STEM Teacher Beliefs about the NASA STELLA Instrument as an Educational Tool for Justice-Centered STEAM Making

Lynn Nichols
Department of Learning Technologies, Design and School Library Media
Towson University
USA
lnicho10@students.towson.edu

Kimberly Corum
Mathematics Department
Towson University
USA
kcorum@towson.edu

Michael P. Taylor
NASA Goddard Biospheric Sciences
National Aeronautics and Space Administration
USA
michael.p.taylor@nasa.gov

Paul Mirel
NASA Goddard Biospheric Sciences
Hexagon US Federal contractor
National Aeronautics and Space Administration
USA
paul.mirel@nasa.gov

Abstract: In order to promote justice-centered making in STEAM classrooms, the NASA Landsat-based Science and Technology Education for Land/Life Assessment (STELLA) instrument is proposed as an affordable educational tool for students to collect and analyze data pertaining to vegetation health, surface temperature, and air quality. This instrument can be used to investigate justice-centered, community-based problems and promote civic engagement toward policy change for a healthier world. Our study applies the MakerTPICK theoretical framework to a qualitative study to explore changes in teacher beliefs about the STELLA instrument following three justice-centered STEAM-making activities pertaining to urban heat islands, air quality, and vegetation health. The implications of this research can be used to inform professional development and promote justice-centered learning in the STEAM classroom.

Keywords: STELLA, MakerTPICK, makerspace, NASA, Landsat, STEAM, microcontroller, TPACK, justice-centered making, social justice

Introduction and Literature Review

In an increasingly costly educational landscape, it is becoming more challenging to find educational tools that are affordable and user-friendly, support data collection, strengthen STEAM content, and enable justice-focused learning. The NASA Landsat-based Science and Technology Education for Land/Life Assessment (STELLA) instruments serve a crucial role in filling this void. These affordable instruments utilize microcontrollers and sensors to mimic the features of the Landsat satellites and collect wavelength data in both the visible and near-infrared spectrum, in addition to surface and air temperature, humidity, barometry, and time (NASA, 2023). Although these instruments have been used in several educational settings, there is little research on their efficacy as an educational tool. This work will evaluate the efficacy of the STELLA instruments in the context of three justice-centered

STEAM-making lessons presented to in-service STEM teachers enrolled in an instructional technology graduate course offered through a university in the mid-Atlantic region of the United States.

The Landsat satellite program serves a crucial role in monitoring the Earth's surface and providing valuable data about crop welfare, arctic pool melts, natural disasters, and other surface-related phenomena to stakeholders around the world (NASA, 2021, 2024b). Landsat emerged in the 1970s following the understanding of the value of aerial photography of the earth's surface taken from space during the testing for the Apollo missions (NASA, 2024a). The project was a joint venture between NASA and the U.S. Geological Survey, who suggested that a remote-sensing satellite could be used to gather data about natural resources (NASA, 2021). Initially, the program was opposed by the Bureau of Budget and the Department of Defense, who disagreed with the fiscal sense of a low-altitude orbit satellite and expressed concern about compromising the integrity of reconnaissance missions, respectively (NASA, 2024a; U.S. Department of the Interior & U.S. Geological Survey, 1997). Initial observations were made in 1965 through remote sensing instruments on planes, and by 1970, NASA was approved to build the earth-observing satellite (NASA, 2024a).

In order to better connect students with the capabilities of the spectroscopic technologies afforded by Landsat and empower students to enact data-based change, NASA Instrument Systems Engineer Paul Mirel designed the STELLA instruments in conjunction with the NASA Landsat Outreach Team (NASA, 2023). The STELLA instrument has been developed to mimic some of the functions of the Landsat spectrometers and support education through hands-on STEM engagement, authentic inquiry, and data-based discovery via learning about remote sensing technologies and applications (NASA, 2023). However, there is limited research into the efficacy of the STELLA instruments as an educational tool. Our research suggests that the STELLA instruments align well with justice-centered STEM making and are a natural fit for makerspace-based curriculum.

Makerspaces and maker-based education are well-documented as having the potential to increase civic engagement with students (London et al., 2010; Twiss, 2017) and benefits include academic growth, community connection, and even improved mental health (Delli Carpini, 2000; Lerner et al., 2005; Twiss, 2017). Educators have the potential to leverage makerspaces to bring awareness to social justice and empower students to combat inequity (Heredia & Tan, 2021). Aguirre et al. (2019) demonstrated that modeling and making with mathematics instilled deeper appreciation and comprehension of justice-centered topics and helped combat perceptions of difficult content to master and challenges of navigating complex student conversations and discomfort. Nichols and Corum (2023, 2024) have shown that modeling justice-centered STEAM-making activities for in-service teachers increases teacher beliefs about the importance of incorporating social justice into STEM classrooms. This current research project explores the intersectionality of STELLA instruments and social justice in the STEAM classroom.

