Potential Challenges of Distance Education on Mars

By Mark Wagner

Abstract

What challenges might face the first school on Mars? The delay in two-way communications alone would be significant, with a wait time between six and forty-four minutes depending on the relative positions of the planets. Bandwidth from Earth to Mars and local cloud computing capacity would also be factors, even with predictive caching. Even without these technical challenges, creating meaningful hands-on collaborative learning for the first students on Mars would be difficult, especially for a small initial cohort of students with few local peers and perhaps no local teacher. Similarly, an open-ended learning space with a variety of tools and materials may be prohibitively resource intensive. Room for athletic facilities or fields would also be an issue. Scheduling will be difficult, due to the different length of the Martian day and year and the need to accommodate adult schedules in a small settlement as well. Emerging technologies suggest solutions to some of these problems, but there will be significant limitations even if the technical goals are realized. In any case, the first education system setup on Mars will require a great deal of planning ahead, acceptance of asynchronous communication methods, and (most of all) significant reservoirs of patience.

Keywords: Mars, Distance Education, Communication, Bandwidth, Resources.

Clearly, educators today need to consider how best to prepare students for humanity's rapidly approaching multi-planet future.[1] But what if we look another turn farther down the road? What about the first students to be educated *in* space? What challenges might face the first school on Mars? The COVID-19 pandemic has highlighted many issues associated with a move to remote learning, and settlements on a distant planet would face these same difficulties … and more. For instance, on Mars, any education system would face a significant delay in live communications with peers, experts, and other resources on Earth. Similarly, hands-on learning of any kind would be challenging, as would scheduling … from daily meetings to academic years. By considering these problems now, educators and space philosophers can help to lay a foundation for a successful education system on Mars in the coming years.

Due to the tremendous distance between Earth and Mars, the delay in radio communications (at the speed of light) is between three and twenty-two minutes each way as the two planets move through their respective orbits, making the wait to receive

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[1] See Mark Wagner, "K12 Education for Space Settlement," docs.google.com/document/d/10KK-MQvD7Lox4CyjYUBwplye66I2p7GnkNRaGqPWjN8; Mark Wagner, "A Novel Approach to a K12 School Focused on Space Exploration," *Journal of Space Philosophy* 10, no. 1 (Fall 2021): 75-83.

a response in two-way communication between six and forty-four minutes (Figure 1).[2] When it comes to live communication (via text, audio, or video), this means at best a student on Mars might receive about sixty responses from a teacher in a six-hour school day, and at worst, no more than eight responses in a school day. Clearly, questions during a live lesson would be impractical. For an asynchronous model where students work independently and send questions when necessary, this might require some patience, but it should be workable.

