celeron® processors repeatedly outperformed the others with faster processing speeds, more ability to multitask across applications without disruptions, and better video quality both when engaging in videoconferencing and screen sharing livestreaming content.**

<sup>1</sup> Source: CoSN's 2018-2019 Annual Infrastructure Report

<sup>2</sup> Source: Zoom - A Message to Our Users

<sup>3</sup> Source: EdWeek Market Brief: Zoom and Google Docs Win Out for Remote Teaching, Survey of Educators Finds

## Key Takeaways

1



While multitasking on video calls to do livestreaming in-game play in Minecraft: Education Edition, **Intel® Core™-based Windows\* devices** perform **an average of 6x faster** than devices powered by AMD\* processors.

3



While multitasking on video calls to livestream and use 3D modeling and simulation applications, **Intel® Core™ and Intel® Celeron®-based Chromebooks** perform **an average of 2.5 seconds faster** than those powered by AMD and MediaTek\* processors.

4



**Intel® Core™ and Intel® Celeron®-based notebooks** perform better than competitors when using Zoom's screen share feature to share and receive streaming video, experiencing little to no lag, delay, or disruption in video quality.

2



When joining a Zoom video call, **Intel®-based Windows notebooks and Chromebooks\*** outperform competitors, with devices powered by **Intel® Core™ i3** technology performing **up to 71.8% faster**.

5



When leaving a breakout room to rejoin the main room in a Zoom video call, **Intel® Core™ i3-based Windows devices** outperform AMD-based devices with speeds **up to 89% faster**. Likewise, **Intel® Core™ i3-based Chromebooks** perform **up to 60% faster** than those powered by AMD technology.

6



When multitasking to engage in complex learning tasks, competitors routinely experience significant errors, delays, and dropped calls.

7



**Intel®-based Windows notebooks and Chromebooks** provide a more reliable experience with less disruptions, allowing parents and caregivers to spend more time supporting their students' learning and less time providing technical support.

8



**Intel®-based Windows notebooks and Chromebooks** are able to enter a Zoom breakout room faster and with fewer delays compared to competitors.



## Videoconferencing for Teaching and Learning

When designing a meaningful virtual learning experience, it's critical for educators to find ways to help students connect, both with content and with each other, with the fewest delays and disruptions. While much of the virtual learning experience is asynchronous—students learning when and where it's most effective for them—educators, students, and caregivers rely heavily on videoconferencing tools during synchronous experiences as a means to create engagement and foster connection. Having to wait or work through device delays and disruptions when learning at home causes more disengagement than in a structured classroom setting. And, many parents and caregivers suffer frustration when trying to support learning while simultaneously offering technology support.

“ The problem isn't necessarily the Chromebook, but rather the underpowered CPU's most of them use to make them inexpensive. If you have an i3, i5 or above, they generally do very well.”

— dasunrule32,  
Senior DevOps Engineer (Reddit)

**According to an October 2020 survey by MDR\*, Zoom is rated as the top-used education app by 60% of K-12 teachers.<sup>4</sup>**

Many educators note challenges across devices when using videoconferencing tools. It can be hard to simply have all of their students join a call. Because of device speeds and internet accessibility issues, students often get stuck in the “land of connection” where educators might have to admit students two or three times before they can successfully join a call. Students also often have trouble logging in as an authenticated user, especially on devices in their household with multiple users. These problems seem to persist and even escalate during a video call when using breakout room functionality.

<sup>4</sup>Source: MDR Insights: Teachers Talk Technology

These tools also often run into video and audio challenges, especially when the teaching and learning requires multitasking. When engaging in activities that require the use of apps and programs outside the videoconferencing tool itself, such as watching a video on YouTube or a livestream on Twitch\*, students often experience very choppy or delayed video feeds and loss of audio. These issues are exacerbated when students are sharing their own screens on devices, especially those with processors not equipped for multitasking. Many videoconferencing tool features, such as shared whiteboards, offer excellent opportunities for collaboration, but can be hard to engage with due to delays and a lag on devices with slower processors.

“ We have several schools who purchased HP 16W64UT Chromebook 11 G8s with AMD A4 9120C CPUs reporting serious performance issues, which we have been able to consistently replicate. We also got our hands on a Lenovo 100e 82CD0000US model with the same processor and are seeing the same problems. Very choppy video and intermittent loss of audio - in all video conf platforms - which gets progressively worse as the number of meeting participants increases.”

— u/ritalyngy (Reddit)



## Devices Used for Testing

Accommodating the needs of students and educators for meaningful virtual learning experiences presents numerous challenges. In the K-12 education ecosystem, many institutions choose between two main platforms - Windows 10 from Microsoft\* and Chrome OS\* from Google\*. According to the latest data from **Futuresource Consulting**, Windows-based systems account for about 22% of the market while Chromebooks account for the majority of device sales in U.S. K-12 education—approximately 60% of the market. For district and school leaders, selecting the right device for teaching and learning can be tough given the ever-increasing number of device choices and configuration options.

This study evaluates processor power needed to reduce delays, make it easier to connect with others, and allow students and educators to spend less time waiting for the device to keep up with learning that requires multitasking. We completed tests for each learning scenario on both Windows-based notebooks operating on Windows 10 Home and Chromebooks operating on Chrome OS version 87.

**Recent data from Canalys\* shows that Chromebook shipments increased 287% in Q4 2020 over Q4 2019, bringing the 2020 full-year total to 30.6 million units.<sup>5</sup>**

<sup>5</sup> Source: Canalys: **Tablets and Chromebooks Set All-time High Shipment Records in Q4 2020**

**Windows-based Test Devices**

	<p><b>ASUS* VivoBook S15</b> 10th Generation Intel® Core™ i5-10210U \$799.99 at time of purchase</p>
	<p><b>Lenovo* Yoga C640</b> 10th Generation Intel® Core™ i3-10110U \$599.99 at time of purchase</p>
	<p><b>HP* 14</b> Intel® Celeron® N4020 \$219.99 at time of purchase</p>
	<p><b>HP* Stream 14</b> AMD A4-9120 \$259.99 at time of purchase</p>
	<p><b>Lenovo* Ideapad 1</b> AMD A6-9220E \$229.99 at time of purchase</p>

Complete details on device specifications and configuration are available in [Appendix A](#).

**Chromebook Test Devices**

	<p><b>Acer* Chromebook Spin 713</b> 10th Generation Intel® Core™ i5-10210U \$629.00 at time of purchase</p>
	<p><b>ASUS* Chromebook Flip C436</b> 10th Generation Intel® Core™ i3-10110U \$699.99 at time of purchase</p>
	<p><b>HP* Chromebook x360</b> Intel® Celeron® N4020 \$299.99 at time of purchase</p>
	<p><b>HP* Chromebook 14</b> AMD A4-9120C \$239.99 at time of purchase</p>
	<p><b>Lenovo* Chromebook 3</b> AMD A6-9220C \$199.00 at time of purchase</p>
	<p><b>Lenovo* Duet</b> MediaTek Helio P60T \$249.00 at time of purchase</p>

Complete details on device specifications and configuration are available in [Appendix A](#).

## Results of Our Testing

During a device adoption process, especially one that is expedited due to emergencies like COVID-19, purchasing low-cost devices may seem like a bargain; however, the disruptions to learning due to slow and inefficient processing can have detrimental effects on both students and educators. Devices with processors powered by Intel® technology create a more seamless teaching and learning experience by reducing disruptions and delays, making it easier to connect with others, and allowing students and educators to spend less time waiting for the processor to keep up with learning that requires multitasking.



**While multitasking on video calls to livestream and use 3D modeling and simulation applications, Intel® Core™ and Intel® Celeron®-based Chromebooks perform an average of 2.5 seconds faster than those powered by AMD and MediaTek processors.**

The learning scenarios we developed and tested were created to realistically simulate what most students and educators experience when using technology, including videoconferencing tools, during hybrid and virtual learning experiences. The focus of this study is to quantify how more powerful processors have a significant impact on the ability to experience and participate in a seamless, synchronous virtual learning experience.

## Testing Methodology

To simulate an authentic, synchronous virtual learning experience we used a total of 20 computers, both Chromebooks and Windows devices, to create an online classroom environment. During testing, one device was used as an educator device, while the others were used as typical student devices. The educator device served as the host for each Zoom videoconferencing session, while each student device joined the video call using a shared access link. We completed a series of tests to capture both quantitative data on processor speeds during learning tasks and multitasking, as well as qualitative data about how processor speeds affect a device's ability to offer a seamless teaching and learning experience.<sup>6</sup>

**While multitasking on video calls to do livestreaming in-game play in Minecraft: Education Edition, Intel® Core™-based Windows devices perform an average of 6x faster than devices powered by AMD processors.**

<sup>6</sup> For complete testing workflows, see [Appendix B](#).

## Learning Scenarios and Outcomes

The following sections outline typical K–12 learning scenarios that compare the learning experience for both educators and students using devices with the featured processors. Each scenario explains the educator or student tasks involved in the activity, gives the outcomes and highlights of the test results, and describes the functionality differences and the timed results for performance.

### High School Classroom Scenario

## Engineering Solutions to Real-world Problems with 3D Modeling and Simulation

#### At a Glance

##### Grade Level

11th grade

##### Subject Area

CTE

##### Class

Principles of Engineering

As a culminating project for their engineering and social change unit, student groups are tasked with identifying a real-world problem that they would like to design a solution for. Students identify and research the topics related to their problem, interview experts and others who provide helpful perspective, and work together to formulate designs for their solutions using 3D modeling and simulation software.

#### Learning Skills

- Simulation and modeling
- Design thinking
- Digital content creation
- Digital communication and collaboration

#### Applications and Tools

- Zoom
- Zoom Whiteboard
- 3D Object Maker\*
- Google Poly\*
- Tinkercad\*
- Twitch
- YouTube
- Google Chat\*
- Google Classroom
- Google Drive\*
- Google Drawings\*

**Throughout the semester,** students in Principles of Engineering have explored mechanisms, the strength of structures and materials, and automation. As a culminating project for their unit on engineering and social change, student groups are tasked with identifying a real-world problem that they would like to design a solution for. Students identify and research the topics related to their problem, interview experts and others who provide helpful perspective, and work together to formulate designs for their solutions.

After curating their research and interview materials and meeting to discuss next steps, students join a weekly Zoom work session. Their teacher begins the Zoom video call, making sure to record it, and students are able to join via a link shared in Google Classroom. After joining the call, students do a quick pair-share exercise in predetermined breakout rooms to discuss what they've discovered so far about the problem they want to solve. While students are engaged in their discussions, the teacher broadcasts time reminders so that each student will have ample time to share. After five minutes, the teacher closes the breakout rooms and students are redirected back to the main session to begin the day's activities.