Context and Theoretical Framework

We define makerspaces as a modular and adaptable collection of furniture, technologies, and tools that support learning through self-driven exploration and play. School makerspaces provide both the opportunities and the technologies to encourage tinkering, learning through play, and building competencies with advanced technologies, such as 3D printers, laser cutters, Wazers, microcontrollers, soldering, movie-making technologies, and computer science tools (Barton et al., 2017; Blackley et al., 2017; Sheridan et al., 2014). Studies on Identity Behavior Theory (IBT) suggest that the connection between identity and self-efficacy is tied to the sense of self (Simons, 2021) and makerspaces that promote belonging and student interests see increased engagement and student self-identification as STEM as part of their identity (Cirell et al., 2020). Making ties to civic engagement and social justice can deepen this sense of STEM as part of one's identity (Cirell et al., 2020; Twiss, 2017).

To allow students the opportunity to use making to address social justice, teachers must receive adequate training on how to incorporate social justice into the classroom makerspace. Banister and Vannatta-Reinhart (2011) established that teachers completing justice-centered work utilizing the TPACK framework were more likely to create spaces for traditionally marginalized voices in their classrooms and opportunities for justice-based civic engagement. This work draws on the Maker Technology, Pedagogy, Inclusion, and Content Knowledge (MakerTPICK) theoretical framework (Nichols et al., 2024), which expands Koehler and Mishra's (2009) Technology, Pedagogy, and Content Knowledge (TPACK) framework to include knowledge of inclusive practices and procedures for makerspaces, thus applying IBT to retain diverse participants in makerspaces.

This work considers the efficacy of using STELLA instruments to situate justice-centered STEM learning in authentic contexts for elementary, middle, and high school teachers. We investigated the following research question: How does participating in STELLA-based justice-centered STEAM-making lessons change teachers' beliefs about incorporating STELLA instruments and social justice into their curriculum?

Major Aspects of Research Project and Methodology

This qualitative research project was implemented with in-service teachers who enrolled in the justice-centered STEAM-making course during the Fall 2024 term. Of the 17 teachers enrolled in the course, 15 teachers are participating in a selective five-year fellowship program aimed at building capacity for justice-centered STEM making and leadership within their district. The STELLA-based, justice-centered STEAM activities were developed by the authors in the summer to fall of 2024 and are paired with three topics: urban heat islands, vegetation health, and air quality. Participants also learned about Landsat, remote sensing, and the value of monitoring vegetation, wildfires, arctic ice, and other environmental phenomena using spectrometers on the low-orbit satellite.

In terms of monitoring vegetation health, Landsat uses visible and near-infrared spectroscopy to monitor vegetation health and help inform farmers about crop infection and blight. When chlorophyll interacts with sunlight, healthy vegetation will reflect light in the visible and near-infrared spectra which is evidenced through peaks in 500 nanometers (nm) to 550 nm and 750nm to 2500 nm range. Participants will learn about how equitable access to nutritious food impacts brain development and about agricultural water loss due to difficulty targeting vegetation roots while farming. Participants will then use the STELLA instruments to model the spectral data collection on Landsat and evaluate the health of a variety of plant samples. Participants will be able to then identify plants that may need additional water, nutrients, or other support based on the logistic data visualization.

The Landsat 7 satellite data helped determine the impact of vegetative regions in urban areas as they relate to urban heat islands (Allen et al., 2024). Dense construction in urban environments in Providence, Rhode Island in 2002 demonstrated greater temperature retention than areas with more trees, such as Buffalo, New York (Allen et al., 2024). Providence, which is 83 percent densely developed, had surface temperatures that were nearly 22 degrees Fahrenheit warmer than surrounding towns, whereas Buffalo, which is 43 percent densely developed, was only 13 degrees Fahrenheit warmer than adjacent regions (Allen et al., 2024). Urban heat islands impact heat-related deaths and illnesses, including respiratory difficulties, heat exhaustion, and heat stroke (US Environmental Protection Agency, 2024). Participants will learn about the impacts of urban heat islands and use the STELLA instrument and heat lamps to gather data and make comparisons about surface temperatures of areas in the shade of plant leaves and uncovered regions.

Regarding air quality, Landsat 8 Operational Land Imager (OLI) satellite data has been previously used to predict the concentration of particulate matter less than ten micrometers (PM10) in Delhi, India (Saraswat et al., 2017). Pollution and air quality are well-documented issues in India, and atmospheric visible spectrum reflectance data collected from Landsat 8 passes was reviewed and compared with data from the Central Pollution Control Board for corresponding dates (Saraswat et al., 2017). Participants will learn about the health impacts of poor air quality and use a variation of the STELLA instrument to review particulate and air quality data and make recommendations about actionable steps that can be taken to improve air quality.