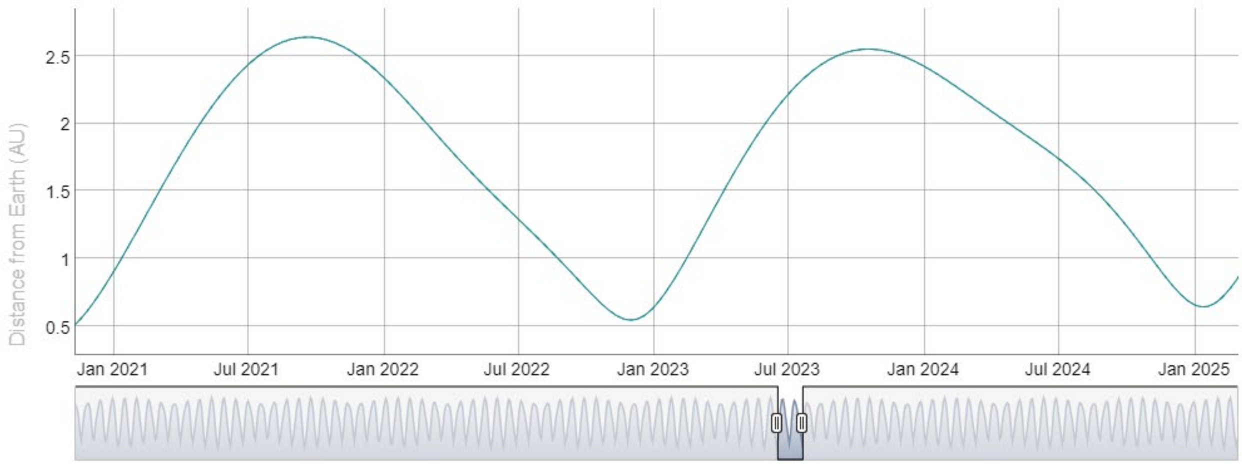

Figure 1: Distance from Earth to Mars in Astronomical Units (the average distance from Earth to the Sun). Each AU represents approximately eight minutes of communications delay, each way.[3]

However, in most asynchronous online programs, students must read and research independently, and any kind of open-ended online research will be similarly frustrating. When Earth and Mars are farthest away, a student who performs a search using Google will have to wait forty-five minutes to see the results of the search—and another forty-five minutes before seeing the first page he or she clicked on. Predictive algorithms and local caching might alleviate this problem to some degree, but any unpredictable or creative lines of inquiry would be painfully impractical.[4]

Bandwidth from Earth to Mars, and local cloud computing capacity on Mars, would also be factors, even with predictive caching. Currently, the bandwidth between Earth and Mars is at most 32 Megabits per second (Mbps),[5] or about 10% the capacity of the home internet connection I used when composing this paper on Google Docs. Clearly this will need to be improved by orders of magnitude before internet use on Mars is viable,

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[2] Mars One, "How Does the Mars Base Communicate with Earth?" www.mars-one.com/faq/technology/how-does-the-mars-base-communicate-with-earth.

[3] Image Source: theskylive.com/how-far-is-mars.

[4] Mars One, "How Does the Mars Base Communicate with Earth?"

[5] NASA, "Mars Curiosity Rover: Communications with Earth," mars.nasa.gov/msl/mission/communications.

especially for media-rich experiences of any kind. Information could be cached locally (Wikipedia, for instance, is only 107.5 GB right now, and it could easily be stored on a single flash drive[6]) but doing this on the scale of the internet would be an ambitious and resource-heavy project, requiring a cloud infrastructure on Mars (mirroring the ones on Earth) for any sort of interactive or collaborative applications, like Google Docs for instance. Currently, the Perseverance Mars Rover uses Earth-based cloud computing instead.[7] Luckily, there are already efforts underway to tackle the need for local cloud computing on Mars,[8] and SpaceX has already announced plans to implement Starlink satellites on Mars, which should provide a local planetary network with bandwidth of at least 300-1,000 Mbps.[9] These efforts could be coupled with higher-bandwidth laser-based communication systems between Earth and Mars,[10] and they may thus make a Martian internet robust enough for educational needs, including local caches and collaborative cloud computing resources. (Of course, Martian students would still not be able to edit a document live with peers on Earth.)

Even if these technical challenges are overcome, creating meaningful hands-on collaborative learning experiences for the first students on Mars would be difficult, especially for a small initial cohort of students, with a limited number of local peers and perhaps no local teacher. Interactive learning is critical for students to develop problem-solving skills (rather than just memorizing and regurgitating information).[11] It also supports increased student engagement and helps to build the necessary relationships and trust between students and teachers.[12] But, due to the communication delay, no face-to-face interaction with peers or experts on Earth would be possible, even via streaming video or virtual reality, as some students were able to do during the COVID-19 pandemic. On the bright side, for some students an asynchronous discussion format actually

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[6] Wikimedia, "Wikimedia Downloads," dumps.wikimedia.org/backup-index.html.

[7] ZDNet, "Cloud Computing is Helping to Keep NASA'S Perseverance Mars Rover on Track," www.zdnet.com/article/cloud-computing-is-helping-to-keep-nasas-perseverance-mars-rover-on-track/.