In order to bring their solutions to life, students will design and build a 3D model and simulation. Before they move to breakout rooms to work, the teacher uses screen sharing to play an instructional video for Tinkercad, a 3D modeling and simulation software. The video offers students an entry point for how to navigate the software to design and build their models. Students use the chat and raise hand features in Zoom to ask questions during the video.

After the mini lesson, students are sent to their breakout rooms to work in small project groups. The teacher is able to move from one breakout room to another in order to assist and check on each group's progress. One student in each group records the breakout room work session locally on their device to add as an artifact to their project folder.



To begin sketching their designs, groups use either the Zoom whiteboard or Google Drawings. They are able to annotate in real time and see one another's changes on the screen. Once they have settled on their design, students use Tinkercad to build the first version of their solution. When they are done, they export these models as OBJ files and save them to their devices. After exporting, students open Google Poly in their web browsers. This tool allows them to animate and showcase their 3D models.

The teacher gives a 5-minute warning and then closes the breakout rooms, redirecting students back to the main room to share their models with the class. After they have screen shared to show their progress, students export their model from Google Poly onto their devices as a GIF file and add it to the project folder.

## Qualitative Testing and Evaluation Highlights

Screen Sharing Streaming Video	
Windows-based Device Results	Chromebook Results
<ul style="list-style-type: none"> <li>The Intel® Core™-based devices performed without lag, delay, or loss of video quality when sharing a live video stream via Zoom’s screen share feature. Each receiving device was able to view this live video stream with little delay, except the AMD A6-based device.</li> <li>The Intel® Celeron®-based device shared its screen without a loss of video quality, while the receiving devices populated the shared screen almost instantly but had slight glitches and loss of video quality.</li> <li>When the devices powered by AMD technology shared their screen with live video streams, there was considerable delay, lag, and loss of video quality on all other devices, even when the AMD-based device had a clear video.</li> <li>Both AMD-based devices experienced video buffering frequently while sharing their screens, while all of the Intel®-based devices shared streaming video without buffering.</li> </ul>	<ul style="list-style-type: none"> <li>The Intel® Core™ and Intel® Celeron®-based devices performed well when using Zoom’s screen share feature to share and receive streaming video. These devices experienced very little lag, delay, or disruption in video quality.</li> <li>Both devices powered by AMD technology experienced delay in sharing their screens with other devices. Once their screen populated on the receiving devices, the video quality was low and there was considerable lag. And, while the MediaTek-based device successfully shared its screen with all three Intel®-based devices, both devices powered by AMD processors experienced lower video quality.</li> <li>The devices powered by AMD and MediaTek technology experienced sudden instances in Zoom of their cameras turning off unexpectedly while sending and receiving screen sharing.</li> </ul>

**Joining a Breakout Room**

Windows-based Device Results	Chromebook Results
<ul style="list-style-type: none"> <li>• The Intel® Core™ and Intel® Celeron®-based devices joined breakout rooms without any significant delays.</li> <li>• The AMD A4-based device was able to join a breakout room after a significant delay of approximately 30 seconds.</li> <li>• The AMD A6-based device experienced a significant delay of approximately 45 seconds when trying to join a breakout room. This device also suffered disruptions with its camera and video toggling on and off, and livestreaming video stopping in the background.</li> </ul>	<ul style="list-style-type: none"> <li>• On all devices, upon joining a breakout room, the browser-based livestreams and videos stopped playing. Videos and livestreams only resumed playing after navigating away from Zoom and back to the web browser.</li> </ul>

## Quantitative Testing and Evaluation Highlights

Windows-based Device Results					
	10th Generation Intel® Core™ i5-10210U	10th Generation Intel® Core™ i3-10110U	Intel® Celeron® N4020	AMD A4-9120 Dual-Core Processor	AMD A6-Series
Joining a Zoom videoconference	0.8 secs	6.9 secs	7.8 secs	16.1 secs	20.5 secs
	<p>The Intel® Core™ i3-based device performed <b>9.3 seconds or 57.4% faster</b> than the AMD A4-9120-based device.</p>				
	<p>The Intel® Core™ i3-based device performed <b>13.6 seconds or 66.5% faster</b> than the AMD A6-based device.</p>				
Joining a breakout room	7.7 secs	6.1 secs	11.9 secs	74.7 secs	55.5 secs
	<p>The Intel® Core™ i3-based device performed <b>68.6 seconds or 91.7% faster</b> than the AMD A4-9120-based device.</p>				
	<p>The Intel® Core™ i3-based device performed <b>49.4 secs or 88.9% faster</b> than the AMD A6-based device.</p>				

**Chromebook Results**

	10th Generation Intel® Core™ i5-10210U	10th Generation Intel® Core™ i3-10110U	Intel® Celeron® N4020	AMD A4-9120C	AMD A6-9220C	MediaTek Helio P60T
Joining a Zoom videoconference	4.1 secs	5.5 secs	7.8 secs	12.8 secs	12.1 secs	11.2 secs
	<p><b>The Intel® Core™ i3-based device</b> performed <b>7.3 seconds or 56.9% faster</b> than the AMD A4-9120C-based device.</p>					
	<p><b>The Intel® Core™ i3-based device</b> performed <b>6.6 seconds or 54.6% faster</b> than the AMD A6-9220C-based device.</p>					
Joining a breakout room	2.1 secs	5.5 secs	2.8 secs	9.4 secs	3.9 secs	4.5 secs
	<p><b>The Intel® Celeron®-based device</b> performed <b>6.6 seconds or 70.2% faster</b> than the AMD A4-9120C-based device.</p>					
	<p><b>The Intel® Celeron®-based device</b> performed <b>1.7 seconds or 37.8% faster</b> than the MediaTek Helio P60T-based device.</p>					

## Middle School Classroom Scenario

# Programming Machines Using the Physics of Minecraft: Education Edition

### At a Glance

#### Grade Level

7th grade

#### Subject Area

CTE

#### Class

Computer Science Discovery

In their Computer Science Discovery class, 7th graders work in small teams of three to compete in the North American Scholastic Esports Federation (NASEF) Rube Goldberg Digital Minecraft\* Contest. Teams of students study physics principles and simple machines, use coding to build inside the Minecraft: Education Edition environment, and demonstrate their finalized machines for the class before submitting them to the contest.

### Learning Skills

- Game-based learning
- Computational thinking
- Digital content creation
- Digital communication and collaboration

### Applications and Tools

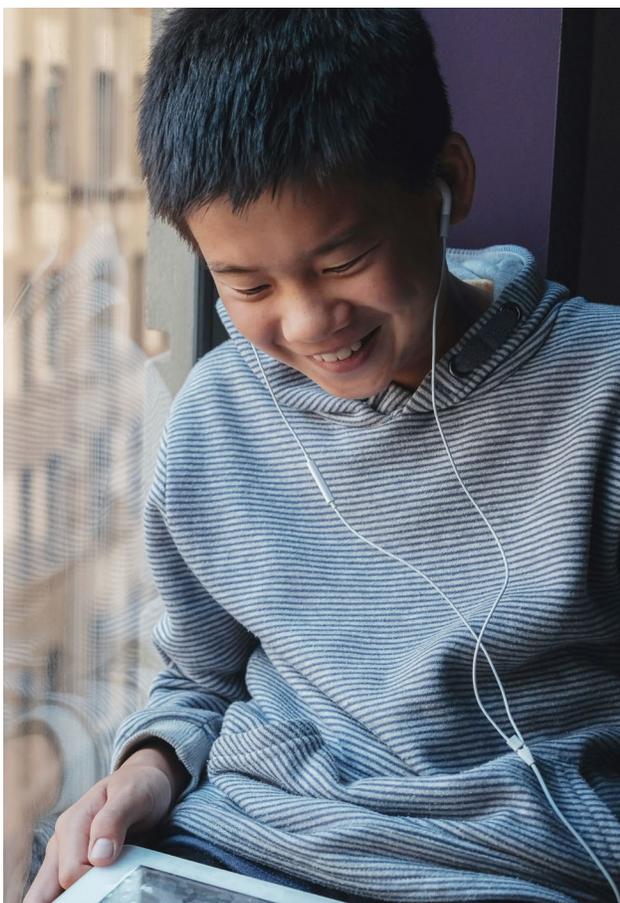
- Zoom
- Minecraft: Education Edition
- Twitch
- Google Chat
- Google Classroom
- Google Drive
- Google Slides\*



### In their Computer Science Discovery class,

7th graders work in small teams of three to compete in the North American Scholastic Esports Federation (NASEF) Rube Goldberg Digital Minecraft Contest. Teams of students study physics principles and simple machines, use their coding skills to build inside the Minecraft: Education Edition environment, and demonstrate their finalized machines for the class before submitting them to the contest.

To begin the class's work session, the teacher starts the Zoom video call, making sure to record it, and students are able to join via a link shared in Google Classroom. Before diving into their shared Minecraft: Education Edition worlds, the teacher asks students to do a quick SEL check-in. Students begin by changing their virtual backgrounds to videos to demonstrate how they're feeling about their contest submissions so far. After each student's virtual background is set, the teacher sends them to breakout rooms to share



one thing they love about their submission, and one thing that is proving to be challenging. While students are discussing, the teacher moves between breakout rooms to engage with the class.

After five minutes, the teacher closes the breakout rooms and students are redirected back to the main session to begin the day's activities. Each week the class tunes in for a "How To" livestream on Twitch for building and coding simple machines inside of the Minecraft: Education Edition environment. The teacher shares their screen and students watch the short livestream together, using the chat as a backchannel for thoughts and questions.

Once the livestream concludes, the teacher opens the team breakout rooms and sends students to get started building and coding. Students open their project HyperDoc in Google Slides so they can synchronously add artifacts, such as screenshots and short screencast videos of the day's work, for the teacher to review. Students work together in their shared Minecraft world to design and add this week's featured simple machine—the lever. As they are working, students take turns sharing their screens to demonstrate their designs, generate code, and problem solve.

When the small group work session is done, the teacher closes the breakout rooms and redirects students back to the main session. Each group takes a turn sharing their screen to showcase their progress on their Rube Goldberg machine. Inside the Minecraft world, the groups explain their designs and the code they are using to bring their machine to life.