Qualitative data collected included participants' narrative summaries of the experience and their written reflections to prompts, as well as researcher-recorded observational field notes during activity implementation. The reflection questions asked participants to describe their experience using the STELLA and the changes in their beliefs about using spectroscopy instruments to teach justice-centered curriculum in STEAM classes. Participants were also asked to describe how they could incorporate STELLA spectroscopy into their STEAM and justice-centered lesson plans. The survey instrument investigated how STELLA might be used in the classroom, which activities most resonated with participants, and if there was interest in learning more about future STELLA-related opportunities. We used the qualitative approach by Merriam and Tisdell (2015) to review data as it was collected to establish initial themes and observations. We also followed Saldaña's (2021) deductive approach to coding the data by creating a list of a priori codes in the first pass of the data and recording the data in subsequent passes of the data. Researchers compared findings prior to the final passes of the data.

Results

Of the 17 teachers who participated in the STELLA-based justice-centered STEAM activities, 15 completed reflections and shared insightful comments about how STELLA can be used in the STEAM classroom. The reflections immediately conveyed enthusiasm for the STELLA. Several teachers reiterated that the STELLA is an engaging tool for teaching and learning. One teacher said, "these seemed like lessons…to keep my students engaged," while another shared, , "these are lesson concepts I have taught in the past and that really get students

engaged." A third teacher stated, "I can imagine students being engaged… right away, and it was compelling to see numbers change in real-time." Additional teachers conveyed excitement for the STELLA and its applications in the STEAM classrooms, describing the STELLA and activity topics as "cool," "interesting," and "impactful."

The responses also indicated that teachers understood the application of the STELLA within the context of the three justice-based STEAM activities and saw potential in using STELLA to reinforce content within their own curricula. Teachers anticipated the following activities would be most applicable to their practice: ten selected the air quality activity, nine selected the urban heat island activity, seven selected the Landsat presentation, and three selected the vegetation health activity. Thirteen teachers are interested in additional information about STELLA and NASA educational opportunities. After coding the data, five themes emerged in the narrative responses about the use of STELLA in the STEM classroom: usefulness in teaching digital fabrication, effectiveness in teaching about remote sensing, creating justice-centered and authentic project opportunities, reinforcing STEM curriculum, and synthesizing data.

Participating teachers anticipated that STELLA instruments would be useful for teaching digital fabrication techniques and makerspace technologies, including 3D-printing, engineering, computer programming, robotics, and electronics. One teacher described the STELLA as a "really cool application" of 3D printing. Another teacher said, "I will use it in my computer programming and research classes for several projects related to robotics," while another teacher said the STELLA could be "used to teach programming and how to collect and analyze data" as well as "the engineering design process." A third teacher stated, "I would like to be able to use the components to teach additional electronics modules in my classes." One teacher even considered how the STELLA could be used for a cross-grade activity: ninth graders would 3D printing the housing, tenth graders study heat transfer, and eleventh graders assembling the electronics. In this way, participants listed several approaches to utilizing STELLA to teach maker technologies and skills.

Participating teachers also reported that STELLA is a useful for teaching students about remote sensing, including Landsat, monitoring environmental conditions and temperature, learning about infrared wavelengths, and troubleshooting and calibration. One teacher summarized that in low-orbit satellite monitoring, "students learn how satellites work and are curious how they are able to sense information about the earth…STELLA can help them understand the technology, collect and analyze data for themselves - working like aerospace engineers." Teachers also cited the benefits of particulate sensing and temperature monitoring. One teacher wrote, "I think the air quality sensors would be interesting to keep track of every day or throughout the day… starting with temperature would be very compelling to students because there are constant complaints about it being too cold or too hot even at the same time." Another teacher wrote that it would be beneficial to "check air quality around different parts of the school and outside… [and] temperature readings around the trees on the playground to see how much of a difference [vegetation] makes." Teachers also mentioned the benefits of using STELLA to teach students about the near-infrared spectrum and the relationship between sunlight, plants, chlorophyll, and near-infrared wavelengths. One teacher stated, "this activity resonated with me because it shows the applications of infrared detection...I was able to make connections to ideas I would have never thought were related." In this way, participants reiterated that STELLA has several applications for teaching and learning about remote sensing.

The STELLA tool can be leveraged to create authentic, justice-centered learning opportunities that promote project-based learning (PBL), civic participation, research, and engagement with content. One teacher wrote, "I can see utilizing the STELLA with preservice teachers in their problem-based learning course and other clinicals experiences." Teacher participants also reiterated the value of using STELLA for inquiry-based projects and interest-based experiences. For example, a teacher stated, "the STELLA would help add additional inquiry to the content…there is space for students to develop their own exploration on these topics with STELLA." Regarding justice-centered projects, one teacher stated, "I would have students collect the data for the letter [to inform about air quality],...have students make the STELLA, and…[record] air quality in the home, apartment, outside in the garden or patio, …playground or green space versus balcony with vegetation," while another shared that the STELLA would be beneficial for "graphing activities with real world connections, ecology, diversity, environmental justice advocacy." In this way, participants stated several ways that STELLA can enhance justice-centered education.