[8] Takashi Iida and Yoshiaki Suzuki, "Future Needs for Communication System in the Mars Human Community," doi.org/10.2514/6.2007-3304.

[9] Ry Crist, "Elon Musk: SpaceX Will Double Starlink's Satellite Internet Speeds in 2021," www.cnet.com/news/elon-musk-spacex-will-double-starlinks-satellite-internet-speeds-in-2021.

[10] Radosław Bielawski and Aleksandra Radomska, "NASA Space Laser Communications System: Towards Safety of Aerospace Operations," *Safety & Defence* 6, no. 2 (2020): 51-62, doi.org/10.37105/sd.85.

[11] See *Internet Learning Journal* 6, no. 1 (Spring 2017), www.apus.edu/academic-community/journals/dl/jolrap-06-01.pdf.

[12] Rebecca Pruitt, "Constructivist Approaches Online and Face-to-Face: The Essential Role of Trust," *Curriculum and Teaching Dialogue* 19, no. 1/2 (2017): 105-27, search.proquest.com/openview/583310c36eba2eb4075fad300f43c2f1.

encourages more participation,[13] and there are team-building strategies that work across time zones on Earth and that might be applicable between planets as well.[14]

These silver linings do not alleviate the challenges involved with creating a hands-on learning experience, especially when it comes to physically making things. Ideally, a maker space is a place where students "have an opportunity to explore their own interests; learn to use tools and materials, both physical and virtual; and develop creative projects."[15] Such spaces can encourage student agency[16] and develop creative competence,[17] which students will surely need to survive and thrive on Mars. But such an open-ended space with a variety of tools and materials may be prohibitively resource-intensive for an early space settlement. While a virtual maker space might alleviate this problem to some degree,[18] the issues of time delay, bandwidth, and local cloud computing resources would once again come into play; an Oculus headset would not operate well when it must wait forty-five minutes for a reply from Facebook servers, and it could not connect Martian students with peers or experts on Earth in real time any more than a Zoom call or radio could.

Similarly, while virtual socialization can be beneficial for some students in some ways,[19] synchronous interactions are unequivocally important to social development,[20] and again, they would not be possible except between the limited number of local Martian students. When it comes to physical education, even students recognize the difficulties inherent in

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[13] Robert M. Davison, Niki Panteli, Andrew M. Hardin, and Mark A. Fuller, "Establishing Effective Global Virtual Student Teams," *IEEE Transactions on Professional Communication* 60, no. 3 (2017): 317-29, doi.org/10.1109/TPC.2017.2702038.

[14] Yasha Sazmand Asfaranjan, Farzad Shirzad, Fatemeh Baradari, Meysam Salimi, and Mehrdad Salehi, "Alleviating the Senses of Isolation and Alienation in the Virtual World: Socialization in Distance Education," *Procedia—Social and Behavioral Science* 93 (2013): 332-37, doi.org/10.1016/j.sbspro.2013.09.199.

[15] Laura Fleming, *Worlds of Making: Best Practices for Establishing a Makerspace for Your School* (Thousand Oaks, CA: Corwin Press, 2015), 5, www.google.com/books/edition/Worlds_of_Making/_XtO5BgAAQBAJ?hl.

[16] Anu Kajamaa and Kristiina Kumpulaine, "Agency in the Making: Analyzing Students' Transformative Agency in a School-Based Makerspace," *Mind, Culture, and Activity* 26, no. 3 (2019): 266-81, doi.org/10.1080/10749039.2019.1647547.

[17] José Luís Saorín, Dámari Melian-Díaz, Alejandro Bonnet, Carlos Carbonell Carrera, Cecile Meier, and Jorge De La Torre-Cantero, "Makerspace Teaching-Learning Environment to Enhance Creative Competence in Engineering Students," *Thinking Skills and Creativity* 23 (2017): 188-98, doi.org/10.1016/j.tsc.2017.01.004.

