CHOOSING CHROMEBOOKS FOR EDUCATION

CONSIDERING COST AND USER EXPERIENCE, EDUCATORS HAVE MANY CHROMEBOOK CHOICES

EXECUTIVE SUMMARY

A broadening trend in K-12 education is the use of Chromebooks, driven by digitization of educational tools and materials. The heart of Chromebooks, Google's Chrome OS, is a **free** operating system, which is maintained and updated by Google over the cloud and helps lower acquisition costs for school districts. According to Google, Chromebooks give "students, teachers, and administrators a simple solution for fast, intuitive, and easy-to-manage computing. Chromebooks provide access to the web's education and collaboration resources."[1]

Moor Insights & Strategy (MI&S), a leading technology industry analyst firm, conducted primary research with educators and performed technical benchmark testing on behalf of ARM Holdings on both ARM- and x86-based Chromebooks. ARM's heritage and experience in enabling quality mobile experiences through rich graphics and power efficient CPUs enable ARM-based Chromebooks to deliver much of what educators and students need. MI&S recommends that educators add ARM-based Chromebooks to their Chromebook consideration set.

RESEARCH

BACKGROUND

To properly test and compare different Chromebooks, MI&S first conducted primary research to identify educational usage trends and common pain points. In December 2015, MI&S polled 252 US-based K-12 educators, including teachers, administrators, and staff at all grade levels. Questions were designed to be completely hardware and operating system agnostic. This approach provided an overview of K-12 students' usage models and problems K-12 educators would like to see solved.

[1] Moor Insights & Strategy did not test subjective "intuitiveness" nor ease of management of Chromebooks in researching this paper and cannot attest to the truthfulness of these claims.

USAGE

For the current school year, 2015-2016, the top activities are…

- Online: Viewing **Images**, Reading **Text**, Watching **Videos**, Listening to **Audio**
- Online or offline: Using a **Word Processing** program, Using a **Presentation Program**
- **Google Docs** (half of all students use at least weekly)

For next school year, 2016-2017, the most commonly anticipated activities are…

- **Creating and delivering presentations**
- **Using a word processing program**
- **Using online resources related to a given subject area**

PAIN POINTS

Educators identify four major pain points that make educational computing experiences difficult—both for their students and for themselves. In order of most to least painful…

- **Internet Connectivity**
- **Battery Life**
- **Performance**
- **Charging Time**

These pain points are for general computing usage and are not specific to any type of computer or computing platform.

WHY CHROMEBOOKS FOR EDUCATION?

Chromebooks are simple to use and power on quickly. According to Google, Chromebooks "boot in 8 seconds and resume instantly—eliminating the time wasted while traditional computers start up and connect to a network. Long battery life means Chromebooks last an entire school day."[2] Chromebooks are capable of working both online and offline, with many major applications like Google Docs having offline capabilities. Chromebooks are also built around the idea that a light operating system

[2] Moor Insights & Strategy did not attempt to verify the boot time claim as part of our testing but can attest to video playback battery life, as shown by our testing described later in this paper.

puts minimal load on the processor on which it runs. Chrome OS will run on both ARM and x86 architecture.

THE CHROME OS HARDWARE ECOSYSTEM

As stated, Chrome OS will run on both ARM and x86 architectures. These two architectures are the foundation for the Chrome OS hardware ecosystem. ARM licenses their architecture to chip partners who then design and manufacture ARM-based SoCs, while Intel designs and builds various x86 CPUs. OEMs then purchase CPUs and SoCs for the Chromebooks they manufacture and sell.

The explosion of "small screen" device usage among K-12 students is driving a need for smartphone- and tablet-style user experiences on "large screen" computers (Chromebooks and PCs). Chrome OS leverages Google's expertise in mobile and in cloud computing to build their mobile innovations into large screen computers. Chrome OS was the first large screen compute ecosystem to take advantage of mobile SoCs. Chromebooks based on ARM mobile SoCs emphasize the user experience, including fast 3D graphics, HD video playback, and power efficiency.

TESTING METHODOLOGY

ARM selected hardware that was a good balance of user experience and price. MI&S tested two Chromebooks that were as comparable as possible: an ARM-based ASUS Chromebook Flip and an x86-based Dell Chromebook 11.

TABLE 1: CHROMEBOOK SPECIFICATIONS

	ARM-based Chromebook	**x86-based Chromebook**
OEM	ASUS	Dell
Model	Chromebook Flip	Chromebook 11
SoC	Rockchip RK3288 1.8 GHz	Intel Celeron N2840 2.16 GHz
Cores	4	2
RAM	4GB	2 GB
Storage	16GB eMMC	16GB eMMC
Display	10.1" (1280x800)	11.6" (1366x768)
Touch	Yes	No
Battery	2-cell 31WHr	3-cell 43WHr
Wi-Fi	Integrated AC	Intel 7260 AC
Weight	0.89 kg / 1.96 lbs	1.245 kg / 2.75 lbs

The primary differences between these two devices are their processors and RAM configuration; the ARM based Chromebook also has a touch screen. The other specifications are as shown.

The testing methodology was designed based on the usages and pain points identified in the educator research, combined with popular Chrome Store applications that fit those needs. The top uses and problems that MI&S tested were:

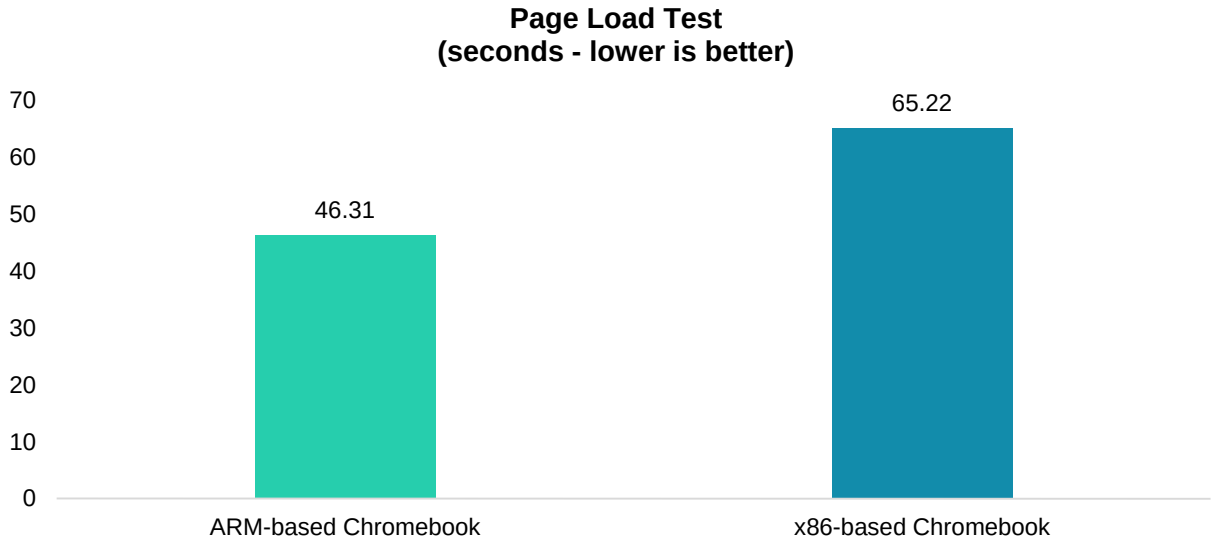
- Online: **Images**, **Text**, **Video**, and **Audio**
- Online or offline: **Document** programs and **Presentation** programs
- **Google Docs**
- **Internet Connectivity**
- **Battery Life**, **Performance**, and **Charging Time**

TESTING RESULTS

MI&S discovered a broad spectrum of results that illustrate the similarities and differences of the Chromebooks with ARM and x86 chipsets. They are ordered in terms of addressing educators' pain points with most important first.

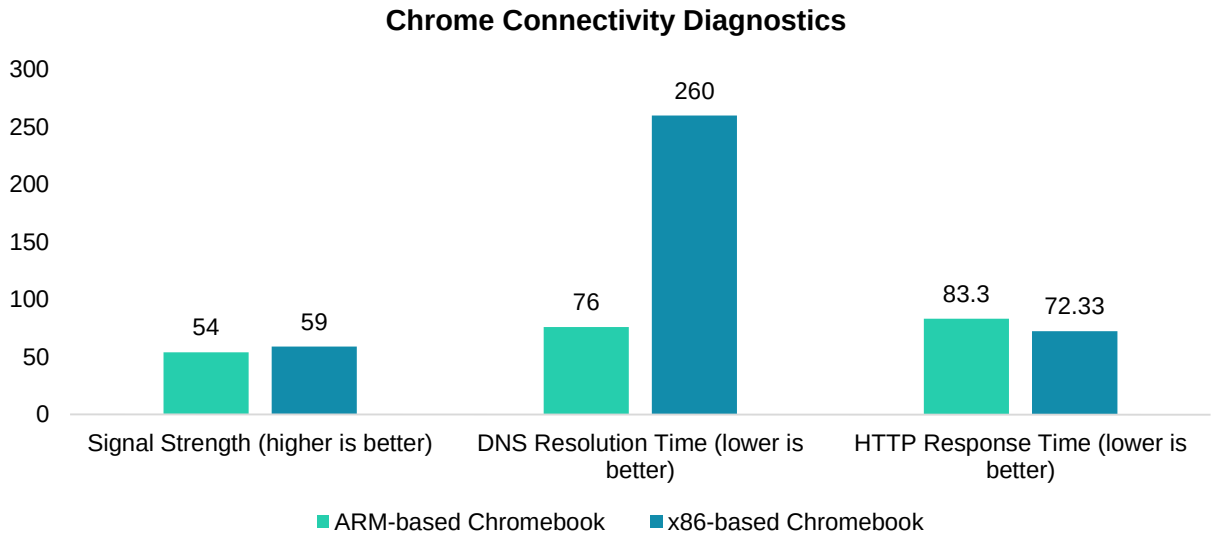
PAGE LOAD TEST

The page load test measures overall connectivity and network performance. It is a combination of seven browser tabs—a number that provides reasonable visibility on screen, yet still pushes system performance—opening simultaneously, including pages like Google and Khan Academy. The ARM-based Chromebook performed better, owing to more CPU cores and RAM.