## Qualitative Testing and Evaluation Highlights

Screen Sharing Live In-Game Play	
Windows-based Device Results	Chromebook Results
<ul style="list-style-type: none"> <li>The Intel® Core™ and Intel® Celeron®-based devices were able to share live in-game play in Minecraft: Education Edition with little to no delay or disruption.</li> <li>Both AMD-based devices experienced “Zoom is not responding” messages when sharing live in-game play in Minecraft: Education Edition, and at best provided a frustrating, delayed, and glitchy experience when screen sharing was possible.</li> </ul>	<ul style="list-style-type: none"> <li>The Intel® Core™-based devices were able to share live in-game play in Minecraft: Education Edition with little to no delay or disruption.</li> <li>The Intel® Celeron®-based device was able to share live in-game play with only a slight lag and little to no disruption in game play. There were similar results for the MediaTek-based device, but it displayed more lag and delay with increased movement during in-game play.</li> <li>Both AMD-based devices experienced significant lag when sharing live in-game play, which increased even more as the character moved through the game.</li> </ul>

**Joining a Breakout Room**

Windows-based Device Results	Chromebook Results
<ul style="list-style-type: none"> <li>• The Intel® Core™ and Intel® Celeron®-based devices joined breakout rooms without any significant delays.</li> <li>• The AMD A4-based device was able to join a breakout room after a significant delay of approximately 30 seconds.</li> <li>• The AMD A6-based device experienced a significant delay of approximately 45 seconds when trying to join a breakout room. This device also suffered disruptions with its camera and video toggling on and off, and livestreaming video stopping in the background.</li> </ul>	<ul style="list-style-type: none"> <li>• On all devices, upon joining a breakout room the browser-based livestreams and videos stopped playing. Videos and livestreams only resumed playing after navigating away from Zoom and back to the web browser.</li> <li>• The AMD-based devices dropped the Zoom video call when being directed to join a breakout room, and had to rejoin and be moved to a breakout room by the host. The AMD A4-based device also received a high CPU usage warning upon returning to the Zoom video call. The AMD A6-based device suffered low video quality upon being moved to a breakout room.</li> <li>• The MediaTek-based device was able to join the breakout room successfully, but suffered low video quality.</li> </ul>

## Quantitative Testing and Evaluation Highlights

Windows-based Device Results					
	10th Generation Intel® Core™ i5-10210U	10th Generation Intel® Core™ i3-10110U	Intel® Celeron® N4020	AMD A4-9120 Dual-Core Processor	AMD A6-Series
Joining a Zoom videoconference	0.8 secs	5.2 secs	14.4 secs	18.5 secs	17.5 secs
	<p>The Intel® Core™ i3-based device performed <b>13.3 seconds or 71.8% faster</b> than the AMD A4-9120-based device.</p>				
	<p>The Intel® Core™ i3-based device performed <b>12.3 or 70.3% faster</b> than the AMD A6-based device.</p>				
Joining a breakout room	7.5 secs	6.2 secs	36.2 secs	42.5 secs	55.1 secs
	<p>The Intel® Core™ i3-based device performed <b>36.3 seconds or 85.4% faster</b> than the AMD A4-9120-based device.</p>				
	<p>The Intel® Core™ i3-based device performed <b>48.9 or 88.8% faster</b> than the AMD* A6-based device.</p>				

**Chromebook Results**

	10th Generation Intel® Core™ i5-10210U	10th Generation Intel® Core™ i3-10110U	Intel® Celeron® N4020	AMD A4-9120C	AMD A6-9220C	MediaTek Helio P60T
Joining a Zoom video-conference	4.8 secs	8.9 secs	10.1 secs	15.2 secs	12.2 secs	10.5 secs
	<p><b>The Intel® Core™ i3-based device</b> performed <b>6.3 seconds or 41.3% faster</b> than the AMD A4-9120C-based device.</p>					
	<p><b>The Intel® Core™ i3-based device</b> performed <b>3.3 seconds or 27.2% faster</b> than the AMD A6-9220C-based device.</p>					
Joining a breakout room	3.1 secs	2.4 secs	3.8 secs	7.8 secs	3.8 secs	3.5 secs
	<p><b>The Intel® Core™ i3-based device</b> performed <b>5.4 seconds or 69.3% faster</b> than the AMD A4-9120C-based device.</p>					
	<p><b>The Intel® Core™ i3-based device</b> performed <b>1.4 seconds or 36.8% faster</b> than the AMD* A6-9220C- based device.</p>					

## Summary of Outcomes

Windows-based Device Results					
Total Scenario Time	10th Generation Intel® Core™ i5-10210U	10th Generation Intel® Core™ i3-10110U	Intel® Celeron® N4020	AMD A4-9120	AMD A6-9220E
11th Grade - <i>Engineering Solutions to Real-world Problems with 3D Modeling and Simulation</i>	8.5 secs	22.4 secs	29.8 secs	115.7 secs	102.7 secs
7th Grade - <i>Programming Machines Using the Physics of Minecraft: Education Edition</i>	8.3 secs	18.9 secs	75.4 secs	101.2 secs	144.7 secs

Chromebook Results						
Total Scenario Time	10th Generation Intel® Core™ i5-10210U	10th Generation Intel® Core™ i3-10110U	Intel® Celeron® N4020	AMD A4-9120C	AMD A6-9220C	MediaTek Helio P60T
11th Grade - <i>Engineering Solutions to Real-world Problems with 3D Modeling and Simulation</i>	6.2 secs	12.2 secs	13.7 secs	24.9 secs	18.8 secs	18.2 secs
7th Grade - <i>Programming Machines Using the Physics of Minecraft: Education Edition</i>	8.0 secs	12.5 secs	16.0 secs	26.1 secs	18.8 secs	17.5 secs

The analysis in this document was done by Clarity Innovations, Inc. and commissioned by Intel®.

Results have been simulated and are provided for informational purposes only. Software and workloads used in performance tests may have been optimized for performance only on Intel® microprocessors. Performance tests, such as SYSmark\* and MobileMark\*, are measured using specific computer systems, components, software, operations, and functions.

Any change to those factors may cause the results to vary. You should consult other information and performance tests to assist you in fully evaluating your contemplated purchases, including the performance of that product when combined with other products. For more complete information about performance and benchmark results, visit [www.Intel.com/benchmarks](http://www.Intel.com/benchmarks).

Performance results are based on testing as of dates shown in configurations and may not reflect all publicly available updates. See backup for configuration details. No product or component can be absolutely secure. Your costs and results may vary.

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# Appendix

## A. Device Specifications

### Windows-based Test Devices

Device	ASUS VivoBook S15	Lenovo Yoga C640	HP 14	HP Stream 14	Lenovo Ideapad 1
<b>Model Number</b>	S532FADH55GN	81UE000WUS	14-dq0002dx	14-cb188nr	81VS009GUS
<b>Operating System</b>	Windows 10 Home	Windows 10 Home	Windows 10 Home	Windows 10 Home	Windows 10 Home
<b>Processor</b>	Intel Core i5-10210U	Intel Core i3-10110U	Intel Celeron N4020	AMD A4-9120	AMD A6-9220E
<b>Processor Frequency</b>	1.6 GHz	2.1 GHz	1.1 GHz	1.5 GHz	1.6 GHz
<b>Storage</b>	512 GB	128 GB	64 GB	32 GB	64 GB
<b>Memory</b>	8 GB	8 GB	4 GB	4 GB	4 GB
<b>Battery Capacity</b>	45 Wh	60 Wh	41Wh	41 Wh	45 Wh
<b>Display Size</b>	15.6 in	13.3 in	14 in	14 in	14 in
<b>Graphics</b>	Intel UHD Graphics	Intel UHD Graphics	Intel® UHD Graphics	AMD Radeon R3	AMD Radeon R4
<b>Networking</b>	802.11ax	802.11ac	802.11a/b/g/n/ac	802.11b/g/n	802.11ac
<b>USB / ports</b>	1x HDMI output 2x USB 2.0 1x USB 3.0	2x USB 3.0 Type A	2x USB Type A 1x USB Type C 1x HDMI output	1x USB 2.0 2x USB 3.0	2x USB 3.0 1x HDMI output
<b>Price at Time of Purchase</b>	\$799.99	\$599.99	\$219.99	\$259.99	\$229.99
<b>Dimensions</b>	9.1" x 14.1" x 0.7"	8.1" x 12" x .7"	8.86" x 12.76" x 0.71"	8.88" x 13.27" x 0.73"	9.3" x 12.9" x 0.78"
<b>Weight</b>	3.97 lbs	2.98 lbs	3.24 lbs	4.3 lbs	3.09 lbs

## Chromebook Test Devices

Device	Acer Chromebook Spin 713	ASUS Chromebook Flip C436	HP Chromebook x360	HP Chromebook 14	Lenovo Chromebook 3	Lenovo Duet
<b>Model Number</b>	CP713-2W-5874	C436FA-DS388T	7PD76UA	6CD26UA	82H40000US	ZA6F0016US
<b>Operating System</b>	Chrome OS 87.0.4280.142	Chrome OS 87.0.4280.142	Chrome OS 87.0.4280.142	Chrome OS 87.0.4280.142	Chrome OS 87.0.4280.142	Chrome OS 87.0.4280.142
<b>Processor</b>	Intel Core i5-10210U	Intel Core i3-10110U	Intel Celeron N4020	AMD A4-9120C	AMD A6-9220C	MediaTek Helio P60T
<b>Processor Frequency</b>	1.60 GHz	2.1 GHz	1.10 GHz	1.6 GHz	1.8 GHz	2.0 GHz
<b>Storage</b>	128 GB	128 GB	32 GB	32 GB	32 GB	128 GB
<b>Memory</b>	8 GB	8 GB	4 GB	4 GB	4 GB	4 GB
<b>Battery Capacity</b>	48 Wh	42 Wh	47 Wh	37 Wh	42 Wh	35 Wh
<b>Display Size</b>	13.5 in	14 in	11.6 in	14 in	11.6 in	10.1 in
<b>Graphics</b>	Intel UHD Graphics 620	Intel UHD Graphics	UHD Graphics 600	Intel HD Graphics	AMD Radeon	ARM G72 MP3 Graphics
<b>Networking</b>	802.11ax	802.11ax	802.11a/ ac/b/g/n	802.11a/b/g/ac	802.11ac	802.11a/ ac/b/g/n
<b>USB / ports</b>	1x USB 3.0 Type A port 1x HDMI Output 2x USB 3.2 Type C port	2x USB Type C port	2x USB Type C port	1x USB 3.0 2x USB 2.0	2x USB 3.1 2x USB 3.2	1x USB Type C
<b>Price at Time of Purchase</b>	\$629.00	\$699.99	\$299.99	\$239.99	\$199.00	\$249.00
<b>Dimensions</b>	11.83" x 9.25" x 0.66"	12.56" x 8.07" x 0.54"	8.2" x 12" x 0.8"	13.27" x 8.94" x 7.2"	7.87" x 11.02" x 0.67"	6.29" x 9.44" x 0.29"
<b>Weight</b>	3.02 lbs	2.6 lbs	3.17 lbs	3.4 lbs	2.42 lbs	1 lbs

## B. High School Classroom Scenario Quantitative Results†

### Test 1 Details

#### Starting a Zoom call (educator)

1. Simultaneously start the timer and click host meeting to start the Zoom video call.
2. When the video call fully connects, stop the timer.