[18] Jennifer Lock, Petrea Redmond, Lindy Orwin, Alwyn Powell, Sandra Becker, Paula Hollohan, and Carol Johnson, "Bridging Distance: Practical and Pedagogical Implications of Virtual Makerspaces," *Journal of Computer Assisted Learning* 36, no. 6 (2020): 957-68, doi.org/10.1111/jcal.12452.

[19] Scott Nicholson, "Socialization in the 'Virtual Hallway': Instant Messaging in the Asynchronous Web-Based Distance Education Classroom," *The Internet and Higher Education* 5, no. 4 (2002): 363-72, doi.org/10.1016/S1096-7516(02)00127-6.

[20] Shelia Y. Tucker, "Promoting Socialization in Distance Education," *Turkish Online Journal of Distance Education* 13, no. 1 (2012): 174-82, dergipark.org.tr/en/pub/tojde/issue/16899/176129.

a remote learning scenario.[21] There would be no sports on Mars, at least at first. (Space for athletic facilities or fields would also be an issue for many sports.) That said, physical education over a distance can be beneficial if it deemphasizes the focus on "hero athletes" and helps students to reflect on their own health instead.[22]

Regardless of physical issues, scheduling would also be a new challenge. Even if students on Mars could interact with a teacher on Earth up to sixty times a day asynchronously, the hours of the school day would change for the teacher (presuming he or she stayed the same for the student). Due to the slightly longer day on Mars, the start time on Earth would shift thirty-seven minutes each day, meaning that in less than two weeks the Martian students would be awake during the teacher's sleep hours … and then the start time would continue shifting until it was morning again two weeks later. This problem might be relieved and/or exacerbated by having teachers in multiple time zones on Earth.[23] In any event, there would also be a question about the academic year; with a Martian year being nearly double the length of an Earth year (687 days), would students on Mars follow Earth's school calendar regardless of the time of year on Mars? Or would Martian education systems leave K-12 behind for a system of seven grades (based on local years) that cover the same developmental stages for students?

Perhaps more importantly, how would parent schedules work? If students are primarily interacting with peers and teachers on Earth in a distance-learning format, how much of their parents' time will be required for supervision? This issue became a struggle for many families during the COVID-19 pandemic, especially for families with two working parents, as all families would almost certainly be in a new Martian settlement. Parents are critical to setting expectations for students,[24] and student supervision requires a lot from parents[25]—so much so that school districts released guidelines for parent self-care during the pandemic.[26] How compatible would this stress be with the realities of surviving and building a settlement on a forbidding planet? One recent model that might be useful on Mars is the formation of learning "pods" consisting of a small number of students with a single teacher or parent supervisor. While this has been touted as a potentially

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[21] Metin Yaman, "Perceptions of Students on the Application of Distance Education in Physical Education Lessons," *Turkish Online Journal of Educational Technology* 8, no. 1 (2009), eric.ed.gov/?id=ED503904.

[22] Regina Celia A. Silva, Vera Lucia de F. F. e Silva, and André Pontes Silva, "Distance Learning for Teaching in Physical Education," *Revista de Educação Física* 25, no. 1 (2019), doi.org/10.1590/S1980-6574201900010002.

[23] Thomas Ormston, "What Time is It?" August 5, 2012, blogs.esa.int/mex/2012/08/05/what-time-is-it/.

[24] Anne Wahlgren, "The Most Important Way Parents Can Support Distance Learning," Printable Parents, printableparents.com/the-most-important-way-parents-can-support-distance-learning/.

[25] "Emergency Distance Learning Day Parent Checklist," iusd.org/sites/default/files/files/Ed_Services/1GeneralDocs/parent_checklist_-_edl.pdf.

[26] Arizona Department of Education, "Arizona Emergency Distance Learning Guidance, August 2020 Update," www.azed.gov/sites/default/files/2020/09/AZ-Emergency-Distance-Learning-Guidance__August-2020-Update.pdf.

revolutionary microschooling model in the wake of the pandemic,[27] it does not address the fundamental childcare problem that traditional schools also solve.[28] At least some subset of Martian parents would need to be on hand to supervise and assist the pod of students. (This could happen in a co-op fashion where parents take turns supervising, but that might not be what is best for students who need competent support.)