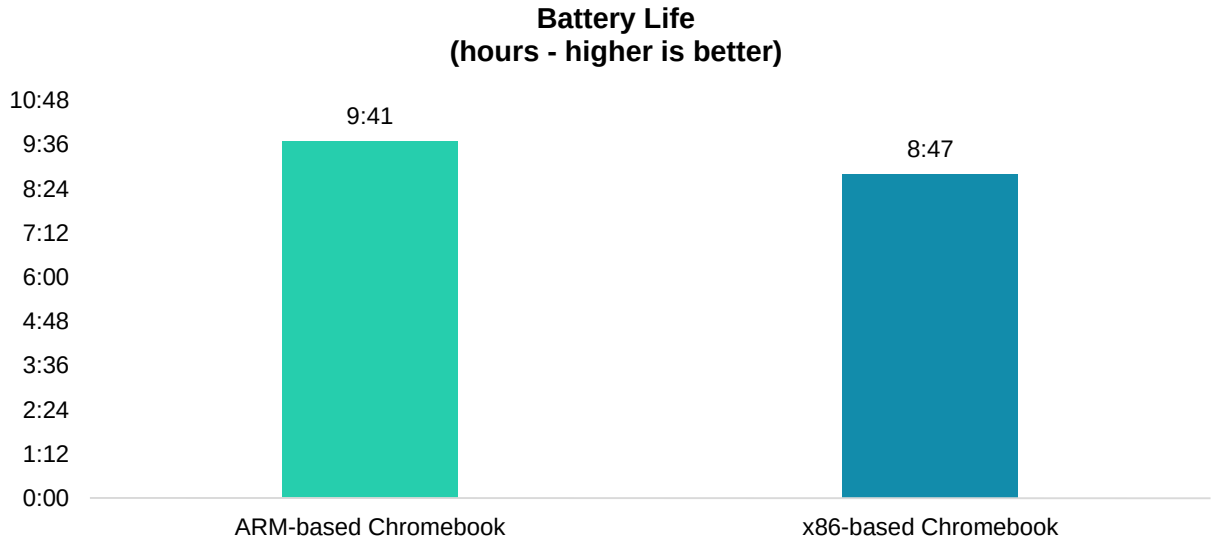
Chrome Connectivity Diagnostics

The Chrome Connectivity Diagnostics tests help quantify the connectivity pain points that educators experience. They are a series of network and wireless connectivity diagnostics designed by Google to help ensure that a Chromebook is experiencing good connectivity and to identify any issues. The x86-based Chromebook had greater signal strength (which should improve wireless performance) and faster in webpage response time. The ARM-based Chromebook had much faster average web address resolution times than the x86-based Chromebook, which would result in faster page loads. Overall wireless performance is break-even between the devices.



Battery Life On Video Playback

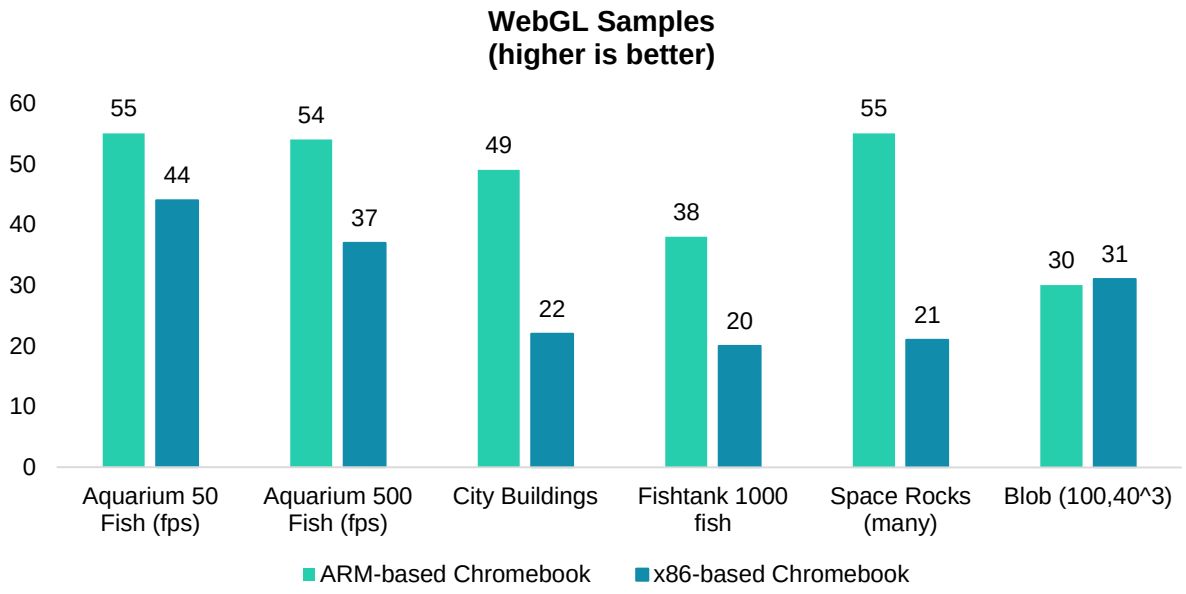
MI&S used video playback to test battery life—one of educators' biggest pain points. The test consisted of manually setting the displays to 100 nits brightness and streaming 720p YouTube videos non-stop, using wireless connectivity and loading a new video every time. The ARM-based Chromebook, in spite of having a 2-cell battery, provides longer battery life than the 3-cell battery in the x86-based Chromebook. This is due to the greater power efficiency of the ARM Rockchip SoC.



3D GRAPHICS

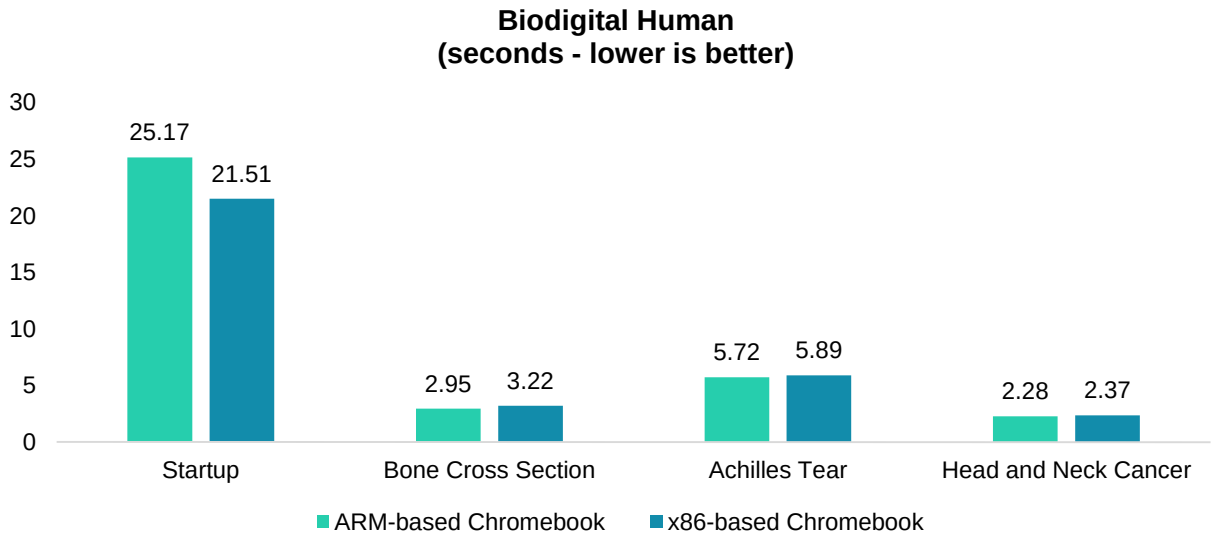
WebGL Samples

WebGL Samples tests 3D graphical performance using sample scenes to determine absolute frames-per-second performance. The test generates 3D objects in a 3D environment to test the browser and underlying hardware's capability to render WebGL scenes. In the majority of the WebGL samples tested, the ARM-based Chromebook outperformed the x86-based Chromebook.