#### Joining a Zoom call (student)

1. Simultaneously start the timer and click the link for the Zoom video call.
2. When the video call fully connects, stop the timer.

		Test 1 Timed Results (seconds)			
		1	2	3	avg
Chromebook Devices	Intel Core i5-10210U	4.1	4.1	4.1	4.1
	Intel Core i3-10110U	6.1	5.2	5.2	5.5
	Intel Celeron N4020	8.2	7.1	8	7.8
	AMD A4-9120C	15.2	12.1	11	12.8
	AMD A6-9220C	13	11.2	12.1	12.1
	MediaTek Helio P60T	11.3	11.1	11.1	11.2
Windows-based Devices	Intel Core i5-10210U	1	0.3	1	0.8
	Intel® Core™ i3-10110U	9.2	6.3	5.1	6.9
	Intel Celeron N4020	9.2	6	8.1	7.8
	AMD A4-9120	16.1	19	13.3	16.1
	AMD A6-9220E	23.2	24.1	14.2	20.5

### Test 2 Details

#### Joining a breakout room (student)

1. Click breakout rooms in the Zoom menu.
2. Set rooms to create 5 breakout rooms that assign automatically.
3. Click create.
4. Simultaneously start the timer and click join on each device.
5. When the device connects to the room, stop the timer.

		Test 2 Timed Results (seconds)			
		1	2	3	avg
Chromebook Devices	Intel Core i5-10210U	4.1	4.1	4.1	4.1
	Intel Core i3-10110U	6.1	5.2	5.2	5.5
	Intel Celeron N4020	8.2	7.1	8	7.8
	AMD A4-9120C	15.2	12.1	11	12.8
	AMD A6-9220C	13	11.2	12.1	12.1
	MediaTek Helio P60T	11.3	11.1	11.1	11.2

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Test 2 Timed Results (seconds)		1	2	3	avg
Windows-based Devices	Intel Core i5-10210U	1	0.3	1	0.8
	Intel® Core™ i3-10110U	9.2	6.3	5.1	6.9
	Intel Celeron N4020	9.2	6	8.1	7.8
	AMD A4-9120	16.1	19	13.3	16.1
	AMD A6-9220E	23.2	24.1	14.2	20.5

### Test 3 Details

#### Host joining a breakout room (educator)

1. Click breakout rooms in the Zoom menu.
2. Select a breakout room to join.
3. Simultaneously start the timer and join the room.
4. When host completely joins the room, stop the timer.
5. Use the menu to join a different room and repeat the timed process.

Test 3 Timed Results (seconds)		1	2	3	avg
Chromebook Devices	Intel Core i5-10210U	2.2	2.1	2	2.1
	Intel Core i3-10110U	n/a	n/a	n/a	n/a
	Intel Celeron N4020	n/a	n/a	n/a	n/a
	AMD A4-9120C	n/a	n/a	n/a	n/a
	AMD A6-9220C	n/a	n/a	n/a	n/a
	MediaTek Helio P60T	n/a	n/a	n/a	n/a
Windows-based Devices	Intel Core i5-10210U	10.1	9	4	7.7
	Intel® Core™ i3-10110U	n/a	n/a	n/a	n/a
	Intel Celeron N4020	n/a	n/a	n/a	n/a
	AMD A4-9120	n/a	n/a	n/a	n/a
	AMD A6-9220E	n/a	n/a	n/a	n/a

### Test 4 Details

#### Rejoining the main session (student)

1. Click breakout rooms in the Zoom menu.
2. Simultaneously start the timer and click close all rooms.
3. When the device connects to the main session, stop the timer.

		Test 4 Timed Results (seconds)			
		1	2	3	avg
Chromebook Devices	Intel Core i5-10210U	n/a	n/a	n/a	n/a
	Intel Core i3-10110U	1.3	1.2	1.1	1.2
	Intel Celeron N4020	2.1	6.2	1.2	3.2
	AMD A4-9120C	3.1	3	2.2	2.8
	AMD A6-9220C	3.1	3	2.3	2.8
	MediaTek Helio P60T	3	2.3	2.2	2.5
Windows-based Devices	Intel Core i5-10210U	n/a	n/a	n/a	n/a
	Intel® Core™ i3-10110U	10	10.1	8.1	9.4
	Intel Celeron N4020	10.3	11.1	9.2	10.2
	AMD A4-9120	24.1	28	22.3	24.8
	AMD A6-9220E	27	28.2	25	26.7

### Scenario totals

		Scenario Totals (seconds)			
		1	2	3	avg
Chromebook Devices	Intel Core i5-10210U	6.3	6.2	6.1	6.2
	Intel Core i3-10110U	13.5	10.6	12.5	12.2
	Intel Celeron N4020	12.5	16.5	12.2	13.7
	AMD A4-9120C	27.5	20.1	27.2	24.9
	AMD A6-9220C	21.3	17.4	17.6	18.8
	MediaTek Helio P60T	18.5	16.6	19.4	18.2
Windows-based Devices	Intel Core i5-10210U	11.1	9.3	5.0	8.5
	Intel® Core™ i3-10110U	26.3	22.5	18.4	22.4
	Intel Celeron N4020	32.6	31.4	25.5	29.8
	AMD A4-9120	63.3	152.1	131.6	115.7
	AMD A6-9220E	69.4	167.4	71.4	102.7

## C. Middle School Classroom Scenario Quantitative Results<sup>†</sup>

### Test 1 Details

#### Starting a Zoom call (educator)

1. Simultaneously start the timer and click host meeting to start the Zoom video call.
2. When the video call fully connects, stop the timer.

#### Joining a Zoom call (student)

1. Simultaneously start the timer and click the link for the Zoom video call.
2. When the video call fully connects, stop the timer.

Test 1 Timed Results (seconds)		1	2	3	avg
Chromebook Devices	Intel Core i5-10210U	5	4.3	5.2	4.8
	Intel Core i3-10110U	7.2	10.2	9.2	8.9
	Intel Celeron N4020	8.2	9.1	13.1	10.1
	AMD A4-9120C	9.3	14.1	22.1	15.2
	AMD A6-9220C	9	11.2	16.5	12.2
	MediaTek Helio P60T	10.2	12	9.3	10.5
Windows-based Devices	Intel Core i5-10210U	1	0.3	1.1	0.8
	Intel® Core™ i3-10110U	4.3	7	4.3	5.2
	Intel Celeron N4020	11	18.1	14	14.4
	AMD A4-9120	14.1	23.2	18.2	18.5
	AMD A6-9220E	15.3	21.2	16.1	17.5

### Test 2 Details

#### Joining a breakout room (student)

1. Click breakout rooms in the Zoom menu.
2. Set rooms to create 5 breakout rooms that assign automatically.
3. Click create.
4. Simultaneously start the timer and click join on each device.
5. When the device connects to the room, stop the timer.

Test 2 Timed Results (seconds)		1	2	3	avg
Chromebook Devices	Intel Core i5-10210U	n/a	n/a	n/a	n/a
	Intel Core i3-10110U	2.1	3.1	2	2.4
	Intel Celeron N4020	2.3	3.1	6	3.8
	AMD A4-9120C	13.2	5.1	5.2	7.8
	AMD A6-9220C	5.1	3.1	3.2	3.8
	MediaTek Helio P60T	3.1	3.2	4.2	3.5

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Test 2 Timed Results (seconds)		1	2	3	avg
Windows-based Devices	Intel Core i5-10210U	n/a	n/a	n/a	n/a
	Intel® Core™ i3-10110U	6.1	6.2	6.2	6.2
	Intel Celeron N4020	19.2	25.2	64.2	36.2
	AMD A4-9120	17.1	20.1	90.2	42.5
	AMD A6-9220E	DNC	21	89.2	55.1

### Test 3 Details

#### Host joining a breakout room (educator)

1. Click breakout rooms in the Zoom menu.
2. Select a breakout room to join.
3. Simultaneously start the timer and join the room.
4. When host completely joins the room, stop the timer.
5. Use the menu to join a different room and repeat the timed process.

Test 3 Timed Results (seconds)		1	2	3	avg
Chromebook Devices	Intel Core i5-10210U	2.1	5.1	2.2	3.1
	Intel Core i3-10110U	n/a	n/a	n/a	n/a
	Intel Celeron N4020	n/a	n/a	n/a	n/a
	AMD A4-9120C	n/a	n/a	n/a	n/a
	AMD A6-9220C	n/a	n/a	n/a	n/a
	MediaTek Helio P60T	n/a	n/a	n/a	n/a
Windows-based Devices	Intel Core i5-10210U	7.1	4.3	11.1	7.5
	Intel® Core™ i3-10110U	n/a	n/a	n/a	n/a
	Intel Celeron N4020	n/a	n/a	n/a	n/a
	AMD A4-9120	n/a	n/a	n/a	n/a
	AMD A6-9220E	n/a	n/a	n/a	n/a

### Test 4 Details

#### Rejoining the main session (student)

1. Click breakout rooms in the Zoom menu.
2. Simultaneously start the timer and click close all rooms.
3. When the device connects to the main session, stop the timer.