Emerging technologies also suggest solutions to some of these problems, but there will be significant limitations even if the technical goals are realized. Virtual reality, for instance, might be able to provide immersive learning experiences to remote students[29] (including the sorts of virtual laboratory environments needed to raise potential scientists on another planet[30]), but ultimately any collaborators, online resources, and cloud computing capacity would have to be provided on the local planetary network as well. There are good reasons not to use VR for learning here on Earth,[31] and these would be multiplied on Mars.

Artificial Intelligence (AI) might also alleviate some of the issues with VR, with the interplanetary communication delay in general and the need to support local pods of students in particular. AI could provide intelligent tutoring systems,[32] as well as serve several other needs, including intelligent laboratory systems, intelligent library resources, and intelligent questioning (or testing/assessment) systems.[33] Of course, an AI that can replicate or replace a human educator may remain a fantastic concept for many years, if it is ever possible in a way that would not detract from healthy human development.

Quantum communication might be held up as a possibility for improving the bandwidth between Earth and Mars, if not potentially eliminating the lightspeed-dependent delay. Quantum communication is mostly used for encryption purposes

[27] Jason Bedrick and Matthew Ladner, "Let's Get Small: Microschools, Pandemic Pods, and the Future of Education in America," Heritage Foundation Backgrounder No. 3540, eric.ed.gov/?id=ED609716.

[28] Michael B. Horn, "The Rapid Rise of Pandemic Pods," *Education Next* 21, no. 1 (2021), search.proquest.com/openview/c2395d6d47f7d66a9a57eed0d4efabd0.

[29] Jennifer L. Penland, Kennard Laviers, Elbert Bassham, and Victor Nnochiri, "Virtual Learning: A Study of Virtual Reality for Distance Education," in *Handbook of Research on Blended Learning Pedagogies and Professional Development in Higher Education*, ed. Jared Keengwe (Hershey, PA: IGI Global, 2019), 156-76, www.igi-global.com/chapter/virtual-learning/208354.

[30] M. T. Valdez, C. M. Ferreira, and F. P. Maciel Barbosa, "Distance Education Using a Desktop Virtual Reality (VR) System," in *2013 24th EAEEIE Annual Conference*, ed. Giorgos M. Papadourakis (Heraklion, Greece: Technological Educational Institute of Crete, 2013), 145-50, doi.org/10.1109/EAEEIE.2013.6576518.

[31] Veronica S. Pantelidis, "Reasons to Use Virtual Reality in Education and Training Courses and a Model to Determine When to Use Virtual Reality," *Themes in Science and Technology Education* 2 no. 1-2 (2009): 59-70, www.timtechconsults.com/images/ttcvreducation%20.pdf.

[32] F. A. Dorca, C. R. Lopes, and M. A. Fernandes, "A Multiagent Architecture for Distance Education Systems," in *Proceedings of the 3rd IEEE International Conference on Advanced Technologies* (New York: IEEE, 2003), 368-69, ieeexplore.ieee.org/abstract/document/1215127.

[33] Utku Kose, *Artificial Intelligence Applications in Distance Education* (Hershey, PA: IGI Global, 2014), www.google.com/books/edition/Artificial_Intelligence_Applications_in/6KN_BAAAQBAJ.

today,[34] but it might also increase the efficiency of communication in deep space.[35] In fact, communication networks on Mars (and between planets) may look very much like the CubeSat Quantum Communications Mission (CQuCoM) of today.[36] However, because of the need for laser (or radio) to transmit the information necessary to compare states of entangled qubits, even quantum communication (as it is understood today) will not be able to overcome the transmission delay due to the speed of light.[37] That said, these avenues of research may turn up surprising new opportunities, and questioning physical limits can be a powerful tool for scientific progress; scientists should "never say never."[38]

Meanwhile, it seems the first education system setup on Mars will require a great deal of planning ahead, acceptance of asynchronous communication methods, and (most of all) significant reservoirs of patience. However, this is no more than was required of pioneers and settlers in earlier periods of human history when messages might take *months* to cross an ocean by boat.