Biodigital Human

Biodigital Human is a 3D application that helps students better understand the human body and human anatomy. MI&S tested how long the Chromebook took to load and render each 3D scene, including initial startup. Performance was close in terms of frame rate, with the ARM-based Chromebook being slightly faster to load most of the scenes.



MI&S also observed an unexplained graphical shading anomaly on the x86-based Chromebook: some parts of the human skeleton did not properly shade, rendering as black areas. This graphic rendering anomaly occurred in Biodigital Human only on the x86-based Chromebook.

FIGURE 1A: BIODIGITAL HUMAN RENDERING ON ARM-BASED CHROMEBOOK AT MAXIMUM 1280X800 RESOLUTION

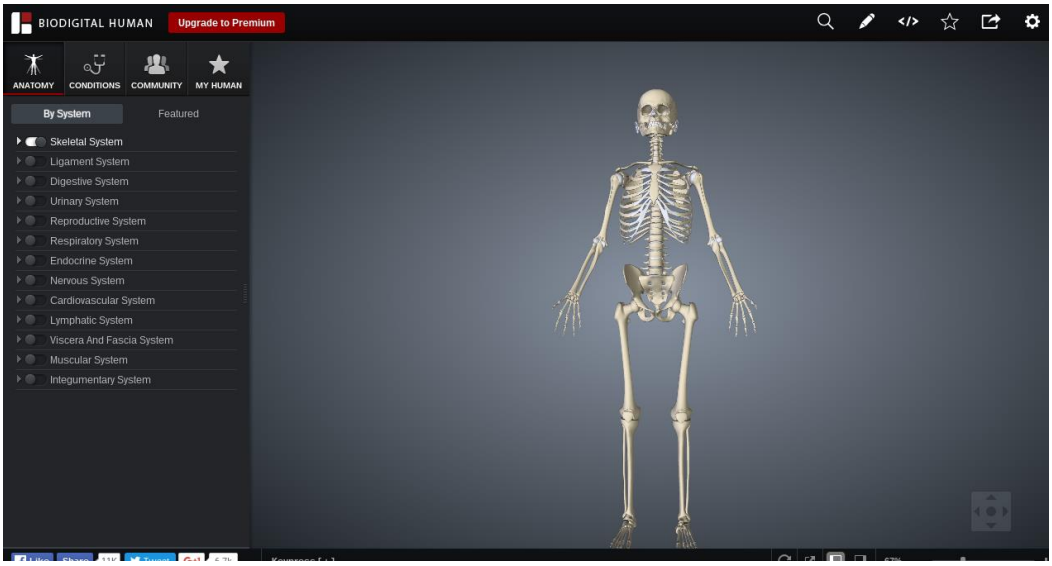
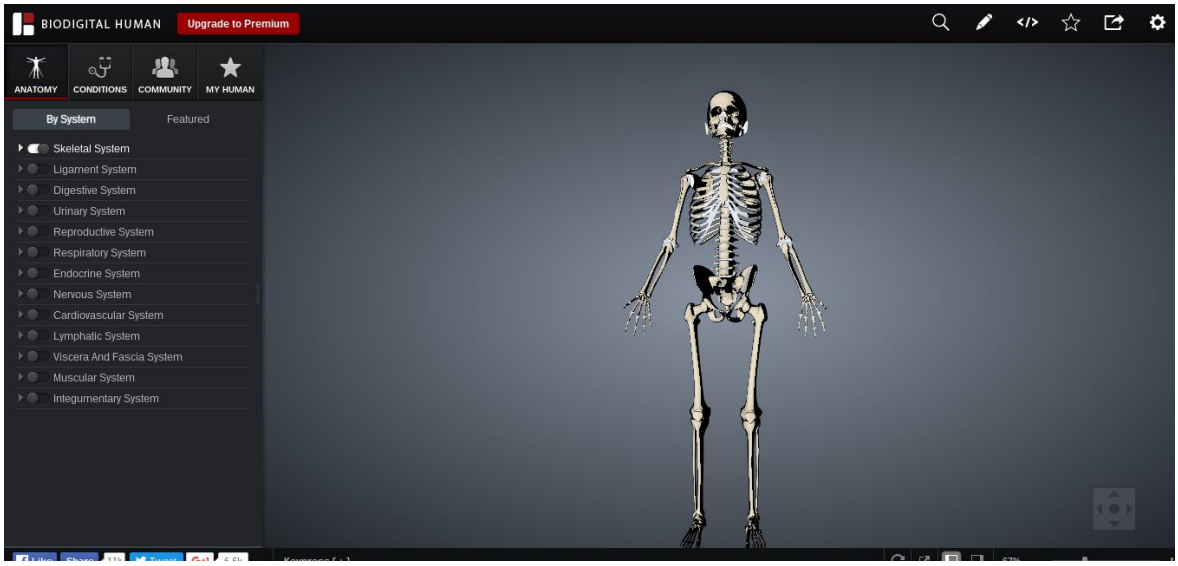
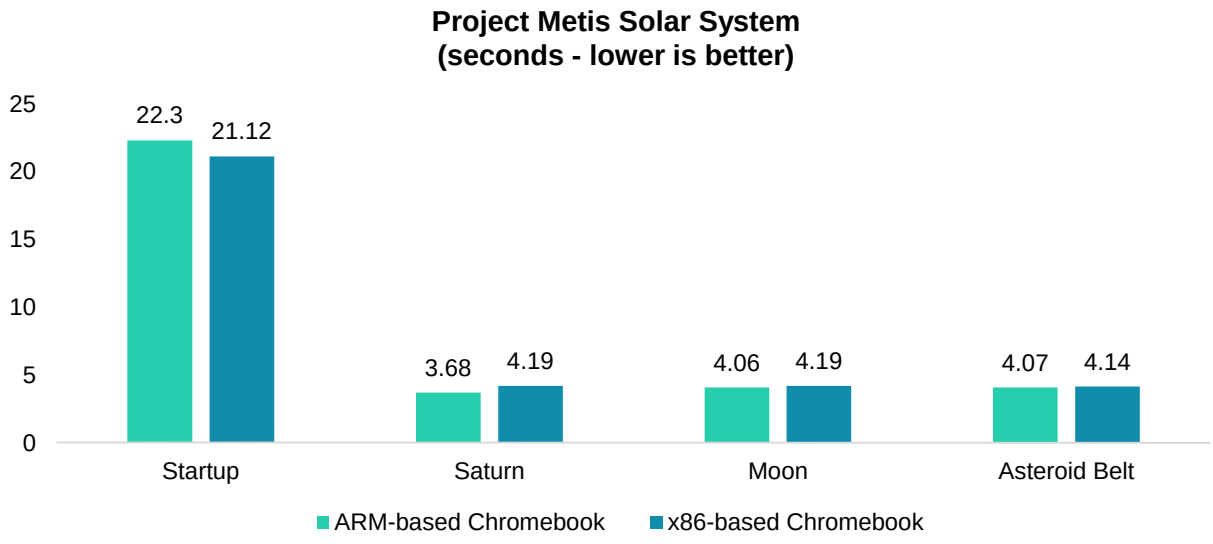