		Test 4 Timed Results (seconds)			
		1	2	3	avg
Chromebook Devices	Intel Core i5-10210U	n/a	n/a	n/a	n/a
	Intel Core i3-10110U	1.2	1.2	1.2	1.2
	Intel Celeron N4020	2.1	2.1	2.1	2.1
	AMD A4-9120C	3.2	3	3	3.1
	AMD A6-9220C	3	3	2.3	2.8
	MediaTek Helio P60T	6	2.3	2.2	3.5
Windows-based Devices	Intel Core i5-10210U	n/a	n/a	n/a	n/a
	Intel® Core™ i3-10110U	8.2	6.3	8.1	7.5
	Intel Celeron N4020	22.2	21.2	31.1	24.8
	AMD A4-9120	9.3	89.2	22.2	40.2
	AMD A6-9220E	DNC	121.1	23	72.1

### Scenario totals

		Scenario Totals (seconds)			
		1	2	3	avg
Chromebook Devices	Intel Core i5-10210U	6.3	6.2	6.1	6.2
	Intel Core i3-10110U	13.5	10.6	12.5	12.2
	Intel Celeron N4020	12.5	16.5	12.2	13.7
	AMD A4-9120C	27.5	20.1	27.2	24.9
	AMD A6-9220C	21.3	17.4	17.6	18.8
	MediaTek Helio P60T	18.5	16.6	19.4	18.2
Windows-based Devices	Intel Core i5-10210U	8.1	4.6	12.2	8.3
	Intel® Core™ i3-10110U	18.6	19.5	18.6	18.9
	Intel Celeron N4020	52.4	64.5	109.3	75.4
	AMD A4-9120	40.5	132.5	130.6	101.2
	AMD A6-9220E	15.3	163.3	128.3	144.7

## D. High School Classroom Scenario Qualitative Results

### Test 1

#### Chromebook Narrative Test

##### Setting a virtual background (student)

1. Click video in the Zoom menu.
2. Click choose virtual background or choose virtual filter.
3. Set and click to exit settings menu.

##### Overall Notes

Virtual backgrounds cannot be set on Chromebooks

#### Windows-based Narrative Test

##### Setting a virtual background (student)

1. Click video in the Zoom menu.
2. Click choose virtual background or choose virtual filter.
3. Set and click to exit settings menu.

##### Overall Notes

Twitch and YouTube were paused after trying to set virtual backgrounds on both AMD devices.

Restarted Twitch on A4, but when trying to restart Twitch on A6, the computer wouldn't respond.

Zoom shut down after being non-responsive on the A6.

Chromebook Devices	Intel Core i5-10210U	No option for setting a virtual background and only option for camera is front camera. Video settings only lets you enable mirror effect.
	Intel Core i3-10110U	No option for setting a virtual background and only option for camera is front camera. Video settings only lets you enable mirror effect.
	Intel Celeron N4020	No option for setting a virtual background and only option for camera is front camera. Video settings only lets you enable mirror effect.
	AMD A4-9120C	No option for setting a virtual background and only option for camera is front camera. Video settings only lets you enable mirror effect.
	AMD A6-9220C	No option for setting a virtual background and only option for camera is front camera. Video settings only lets you enable mirror effect.
	MediaTek Helio P60T	No option for setting a virtual background and only option for camera is front camera. Video settings only lets you enable mirror effect.
Windows-based Devices	Intel Core i5-10210U	Set virtual background and filter and it appeared almost immediately on each screen.
	Intel® Core™ i3-10110U	When uploading an image to set as virtual background, got the prompt to "download virtual background pack." Also got the message "using a virtual background will decrease your video resolution to maintain CPU bandwidth." Set virtual background and it appeared almost immediately on each screen. There is no option for a filter without uploading your own.
	Intel Celeron N4020	Device does not support virtual backgrounds. See <a href="https://support.zoom.us/hc/en-us/articles/360043484511">https://support.zoom.us/hc/en-us/articles/360043484511</a> Requires core i5 or greater; AMD Ryzen 5 or greater, or 8 cores at 3.0GHz per Zoom specs. When uploading an image to set as a virtual background, it allowed me to choose an image. However, upon clicking okay, got the message "your device does not support virtual backgrounds." Was able to upload an image but not select it as a background.

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A6 and A4 Settings > Statistics  
 "High CPU usage may be affecting your meeting experience; please close other applications"  
 Showing 100% CPU usage; N4020 is in the 70-90% usage.

A6 is extremely laggy when trying to open other applications (e.g., opening snipping tool from the Start menu barely works).

Windows-based Devices	<p><b>AMD A4-9120</b></p>	<p>Device does not support virtual backgrounds. See <a href="https://support.zoom.us/hc/en-us/articles/360043484511">https://support.zoom.us/hc/en-us/articles/360043484511</a></p> <p>Requires core i5 or greater; AMD Ryzen 5 or greater, or 8 cores at 3.0GHz per Zoom specs.</p> <p>When uploading an image to set as virtual background, there is a lot of lag time. It allowed me to choose an image and then did nothing for a while. Waited 5 mins and never got the message "your device does not support virtual backgrounds" like on the Core-i3 device. Closed out of settings. Came back to virtual backgrounds and got the message "your device does not support virtual backgrounds."</p> <p>While testing the virtual background on another device, noticed that the screen flashed repeatedly.</p>
	<p><b>AMD A6-9220E</b></p>	<p>Device does not support virtual backgrounds. See <a href="https://support.zoom.us/hc/en-us/articles/360043484511">https://support.zoom.us/hc/en-us/articles/360043484511</a></p> <p>Requires core i5 or greater; AMD Ryzen 5 or greater, or 8 cores at 3.0GHz per Zoom specs.</p> <p>When uploading an image to set as virtual background, the window to select an image gives the message "not responding." After a few minutes the window populated and then became unresponsive again. I could not complete the rest of this test.</p> <p>Eventually Zoom shut down.</p> <p>Very lagging to even bring up the file manager to locate an image.</p> <p>Was able to upload an image but not select it as a background.</p>

## Test 2

### Chromebook Narrative Test

#### Whiteboard test - Screen share Google Drawings

1. Click share screen in Zoom menu.
2. Choose Google Drawings tab or whiteboard application.

#### Overall Notes

YouTube stops on all devices when screen is shared.

### Windows-based Narrative Test

#### Starting and collaborating on a whiteboard (educator)

1. Click share screen in the Zoom menu.
2. Click whiteboard.
3. Click share.

#### Collaborating on a whiteboard (student)

1. Choose view options from the top Zoom menu.
2. Choose annotate.

#### Overall notes

Zoom shut down on the A4 after trying to complete the whiteboard test.

Overall CPU usage was high on A4 and A6.

Chromebook Devices	Intel Core i5-10210U	No issues
	Intel Core i3-10110U	When teacher starts/stops sharing, Twitch and YouTube videos stop. Hardly any lag in seeing changes made to drawing.
	Intel Celeron N4020	When teacher starts/stops sharing, Twitch and YouTube videos stop. Making changes and seeing changes in the drawing has hardly any delay or lag.
	AMD A4-9120C	When navigating to Google Drawings, Chrome quit and all tabs had to be reopened. Slight lag with teacher seeing additions to the drawing from this device, and slight lag in this device seeing the changes from teacher/other students. When teacher starts/stops sharing, YouTube video stops.
	AMD A6-9220C	When teacher starts/stops sharing, Twitch and YouTube videos stop. Google Drawings reacted slowly when trying to add to the drawing and populated slowly on all of the other devices. Quite a bit of lag with teacher seeing additions to the drawing from this device, and slight lag in this device seeing the changes from teacher/other students.
	MediaTek Helio P60T	When teacher starts/stops sharing, Twitch and YouTube videos stop. Very little lag in Google Drawings when trying to add to the drawing. Populated quickly on most devices, except for the A6. Quite a bit of lag with teacher seeing additions to the drawing from this device, and slight lag in this device seeing the changes from teacher/other students. Zoom settings: send - 11fps; receive - 14fps
Windows-based Devices	Intel Core i5-10210U	When sharing the whiteboard from Zoom, it populated quickly on four devices in succession — Core-i5, Core-i3, Celeron, A4. Had to relaunch Zoom on the A6 and it opened to the whiteboard.
	Intel® Core™ i3-10110U	When the host writes on the whiteboard it shows on the screen almost immediately with no lag. When annotating on the shared whiteboard, it shows on the Core-i5 almost immediately with no lag. The Celeron, A4, and A6 all have a slight lag.

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Windows-based Devices	<p><b>Intel Celeron N4020</b></p>	<p>When the host writes on the whiteboard it shows on the screen almost immediately with no lag.</p> <p>When annotating on the shared whiteboard, it shows on the Core-i5 and Core-i3 almost immediately with no lag. The A6 has a slight lag. The A4 took almost 2 seconds to show the annotation.</p>
	<p><b>AMD A4-9120</b></p>	<p>When the host writes on the whiteboard it shows on the screen with a slight lag.</p> <p>When annotating on the shared whiteboard, the screen flashed and the view option controls went away.</p> <p>When annotating on the shared whiteboard, there was quite a bit of lag when choosing a color to draw with.</p> <p>When annotating it didn't immediately show on this or any other screens. When it did show up, it was immediate on the Core-i5, Core-i3, Celeron, and A6 with no lag.</p> <p>When checking settings Zoom was largely unresponsive. Could not complete this part of the test.</p>
	<p><b>AMD A6-9220E</b></p>	<p>When the host writes on the whiteboard it shows on the screen with a noticeable amount of lag. Slowest of the group.</p> <p>When annotating on the shared whiteboard, it shows on the Core-i5, Core-i3, and Celeron almost immediately with no lag. The A4 was unresponsive and had a flashing screen.</p>

## Test 3

### Chromebook Narrative Test

#### Sharing screen

1. Open the appropriate file, application, or browser tab.
2. Click share screen in the Zoom menu.
3. Choose the appropriate display.
4. Click share.
5. While screen sharing, record Zoom settings.

#### Overall Notes

YouTube and Twitch paused on all devices when teacher starts or stops screen sharing.

Devices generally seem to lag (Celeron not as bad, i3 is fine).

A6, A4, and MediaTek cameras turned off on their own during the testing.

### Windows-based Narrative Test

#### Sharing screen (video or audio)

1. Open the appropriate file, application, or browser tab.
2. Click share screen in the Zoom menu.
3. Choose the appropriate display.
4. Click share.
5. While screen sharing, record Zoom settings.

#### Overall notes

Overall CPU usage was high on A4 and A6.