So, while the delay in communication, the difficulty in providing collaborative hands-on learning experiences, and the issues related to scheduling (not to mention the related technical challenges) might be significant, these are all factors that can be addressed with planning. Local infrastructure, best practices for asynchronous learning coupled with the best of microschooling pods, and judicious use of emerging technologies (like VR, AI, and whatever quantum communication may offer in the coming years) can all help to alleviate the challenges of establishing the first education system on Mars, even for very small numbers of students in the earliest settlements. Once again, planning, patience, and creative problem-solving will open up new possibilities in human history.

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Editors' Notes: Today a number of robotic missions launched by space agencies around the globe are currently focused on the exploration of Mars, with both NASA and SpaceX

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[34] Picoquant, "Quantum Communication," www.picoquant.com/applications/category/quantum-optics/quantum-communication.

[35] Markus Aspelmeyer, Thomas Jennewein, and Anton Zeilinger, "Long-Distance Quantum Communication with Entangled Photons using Satellites," www.arxiv-vanity.com/papers/quant-ph/0305105/.

[36] Daniel K. L. Oi, Alex Ling, Giuseppe Vallone, Paolo Villoresi, Steve Greenland, Emma Kerr, Malcolm Macdonald, Harald Weinfurter, Hans Kuiper, Edoardo Charbon, and Rupert Ursin, "CubeSat Quantum Communications Mission," *EPJ Quantum Technology* 4, no. 6 (2017), doi.org/10.1140/epjqt/s40507-017-0060-1.

[37] Chad Orzel, "The Real Reasons Quantum Entanglement Doesn't Allow Faster-Than-Light Communication," *Forbes*, May 4, 2016, www.forbes.com/sites/chadorzel/2016/05/04/the-real-reasons-quantum-entanglement-doesnt-allow-faster-than-light-communication.

[38] Kruti Shrotri, "Superluminal Communication: We're Talking Faster than Light," *I, Science*, isciencemag.co.uk/features/superluminal-communication-were-talking-faster-than-light/.

making plans to land people there to establish permanent settlements within a decade. The question of raising and educating students cannot be too far behind. So, this paper considers the challenges that might be posed by establishing the first school on Mars. Undoubtedly, the distance to Mars creates the greatest challenge. Consider the consequences the communication delay alone has for a class of very remote students; everything from basic asynchronous communication like text messages to virtual reality would be impossible without significant local resources. These issues will need to be addressed for a multi-generational settlement on Mars to be successful. ***Gordon Arthur and Mark Wagner*.**

About the Author: Mark Wagner serves as President of the Space Prize Foundation, a non-profit organization focused on promoting STEM education and increasing the representation of women in aerospace careers. He also teaches the Space Education graduate certificate program at Kepler Space Institute and is the Associate Editor of the *Journal of Space Philosophy*. In addition, he is the founder of ARES Learning, a vision for schools that prepare students with the skill sets and mindsets they will need to be successful in the growing space economy—and in humanity's rapidly approaching multi-planet future. Mark has a PhD in Educational Technology and a master's degree in Cross-Cultural Education. He also holds graduate certificates in Space Education and Space Philosophy. He is the author of *More Now: A Message from the Future for the Educators of Today* (2018) and a forthcoming book about space education, which explores both current opportunities on Earth, and the possibilities for teaching students on the Moon, on Mars, and in deep space habitats. Outside his work, Mark loves playing hockey, practicing martial arts, and obsessing over his '62 beetle, which now runs on an electric motor and Tesla batteries. He is a certified health coach and biohacking enthusiast, who also enjoys songwriting, spending time in nature, and exploring the world with his friends and family.