FIGURE 1B: BIODIGITAL HUMAN 3D RENDERING ON X86-BASED CHROMEBOOK AT MAXIMUM 1366X768 RESOLUTION



Project Metis Solar System

Project Metis Solar System is a 3D application designed to show students the solar system with depth and scale. The test is designed to measure the time it takes the Chromebook to load the scene, as well as startup the application. In Project Metis Solar System, the ARM-based Chromebook performed slightly better than the x86-based Chromebook in loading most of the scenes.



In Project Metis Solar System, MI&S observed an unexplained graphical anomaly with the x86-based Chromebook: The Asteroid Belt did not render completely (see red arrow). This graphic rendering anomaly occurred in Project Metis Solar System only on the x86-based Chromebook.

FIGURE 2A: PROJECT METIS SOLAR SYSTEM 3D RENDERING ON ARM-BASED CHROMEBOOK AT MAXIMUM 1280X800 RESOLUTION

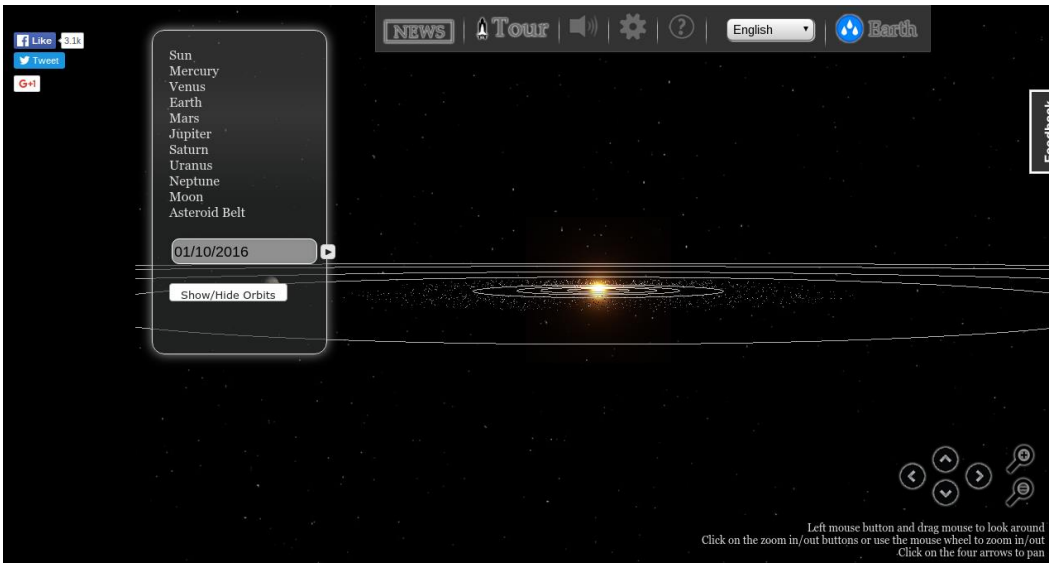
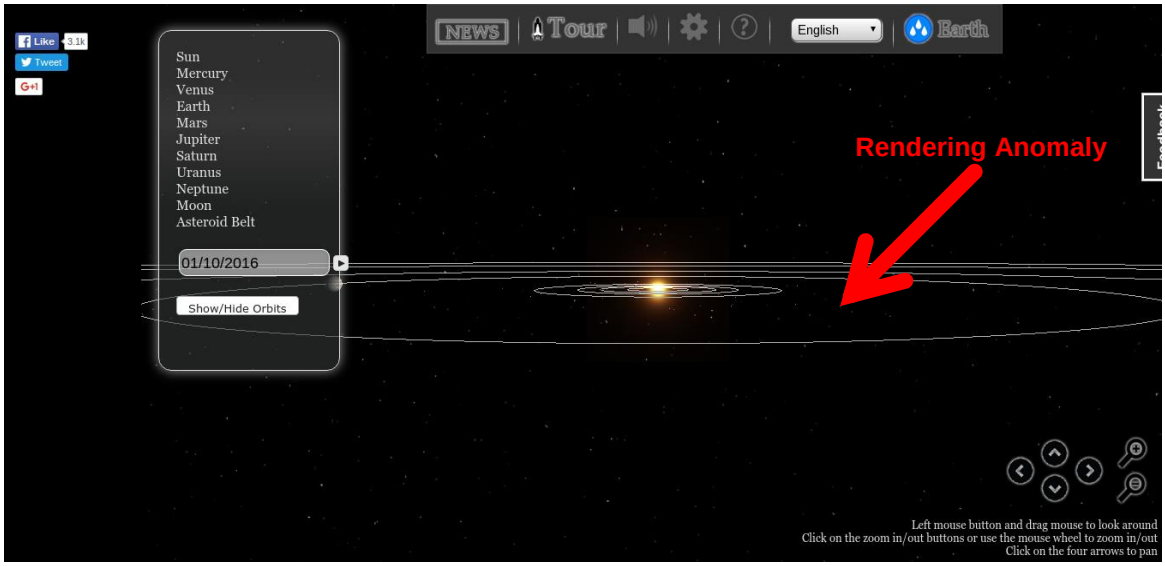