Chromebook Devices	Intel Core i5-10210U	<p>Screen sharing happened immediately upon choosing an application or screen to share and clicking share.</p> <p>When student (i3) shares screen while host is sharing screen, the switch is almost instant.</p> <p>When student (i3) shares a Chromebook app, the educator device takes a second or two to load.</p>
	Intel Core i3-10110U	<p>YouTube and Twitch both stop when teacher shares screen.</p> <p>Video has very little lag, but looks a little glitchy on all student devices.</p> <p><b>When student shares screen:</b></p> <p>Twitch and YouTube stop on all devices.</p> <p>No lag on Core-i5. Slight lag on i3, both AMDs, and the MediaTek.</p>
	Intel Celeron N4020	<p>Device got kicked off of Zoom when teacher shared screen. Zoom reloaded the meeting, shows camera as on but participants cannot see video. All participant videos are frozen or moving extremely slowly. Settings show send and receive at 0fps.</p> <p>Twitch frequently buffers.</p> <p>There's an extreme lag on viewing what is on the teacher's screen (~10 seconds).</p> <p>YouTube and Twitch both stop when teacher shares screen.</p> <p>Video has very little lag, but looks a little glitchy on all student devices.</p> <p><b>When student shares screen:</b></p> <p>Twitch and YouTube stop on all devices..</p> <p>There was a delay in the screen sharing populating on all other devices. Once it comes up, it has a noticeable lag and is glitchy on all other devices.</p>
	AMD A4-9120C	<p>YouTube and Twitch both stop on this device when teacher shares screen.</p> <p>Video has very little lag, but looks a little glitchy on all student devices.</p> <p>Device video does not show to others in class, but device shows the camera is on.</p> <p>YouTube stayed on when the teacher shared their screen, but paused when the teacher stopped screen sharing.</p> <p><b>When student shares screen:</b></p> <p>Twitch and YouTube stop on all devices.</p> <p>There was a delay in the screen sharing populating on all other devices. Once it comes up, it has a noticeable lag and is glitchy on all other devices.</p>

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When the AMD devices shared tabs with livestreams, there was considerable delay, lag, and glitches on all other devices, even when the AMD device had a clear video.

The A6 struggled the most with sending and receiving screen sharing.

The A6 and A4 (especially the A6) were buffering the YouTube video frequently; all Intel devices streamed without buffering.

Even after 10 mins the A6 never managed to load the Twitch stream; A4 was slower to load but not that bad; i3 loaded Twitch quickly with no issues while on Zoom; N4020 had very low resolution for Twitch. Conclusion: the A4 and A6 don't stream video well in the background; the Celeron is ok and the I3 is nearly ideal.

Chromebook Devices	<p><b>AMD A6-9220C</b></p>	<p>YouTube and Twitch both stop on this device when teacher shares screen.</p> <p>Video has very little lag, but looks a little glitchy on all student devices.</p> <p>Device video does not get show to others in class, but device shows camera is on.</p> <p>When teacher shared screen, YouTube stayed on, but when teacher stops sharing screen, youtube pauses.</p> <p><b>When student shares screen:</b></p> <p>Twitch and YouTube stop.</p> <p>There was a delay in the screen sharing populating on all other devices. Once it comes up, it has a noticeable lag and is glitchy on all other devices.</p>
	<p><b>MediaTek Helio P60T</b></p>	<p>YouTube and Twitch both stop on this device when teacher shares screen.</p> <p>Video has very little lag, but looks a little glitchy on all student devices.</p> <p><b>When student shares screen:</b></p> <p>Twitch and YouTube stop on all devices.</p> <p>Tabs are slow to load.</p> <p>No lag on Core-i5 or Core-i3. Slight lag on Celeron and both AMDs.</p>
Windows-based Devices	<p><b>Intel Core i5-10210U</b></p>	<p>When host screen shares Edge window, it shows up almost immediately on each of the other devices.</p> <p>When switching tabs to screen share Twitch, it shows up almost immediately on the Core-i3, Celeron, and A6. There was slight lag and delay on the A4.</p> <p>When ending screen sharing, it ended immediately on all devices.</p>
	<p><b>Intel® Core™ i3-10110U</b></p>	<p>When host screen shares Edge Window, it shows up almost immediately. When switching tabs to share Twitch, it shows up immediately with no lag.</p> <p>When sharing Edge Window from this device, screen share shows up immediately on Core-i5, Celeron, and A4. There is a slight delay and lag on A6. When switching to the Twitch tab, each device except the A6 showed the new display at the same time with little lag or delay. Same results when switching to the YouTube tab. The A6 showed a glitchy and lagging screen.</p>

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Windows-based Devices	<p><b>Intel Celeron N4020</b></p>	<p>When host screen shares Edge Window, it shows up almost automatically. When switching tabs to share Twitch, it shows up immediately with no lag.</p> <p>When sharing Edge Window from this device, screen share shows up immediately on all devices. When switching to the Twitch tab, each device showed the new display at the same time. There was quite a bit of lag and delay on each of the other devices and none had a clear video of the stream.</p>
	<p><b>AMD A4-9120</b></p>	<p>When host screen shares Edge Window, it shows up almost immediately. When switching tabs to share Twitch, it shows up immediately with no lag.</p> <p>When sharing Edge Window from this device, screen share shows up immediately on Core-i5, Core-i3, and Celeron. There is a slight delay in the screen showing on the A6. When switching to the Twitch tab, the device shared the screen but immediately began buffering the live feed. Each device showed the new display at the same time. There was quite a bit of lag and delay on each of the other devices and none had a clear video of the stream.</p>
	<p><b>AMD A6-9220E</b></p>	<p>When host screen shares Edge Window, it shows up almost immediately. When switching tabs to share Twitch, it shows up immediately with no lag.</p> <p>When sharing Edge Window from this device, the screen shows up immediately on all other devices.</p> <p>When switching to the Twitch tab, the device shared the screen but immediately began buffering the live feed, and when it came back it was delayed and glitchy. It took 15 secs for the other devices to show the screen share. There was quite a bit of lag and delay on each of the other devices and none had a clear video of the stream.</p> <p>When switching to the YouTube tab, similar results occurred. It took 3 seconds for the other devices to show the new screen and they were all delayed, lagging, and glitchy. The stream on this device had good quality when sharing this tab.</p>

## Test 4

### Chromebook Narrative Test

#### Joining breakout rooms

1. Click breakout rooms in the Zoom menu.
2. Set breakout rooms to automatically have students join.
3. Open all rooms.

#### Overall notes

YouTube pauses when student navigates to Zoom. Video will only continue to play if student is on the YouTube tab, or if they are in a web browser.

### Windows-based Narrative Test

#### Choosing a breakout room

1. Click breakout rooms in the Zoom menu.
2. Choose breakout room and click join.
3. Click join room.

#### Overall Notes

The A6 could not complete this test as it never joined the breakout room.

Chromebook Devices	Intel Core i5-10210U	The host has limited options on the Chromebook for creating breakout rooms. There is no option to send participants to breakout rooms automatically to avoid each participant having to click join.
	Intel Core i3-10110U	YouTube and Twitch both stop when in breakout room.
	Intel Celeron N4020	YouTube and Twitch both stop when in breakout room.
	AMD A4-9120C	YouTube and Twitch both stop when in breakout room. Twitch buffers a lot. Video has extreme lag.
	AMD A6-9220C	YouTube and Twitch both stop when in breakout room.
	MediaTek Helio P60T	YouTube and Twitch both stop when in breakout room.
Windows-based Devices	Intel Core i5-10210U	Set up and opened the breakout rooms. Immediately each device received a message at the bottom of the Zoom window to "join a breakout room."  When closing the breakout rooms, all devices came back to the main session without delay, except the A6. It took a considerable amount of time to rejoin the main session even though it never joined the breakout room.
	Intel® Core™ i3-10110U	Chose breakout room 1 and joined without much delay.
	Intel Celeron N4020	Chose breakout room 2 and joined without much delay.
	AMD A4-9120	Chose breakout room 3. Joined breakout room with a significant delay of about 30 seconds.  Twitch stream stopped in the background.
	AMD A6-9220E	DNC (one instance of testing).  Chose breakout room 4. Got the "joining room 4" message box on the screen and after 1 min this device still hadn't joined the room.  Joined breakout room with a significant delay of about 45 seconds.  Video stopped streaming and had to toggle off/on before it came back on.  Twitch stream stopped in the background.

## Test 5

### Chromebook Narrative Test

Recording session locally from main room (educator)

Recording session locally from breakout room (student)

#### Overall Notes

Students have no record options.

### Windows-based Narrative Test

#### Host Moving Between Breakout Rooms

1. Click breakout rooms in the Zoom menu.
2. Select a breakout room to join.
3. Use the menu to join a different room and repeat the timed process.

#### Overall Notes

A4 displayed the "high CPU usage" warning and occasionally the A6 did, as well, during this test.

Chromebook Devices	Intel Core i5-10210U	No issues recording
	Intel Core i3-10110U	N/A
	Intel Celeron N4020	N/A
	AMD A4-9120C	N/A
	AMD A6-9220C	N/A
	MediaTek Helio P60T	N/A
Windows-based Devices	Intel Core i5-10210U	Opened all breakout rooms. Each device went immediately to their breakout room, except for the A6. It had similar results as the previous test. It took about 1.5 mins for the A6 to join the assigned breakout room.  Joined breakout room 1 with no delay. Joined breakout room 2 with no delay.
	Intel® Core™ i3-10110U	N/A
	Intel Celeron N4020	N/A
	AMD A4-9120	N/A
	AMD A6-9220E	N/A

## Test 6

### Windows-based Narrative Test

Video/camera on and off

#### Overall notes

Bandwidth dropped considerably on each device when camera was turned off.

It might be possible to get a usable experience with the AMD devices only if cameras are turned off the entire time.

The A6 froze during this test and was unable to turn off video; when it finally un-froze (on its own) the CPU usage was at 100%.

N4020 CPU usage dropped to below 50% when video was turned off.

A4 CPU usage dropped a bit to 85% when video was turned off (and occasionally still jumped to 100%).

Chromebook Devices	Intel Core i5-10210U	N/A
	Intel Core i3-10110U	N/A
	Intel Celeron N4020	N/A
	AMD A4-9120C	N/A
	AMD A6-9220C	N/A
	MediaTek Helio P60T	N/A
Windows-based Devices	Intel Core i5-10210U	On: 14% Zoom; 28% overall Off: 8% Zoom; 14% overall
	Intel® Core™ i3-10110U	On: 17% Zoom; 43% overall Off: 9% Zoom; 28% overall
	Intel Celeron N4020	On: 22% Zoom; 56% overall Off: 14% Zoom; 41% overall
	AMD A4-9120	On: 43% Zoom; 98% overall Off: 19% Zoom; 90% overall
	AMD A6-9220E	On: 100% Zoom; 100% overall Off: 100% Zoom; 100% overall

## E. Middle School Classroom Scenario Qualitative Results

### Test 1

#### Chromebook Narrative Test

##### Setting a virtual background (student)

1. Click video in the Zoom menu.
2. Click choose virtual background or choose virtual filter.
3. Set and click to exit settings menu.

##### Overall Notes

Virtual backgrounds cannot be set on Chromebooks.