FIGURE 2B: PROJECT METIS SOLAR SYSTEM 3D RENDERING ON X86-BASED CHROMEBOOK AT MAXIMUM 1366X768 RESOLUTION



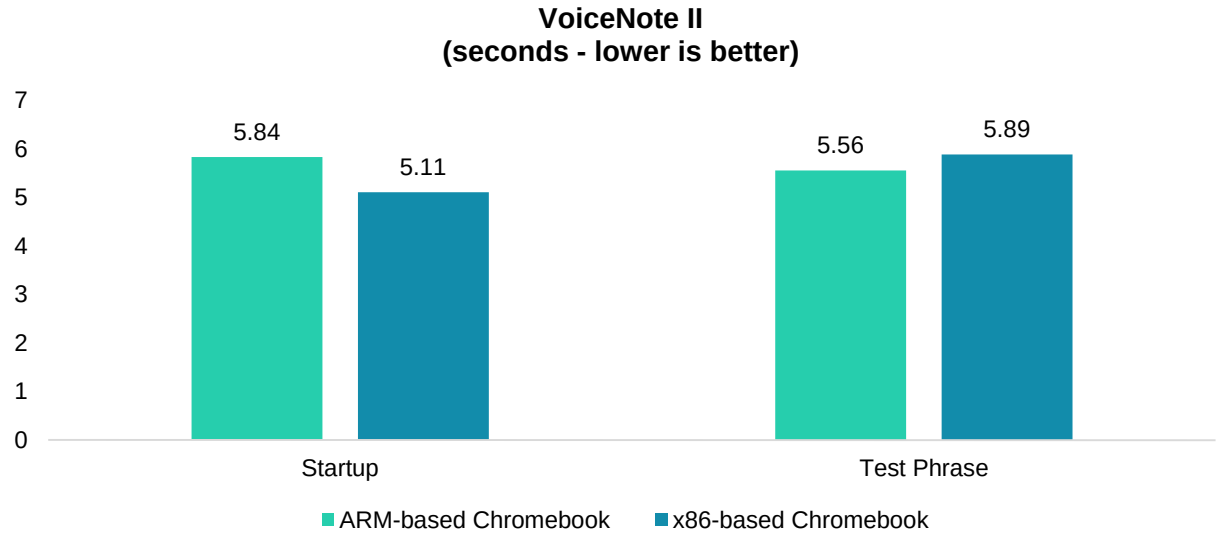
Because the Chrome OS abstracts the hardware, it was not possible to find root cause for the rendering anomalies observed on the x86-based Chromebook with these applications. They could be attributable to one (or more) of a number of factors, including software drivers, OS abstraction, application code, or graphics processing. It is not within the scope of this paper to identify root cause for the observed anomaly. Readers should not infer that any other x86-based Chromebook, including other Dell Chromebooks, would have this issue with these particular applications. Likewise, readers should not infer that programs requiring similar graphic rendering will exhibit the same anomaly. MI&S will update this paper if it is shown that this issue is resolved.

VIDEO PERFORMANCE

MI&S tested the absolute maximum video bandwidth capabilities of each device by playing back two YouTube videos side by side at 1080p resolution. Playing back both videos (the same video played back twice) revealed the peak video bandwidth capabilities of each of the Chromebooks. The ARM-based Chromebook handled multiple high definition video streams better than the x86-based Chromebook, resulting in smoother playback. Although a K-12 student might be unlikely to need two 1080p videos to play simultaneously side-by-side, the test does illustrate potential video capabilities.

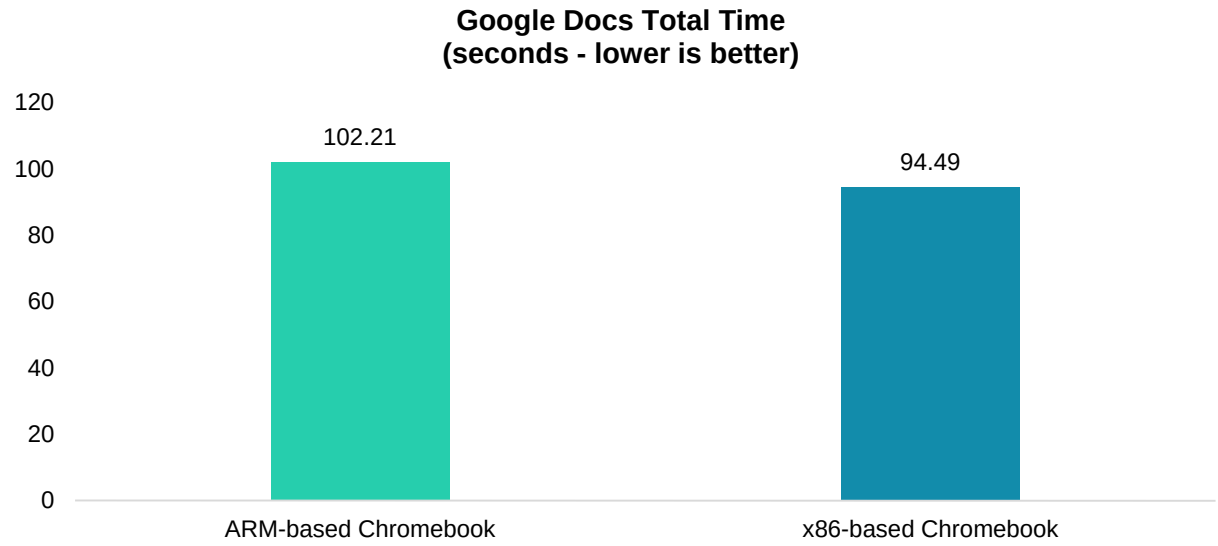
VOICENOTE II

Testing with VoiceNote II measures application startup time and voice-to-text transcription. The x86-based Chromebook started up faster. However, the ARM-based Chromebook transcribed voice-to-text slightly faster, which represents more typical usage of how students interact with the application. Transcription accuracy was not tested.



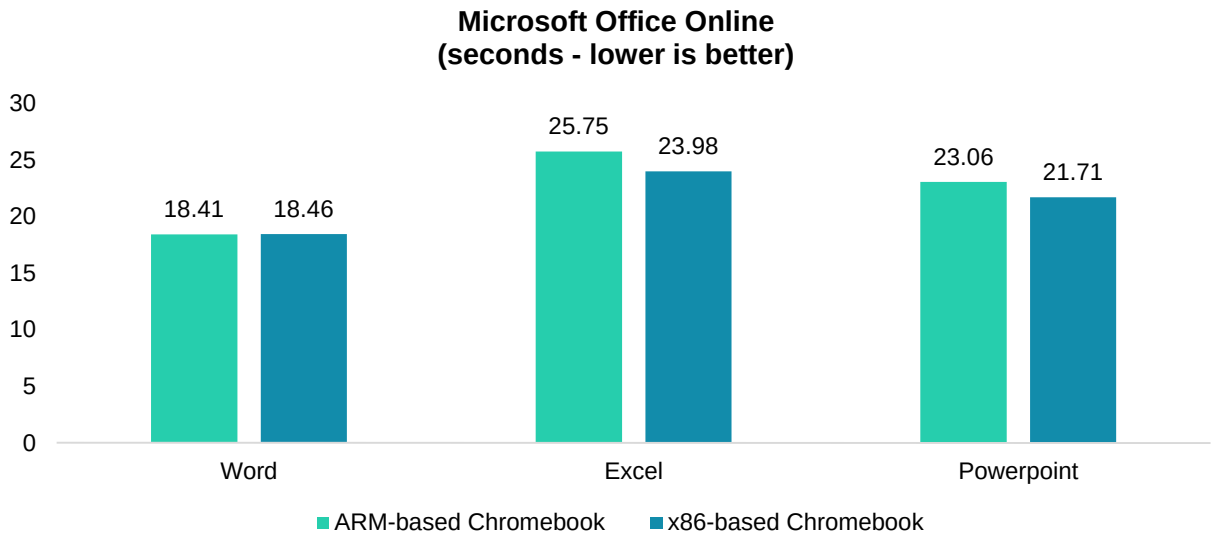
GOOGLE DOCS SUITE

To measure Google Docs performance, MI&S combined all three of the major Docs applications' performance in word processing, spreadsheets, and presentations. MI&S believes the performance difference between the Chromebooks is not significant enough for a user to notice.



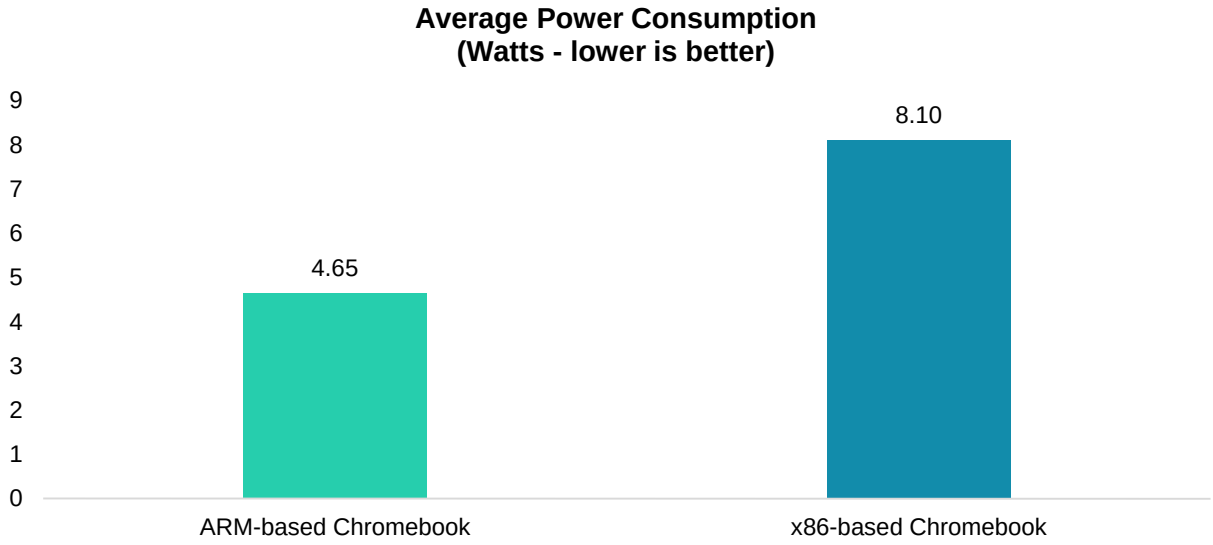
OFFICE ONLINE

The Microsoft Office Online test measured word processing, spreadsheets, and presentations applications' performance on Microsoft's cloud platform. MI&S ran multiple tools, including startup. Microsoft Word Online performance was comparable, and Microsoft Excel Online and Microsoft PowerPoint Online were faster on the x86-based Chromebook.