#### Windows-based Narrative Test

##### Setting a virtual background

1. Click video in the Zoom menu.
2. Click choose virtual background or choose virtual filter.
3. Set and click to exit settings menu.

##### Overall Notes

On the Core-i3, overall CPU usage was at 98% (red/high). This is the first time I've seen this message on this device.

Got "your internet is unstable" messages on both the A4 and A6 after this test.

Chromebook Devices	Intel Core i5-10210U	No option for setting a virtual background and only option for camera is front camera. Video settings only lets you enable mirror effect.
	Intel Core i3-10110U	No option for setting a virtual background and only option for camera is front camera. Video settings only lets you enable mirror effect.
	Intel Celeron N4020	No option for setting a virtual background and only option for camera is front camera. Video settings only lets you enable mirror effect.
	AMD A4-9120C	No option for setting a virtual background and only option for camera is front camera. Video settings only lets you enable mirror effect.
	AMD A6-9220C	No option for setting a virtual background and only option for camera is front camera. Video settings only lets you enable mirror effect.
	MediaTek Helio P60T	No option for setting a virtual background and only option for camera is front camera. Video settings only lets you enable mirror effect.
Windows-based Devices	Intel Core i5-10210U	Set virtual background and filter and it appeared almost immediately on each screen.
	Intel® Core™ i3-10110U	When uploading an image to set as virtual background, got the prompt to "download virtual background pack." Also got the message "using a virtual background will decrease your video resolution to maintain CPU bandwidth." Set virtual background and it appeared almost immediately on each screen. There is no option for a filter without uploading your own.
	Intel Celeron N4020	Device does not support virtual backgrounds. See <a href="https://support.zoom.us/hc/en-us/articles/360043484511">https://support.zoom.us/hc/en-us/articles/360043484511</a> Requires core i5 or greater; AMD Ryzen 5 or greater, or 8 cores at 3.0GHz per Zoom specs. When uploading an image to set as a virtual background, it allowed me to choose an image. However, upon clicking okay, got the message "your device does not support virtual backgrounds." Was able to upload an image but not select it as a background.

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Windows-based Devices	<p><b>AMD A4-9120</b></p>	<p>Device does not support virtual backgrounds. See <a href="https://support.zoom.us/hc/en-us/articles/360043484511">https://support.zoom.us/hc/en-us/articles/360043484511</a></p> <p>Requires core i5 or greater; AMD Ryzen 5 or greater, or 8 cores at 3.0GHz per Zoom specs.</p> <p>When uploading an image to set as a virtual background, there is a lot of lag time. It allowed me to choose an image and then did nothing for a while. Waited 5 mins and never got the message "your device does not support virtual backgrounds" like on the Core-i3 device. Closed out of settings. Came back to virtual backgrounds and got the message "your device does not support virtual backgrounds."</p> <p>While testing the virtual background on another device, noticed that the screen flashed repeatedly.</p>
	<p><b>AMD A6-9220E</b></p>	<p>Device does not support virtual backgrounds. See <a href="https://support.zoom.us/hc/en-us/articles/360043484511">https://support.zoom.us/hc/en-us/articles/360043484511</a></p> <p>Requires core i5 or greater; AMD Ryzen 5 or greater, or 8 cores at 3.0GHz per Zoom specs.</p> <p>When uploading an image to set as a virtual background, the window to select an image gives the message "not responding." After a few minutes the window populated and became unresponsive again. I could not complete the rest of this test.</p> <p>Eventually Zoom shut down.</p> <p>Very lagging to even bring up the file manager to locate an image.</p> <p>Was able to upload an image but not select it as a background.</p>

## Test 2

### Chromebook Narrative Test

#### Whiteboard test - Screen share Google Drawings

1. Click share screen in Zoom menu.
2. Choose Google Drawings tab or whiteboard application.

#### Overall Notes

Twitch stops on all devices when screen is shared.

### Windows-based Narrative Test

#### Starting and collaborating on a whiteboard (educator)

1. Click share screen in Zoom menu.
2. Click whiteboard.
3. Click share.

#### Collaborating on a whiteboard (student)

1. Choose view options from the top Zoom menu.
2. Choose annotate.

#### Overall notes

Zoom closed unexpectedly on the A6 after the previous test, so it had to be restarted. No issues with A6 on 2nd round of testing.

Chromebook Devices	Intel Core i5-10210U	No issues
	Intel Core i3-10110U	When teacher starts/stops sharing, Twitch livestream stops. Twitch does not stay playing when navigating away from Chrome browser.  Little to no lag, can see changes made by others quickly and can add to the drawing with no delays.
	Intel Celeron N4020	When teacher starts/stops sharing, Twitch livestream stops. Twitch does not stay playing when navigating away from Chrome browser.  Making changes and seeing changes to the drawing has hardly any delay or lag.
	AMD A4-9120C	When teacher starts/stops sharing, Twitch livestream stops. Twitch video paused and takes a long time to load. Chat stream continues, but video buffers for a while. Video pauses when student navigates away from Chrome browser.  Making changes to the drawing on this device has a slight lag. Seeing changes has hardly any delay or lag.  Device is generally slow. Browser tabs reload when navigating between them and take a long time to fully load.
	AMD A6-9220C	When teacher starts/stops sharing, Twitch livestream stops.  There was quite a bit of lag when trying to navigate Chrome browser tabs to add to the drawing. Making changes to the drawing on this device has a considerable lag. Seeing changes also has a noticeable lag.  Starting note: Student kicked out of Zoom prior to having testing all set up. Student had all programs/tabs open, but had not yet signed into Minecraft. Student got kicked out of Zoom while Minecraft was loading (prior to login). Student was automatically reconnected to Zoom.  On login to Minecraft, a message appeared: "Minecraft Education Edition isn't responding." Given the option to close the app, wait, or send feedback. Pressed "Wait" and then student was kicked out of Zoom again. Once finally back in Zoom with Minecraft running, student video was not displaying or was frozen on other devices.  Student keeps getting kicked out of Zoom when trying to navigate to other programs.  Twitch livestream flickers, and pauses when student navigates away from Chrome browser.  "Your high CPU usage is affecting your meeting quality" message appears in Zoom.

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<p style="writing-mode: vertical-rl; transform: rotate(180deg);">Chromebook Devices</p>	<p><b>MediaTek Helio P60T</b></p>	<p>When teacher starts/stops sharing, Twitch livestream stops. Twitch pauses when student navigates away from the Chrome browser.</p> <p>Making changes to the drawing on this device has a slight lag. Seeing changes also has a slight lag.</p> <p>Device screen went black, then came back on, but the Zoom screen remains completely black. Other computers still see the student's video, but student cannot see anything. Student had to leave the Zoom meeting and rejoin. Rejoining took 2 tries, the first time with a message "Your meeting should start in a few seconds" but meeting didn't load. Had to rejoin the meeting again.</p> <p>Once student was back in Zoom, Minecraft reloaded.</p>
<p style="writing-mode: vertical-rl; transform: rotate(180deg);">Windows-based Devices</p>	<p><b>Intel Core i5-10210U</b></p>	<p>When sharing the whiteboard from Zoom, it populated quickly on two devices in succession — Core-i3 and the Celeron. It took the A4 and A6 longer to load.</p>
	<p><b>Intel® Core™ i3-10110U</b></p>	<p>When the host writes on the whiteboard it shows on the screen almost immediately with no lag.</p> <p>When annotating on the shared whiteboard, it shows on the Core-i5 almost immediately with no lag. The Celeron, A4, and A6 all have a slight lag.</p>
	<p><b>Intel Celeron N4020</b></p>	<p>When the host writes on the whiteboard it shows on the screen almost immediately with no lag.</p> <p>When annotating on the shared whiteboard, it shows on the Core-i5 and Core-i3 almost immediately with no lag. The A6 has a slight lag. The A4 took almost 2 seconds to show the annotation.</p>
	<p><b>AMD A4-9120</b></p>	<p>When the host writes on the whiteboard it shows on the screen with a slight lag.</p> <p>When annotating on the shared whiteboard, the screen flashed and the view option controls went away.</p> <p>When annotating on the shared whiteboard, there was quite a bit of lag when choosing a color to draw with.</p> <p>When annotating it didn't immediately show on this or any other screens. When it did show up, it was immediate on the Core-i5, Core-i3, Celeron, and A6 with no lag.</p>
	<p><b>AMD A6-9220E</b></p>	<p>When the host writes on the whiteboard it shows on the screen with a noticeable amount of lag. Slowest of the group.</p> <p>When annotating on the shared whiteboard, it shows on the Core-i5, Core-i3, and Celeron almost immediately with no lag. The A4 was unresponsive and had a flashing screen.</p>

## Test 3

### Chromebook Narrative Test

#### Sharing screen

1. Open the appropriate file, application, or browser tab.
2. Click share screen in the Zoom menu.
3. Choose the appropriate display.
4. Click share.
5. While screen sharing, record Zoom settings.

#### Overall Notes

The cameras on the AMDs and the MediaTek turned off on their own upon screen sharing.

### Windows-based Narrative Test

#### Sharing screen (video or audio)

1. Open the appropriate file, application, or browser tab.
2. Click share screen in the Zoom menu.
3. Choose the appropriate display.
4. Click share.
5. While screen sharing, record Zoom\* settings.

#### Overall notes

The A6 and A4 were both unable to complete all of these tests as they both froze and became non-responsive.

When trying to restart the A6 to rejoin the Zoom call, it took a long time for it to even power back up and load.

Chromebook Devices	Intel Core i5-10210U	<p>Host has options to have only one person share or have multiple people share simultaneously.</p> <p>Screen sharing happened immediately upon choosing an application or screen to share and clicking share, except on the A4 where there was considerable lag in loading the screen.</p> <p>When screen sharing in-game play, there is a slight lag on the Core-i3 and considerable lag on the Celeron, AMDs, and MediaTek.</p>
	Intel Core i3-10110U	<p>Twitch livestream pauses on screen share.</p> <p>Slight lag when host shares in-game play.</p> <p><b>When student shares screen:</b></p> <p>Twitch livestream stopped on all devices.</p> <p>No lag on Core-i5. Slight lag on Celeron. Considerable lag on both AMDs and MediaTek when sharing in-game play.</p>
	Intel Celeron N4020	<p>Twitch livestream pauses on screen share.</p> <p>Considerable lag when host shares in-game play.</p> <p><b>When student shares screen:</b></p> <p>Twitch livestream stopped on all devices.</p> <p>Slight lag on Core-i5 and Core-i3. Considerable lag on both AMDs and MediaTek when sharing in-game play.</p>
	AMD A4-9120C	<p>Twitch livestream pauses on screen share.</p> <p>Considerable lag when host shares in-game play.</p> <p><b>When student shares screen:</b></p> <p>Twitch livestream stopped on all devices.</p> <p>Camera turned off on its own after starting screen share.</p> <p>There was lag on this device when beginning in-game play while screen sharing.</p> <p>Considerable lag on all devices when sharing in-game play. They took at least 2-3 seconds to catch up. The more movement in-game, the more lag and delay seen.</p>
	AMD A6-9220C	<p>Twitch livestream pauses on screen share.</p> <p>Considerable lag when host shares in-game play.</p> <p><b>When student shares screen:</b></p> <p>Twitch livestream stopped on all devices.</p> <p>Camera turned off on its own after starting screen share.</p> <p>There was considerable lag on all devices when sharing in-game play. They took at least 1-2 seconds to catch up. The more movement in-game, the more lag and delay seen.</p>

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Chromebook Devices	<p><b>MediaTek Helio P60T</b></p>	<p>Twitch livestream pauses on screen share.</p> <p>Considerable lag when host shares in-game play.</p> <p><b>When student shares screen:</b></p> <p>Twitch and YouTube stopped on all devices.</p> <p>Camera turned off on its own after starting screen share.</p> <p>Slight lag on all devices when sharing in-game play. The more movement in-game, the more lag and delay seen.</p>
Windows-based Devices	<p><b>Intel Core i5-10210U</b></p>	<p>When sharing the whiteboard from Zoom, it populated quickly on two devices in succession—Core-i3 and the Celeron. It took the A4 and A6 longer to load.</p>
	<p><b>Intel® Core™ i3-10110U</b></p>	<p>When host screen shares Edge Window, it shows up almost immediately. When switching tabs to share Twitch, it shows up immediately with no lag.</p> <p>When sharing Edge Window from this device, screen share shows up immediately on Core-i5, Celeron, and A4. There is a slight delay and lag on A6. When switching to the Twitch tab, the Core-i5 and Celeron showed the new display at the same time with little lag or delay. The A4 and A6 had considerable delay and lag.</p> <p>Similar results when sharing Minecraft: Education Edition screen. When screen sharing while doing in-game play, the Core-i5 had a slight lag. The Celeron and A4 had more lag, and the A6 had considerable lag and there was no fluidity to the streaming game play.</p>
	<p><b>Intel Celeron N4020</b></p>	<p>When host screen shares Edge Window, it shows up almost immediately. When switching tabs to share Twitch, it shows up immediately with no lag.</p> <p>When sharing Edge Window from this device, screen share shows up immediately on all devices. When switching to the Twitch tab, the Core-i5 and Celeron showed the new display at the same time with little lag or delay. The A4 and A6 had considerable delay and lag.</p> <p>When sharing Minecraft: Education Edition screen, the Core-i5 and Core-i3 devices showed the screen almost immediately. When screen sharing while doing in-game play, the Core-i5 and Core-i3 had a slight lag. The Celeron had more lag, and the A4 and A6 had considerable lag and there was no fluidity to the streaming game play.</p>

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Windows-based Devices	<p><b>AMD A4-9120</b></p>	<p>When host screen shares Edge Window, it shows up almost immediately. When switching tabs to share Twitch, it shows up immediately with no lag.</p> <p>When sharing Edge Window from this device, it took a while for the screen sharing menu to appear on the screen. When trying to choose a screen to share, the screen flashed and then froze. Was not able to complete the test to screen share Edge Window, Twitch, or Minecraft: Education Edition. Got the message "Zoom is not responding." When it did work, it took 15 seconds before the share options appeared. Did not fail as in Test 1 but took a long time to be able to screen share.</p>
	<p><b>AMD A6-9220E</b></p>	<p>When host shares screen, there is a bit of delay in the share appearing but not too bad. In comparing the two, I did notice a delay in what the host was sharing and what was being displayed.</p> <p>When sharing Edge Window from this device, it took a few extra seconds for the screen sharing menu to appear on the screen. When trying to select a screen to share, it showed that the screen was shared on the device but it took about 7 seconds for the Edge Window screen to show on the Core-i5, Core-i3, and Celeron. The A4 was still not responding via the previous test. Got a message on the A4 that said "screensharing not working, error code 1."</p> <p>When switching to the Twitch tab, the tab wouldn't respond and I got the message "your internet is unstable." The screen wouldn't load on this device and just showed the non-loading screen. At this point the screen was not responding. Could not complete the Minecraft: Education Edition screen share as the device was frozen and not responding.</p> <p>When it did work, it was a similar experience as the A4 when sharing Minecraft and Twitch, in that it took about 15 seconds for the sharing menu to appear before I could select the screen. Once I was sharing, I experienced a lot of lag in using Minecraft during gameplay and even selecting a different browser tab.</p>

## Test 4

### Chromebook Narrative Test

#### Joining breakout rooms

1. Click breakout rooms in the Zoom menu.
2. Set breakout rooms to automatically have students join.
3. Open all rooms.

#### Overall notes

Twitch pauses when navigating to Zoom; however, if a student navigates from the Chrome browser to another app (e.g., Minecraft, 3D Object Maker), the Twitch livestream continues to play.

A4 dropped the Zoom call and had to rejoin.

### Windows-based Narrative Test

#### Choosing a breakout room

1. Click breakout rooms in the Zoom menu.
2. Choose breakout room and click join.
3. Click join room.

#### Overall Notes

The A6 was unable to complete this test, as Zoom became non-responsive when trying to join a breakout room and then shut down. I had to rejoin the Zoom meeting.

Chromebook Devices	Intel Core i5-10210U	The host has limited options on the Chromebook for creating breakout rooms. There is no option to send participants to breakout rooms automatically to avoid each participant having to click join.
	Intel Core i3-10110U	Twitch pauses livestream when navigating away from Chrome to join the breakout room. No noticeable lag on Minecraft: Education Edition or any browser tabs.
	Intel Celeron N4020	Twitch pauses livestream when navigating away from Chrome to join the breakout room. Slight lag on Minecraft: Education Edition, but no noticeable lag on any browser tabs.
	AMD A4-9120C	Twitch pauses livestream when navigating away from Chrome to join the breakout room. Twitch does not play the livestream after multiple attempts, browser tab has to be refreshed, and the stream takes a long time to load after pressing the play button many times. Noticeable lag on Minecraft: Education Edition when doing in-game play. Twitch had a slight lag and had to buffer once. No lag with browser tabs. While doing this test, the device dropped the Zoom call and had to rejoin the main session to be reassigned (and join) a breakout room. Upon returning, got a message about CPU usage being high.
	AMD A6-9220C	Twitch pauses livestream when navigating away from Chrome to join the breakout room. No noticeable lag on Minecraft: Education Edition when doing in-game play. Twitch had a slight lag, and no lag noticeable on browser tabs. While doing this test, the device dropped the Zoom call and had to rejoin the main session to be reassigned (and join) a breakout room. Zoom gave a warning of high CPU usage: "CPU usage is affecting meeting quality". Device did not get a pop-up to join the breakout room and is stuck in the main session. Teacher had to move the student back to the breakout room. Very low video quality of other participants. Tabs are slow to respond and many reload.
	MediaTek Helio P60T	Twitch pauses livestream when navigating away from Chrome to join the breakout room. No noticeable lag on Minecraft: Education Edition or any browser tabs. Students video freezes, or has significant lag on other student computers. Very low video quality of other participants.

Table continues on next page

Windows-based Devices	Intel Core i5-10210U	<p>Set up and opened the breakout rooms. Upon opening the breakout rooms, there was no Zoom message asking participants to join.</p> <p>When closing the breakout rooms, the A4 and A6 were delayed by ~10 secs before rejoining the main session.</p>
	Intel® Core™ i3-10110U	Chose breakout room 1 and joined without much delay.
	Intel Celeron N4020	Chose breakout room 2 and joined without much delay.
	AMD A4-9120	Chose breakout room 3 and joined without much delay.
	AMD A6-9220E	<p>When trying to navigate to the Zoom menu to choose a breakout room, device was non-responsive. After a few seconds, I was able to navigate to the menu. Chose breakout room 4 and was not able to join the breakout room, as Zoom was not responding.</p> <p>Message on the host device showed the A6 in the breakout room as "not joined" and then disappeared as if the device was no longer in the call. There was no prompting on the device screen that the Zoom call had dropped.</p> <p>When it did work, chose breakout room 1 and joined with significant delay of more than 30 seconds.</p>

## Test 5

### Chromebook Narrative Test

Recording session locally from main session (educator)

Recording session locally from breakout room (student)

#### Overall Notes

Students have no record options.

### Windows-based Narrative Test

#### Host Moving Between Breakout Rooms

1. Click breakout rooms in the Zoom menu.
2. Select a breakout room to join.
3. Use the menu to join a different room and repeat the timed process.

Chromebook Devices	Intel Core i5-10210U	No issues recording
	Intel Core i3-10110U	N/A
	Intel Celeron N4020	N/A
	AMD A4-9120C	N/A
	AMD A6-9220C	N/A
	MediaTek Helio P60T	N/A
Windows-based Devices	Intel Core i5-10210U	Opened all breakout rooms. Each device went immediately to their breakout room, except for the A6. It had similar results as the previous test. It took about 1.5 mins for the A6 to join the assigned breakout room.  Joined breakout room 1 with no delay. Joined breakout room 2 with no delay.
	Intel® Core™ i3-10110U	N/A
	Intel Celeron N4020	N/A
	AMD A4-9120	N/A
	AMD A6-9220E	N/A

## Test 6

### Windows-based Narrative Test

Video/camera on and off

Chromebook Devices	Intel Core i5-10210U	N/A
	Intel Core i3-10110U	N/A
	Intel Celeron N4020	N/A
	AMD A4-9120C	N/A
	AMD A6-9220C	N/A
	MediaTek Helio P60T	N/A
Windows-based Devices	Intel Core i5-10210U	On: 10% Zoom; 34% overall Off: 3% Zoom; 13% overall
	Intel® Core™ i3-10110U	On: 16% Zoom; 99% overall Off: 10% Zoom; 86% overall
	Intel Celeron N4020	On: 26% Zoom; 95% overall Off: 17% Zoom; 63% overall
	AMD A4-9120	On: 41% Zoom; 100% overall Off: 30% Zoom; 100% overall
	AMD A6-9220E	On: 40% Zoom; 100% overall Off: 32% Zoom; 100% overall