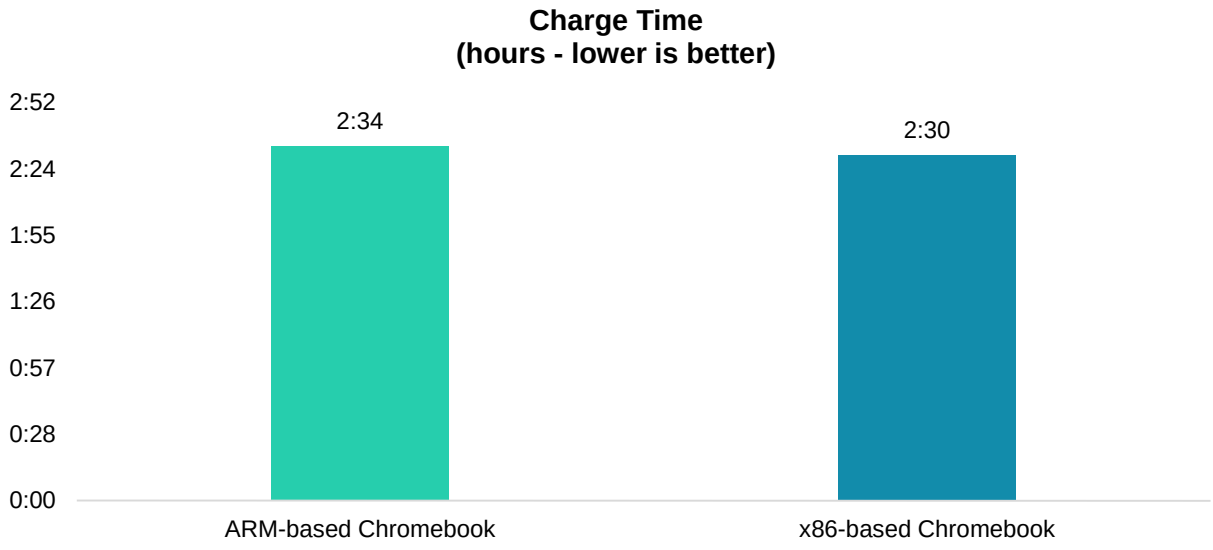
SYSTEM AVERAGE POWER CONSUMPTION

To test overall power consumption, devices played back a 1080p video in full screen after the battery was charged to 100% (to ensure the Chromebook was drawing power directly from the wall plug and measured via Wattage meter). The ARM-based Chromebook drew significantly less power, which helps explain its longer battery life.



CHARGE TIME

Charge time is a major pain point for educators. This test consisted of depleting the battery until the Chromebook shut off and then measured the time to reach a full charge. Both Chromebooks charged in a similar amount of time, even though Dell provides a 65W charger while ASUS' is only 22W. Despite being plugged in for a slightly-shorter amount of time, the x86-based Dell Chromebook's 65W charger draws significantly more electricity, which results in more power consumption and electricity costs.



INTERPRETATION

The GPU that enables 3D graphics in ARM-based Chromebooks, like the ASUS Chromebook Flip, is ARM's own Mali-T7 series graphics processor. This GPU is purpose-built for high performance at extremely low power, which makes it a power-efficient Chromebook GPU. This technology allows the ARM-based Chromebook we tested to outperform in most graphical capabilities with lower power. The ARM CPU inside of ARM-based SoCs also gets its pedigree from smartphones and is highly power-efficient like their GPU.

In these tests, battery life is better on the ARM-based Chromebook thanks to power efficient CPUs and GPUs that deliver quality user experiences. ARM's focus on power efficiency translates to Chromebooks with longer battery life. Longer battery life means reductions in battery costs and weight. Shorter charge times and lower power consumption are possible thanks to the combination of all the power efficient components of ARM-based SoCs. The result is smaller TDPs (Thermal Design Power), which can help reduce costs further with less cooling and make ARM-based Chromebooks lighter as well.

CONCLUSION

Moor Insights & Strategy's testing shows that the performance and battery life while playing videos on ARM-based Chromebooks, like the ASUS Chromebook Flip, meet the experiential needs of educators and students. The experiential CPU performance between the competitive processors is roughly the same. 3D graphics and battery life on videos affect the overall user experience, as does the overall weight of the device, and here the ARM-based Chromebook does better, due to both smaller battery and screen size.

The less expensive and lower TDP (thermal design point) ARM-based Rockchip RK3288 SoC allows for more feature choices. The Chromebook Flip is an example of these choices as it features a touch screen and the ability to turn into a tablet. For instance, the lower cost of the SoC could enable the ASUS Chromebook Flip to be configured with double the RAM of the Dell Chromebook 11 which helps improve user experience. ARM's power efficiency also allows OEMs to build devices with smaller, lighter batteries—saving on cost and weight—and do it all while offering a compelling user experience with features like touch screens and all day battery life.

ARM-based Chromebooks may offer more flexibility and a more even playing field. There are additional factors that educators may find more important, like warranties, durability and the final TCO, which Moor Insights & Strategy did not test or compare for this paper.

RECOMMENDATION

Benchmark testing reveals that the ARM-based Asus Chromebook Flip delivers on what educators say their students need from Chromebooks. ARM-based Chromebooks may give educators more choices and flexibility on how they want their students to experience their computing with fast graphics, video, and long battery life. This flexibility now gives schools a choice, thanks to competition from ARM. Schools should consider evaluating ARM-based Chromebooks for education for the experience and power efficiency that they deliver in the classroom.

GLOSSARY

- **ARM -** a processor instruction set and IP technology company "ARM provides CPU, GPU and other key building blocks that power 85 percent of mobile compute devices such as smartphones and tablets. ARM licenses its IP to the world's leading semiconductor companies who collectively have shipped over 60 billion ARM based chips to date. ARM is now bringing the same power-efficient computing and silicon supplier diversity to large screen compute devices"
- **x86 -** a processor instruction set architecture from Intel
- **CPU -** central processing unit
- **GPU -** graphics processing unit
- **Chrome Store -** Google's marketplace for Chrome OS applications
- **DNS Resolution Time -** the time it takes to resolve a website's physical IP address through its name via the domain name server (DNS) network
- **Webpage Response Time -** the time it takes a page to respond to a request

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