Teacher participants also anticipated that the STELLA would be useful in teaching content, especially reinforcing concepts about Landsat, urban heat islands, air quality, and vegetation health. Multiple teachers suggested ways that STELLA could be used to enhance learning about vegetation. One teacher said the STELLA could be used for "working with plants in the classroom, allowing students to keep track of vegetation health" and another stated it "could be used to visualize rates of change of vegetation and heat over time…this could be used to make connections to the work of studying rates of change." One teacher shared, "we have taught several lessons on air quality, heat islands, albedo and building materials…[it] could add another layer of exploration to those lessons," reiterating the STELLA's benefits to teaching about environmental impacts. Another teacher mentioned the benefits

of connecting satellites and environmental monitoring, commenting "The presentation explained how Landsat and STELLA work and answers a lot of [student] questions…" In this way, STELLA can benefit teaching and learning for existing topics in the curricula.

Teacher participants also expected that the STELLA could be used to promote data collection, data analysis, and data visualization by creating authentic informatics opportunities in the STEM classroom. One teacher wrote, "STELLA can be used in the classroom to read and find data with students. This information can be used for practicing data driven instruction. This technology can be used for student advocacy… backed by scientific data." Teachers mentioned the benefits of generating and analyzing data with students. One participant stated, "I thought it was really cool to collect… data over time," while another thought STELLA allowed for "real world applications and immediate data generation." Comments about the benefits of using STELLA-generated data were found in most survey responses, demonstrating the potential for using STELLA in the classroom.

Discussion and Limitations

The results indicate that the STELLA tool can support students' engagement with the STEAM curriculum, data analysis, remote sensing, and PBL. Previous work has established that instructor-modeled justice-centered STEAM-making lessons coupled with TPACK-based lesson planning galvanize participant confidence in incorporating these maker technologies in their classrooms (Nichols & Corum, 2023). The STELLA technologies are relatively new but align well with justice-centered maker contexts, and these results demonstrate their efficacy in the STEAM classroom. The results indicate that STELLA tools can make significant contributions to education, both in regard to reinforcing current content and creating opportunities for student research and discovery based on their own interests. The teachers in the study were actively engaged in their experiences with STELLA and were eager for future opportunities to work with this technology, indicating great potential for adding STELLAs to STEAM classrooms around the world.

Although the results are promising, there are several limitations that are important to acknowledge. Teachers self-selected participation in the class, and the data was self-reported; thus, the results may inherently tend towards support of justice-centered activities. Second, the survey did not specifically invite critique of using the STELLA in the classroom, so the results may not capture negative feedback about the STELLA. However, participants were invited to share any additional comments or questions and could have included negative feedback in this location. In order to inspire the most detailed responses from participants about how the STELLA may be used, the questions were also loaded in order to invite participants to dig deep and produce detailed, thoughtful responses about how the instrument could be used (Groves et al., 2011). The sample size of fifteen participants may also impact the ability to broadly apply the results of the study.

Conclusions and Implications for Future Work

STELLA technologies have significant potential for promoting civic engagement in the STEAM classroom and aiding in the teaching of essential skills and topics. This study indicated that teachers are eager for additional training with STELLA-based tools and believe it creates engaging and meaningful opportunities for students, particularly for digital fabrication, teaching about remote sensing, authentic project opportunities, STEAM curricula, and learning with data. Teachers indicated interest in additional STELLA curriculum materials, which may indicate that additional STELLA studies should be conducted and resulting lesson plans shared in an online repository of lessons and resources. Additional research can also be conducted on the efficacy of including STELLAs in curricular design, professional development, and teacher practice. In conclusion, the low cost of STELLA instruments makes them a valuable tool for connecting students with real-world issues, NASA learning, and justice-centered STEM making.

References

Aguirre, J. M., Anhalt, C. O., Cortez, R., Turner, E. E., & Simic-Muller, K. (2019). Engaging teachers in the powerful combination of mathematical modeling and social justice: The Flint water task. Mathematics Teacher Educator, 7(2), 7–26. https://doi.org/10.5951/mathteaceduc.7.2.0007

Allen, J., Simmon, R., & Scott, M. (2024). Urban Heat Islands. Landsat Image Gallery. https://landsat.visibleearth.nasa.gov/view.php?id=47704

Banister, S., & Reinhart, R. V. (2011). TPCK for impact: Classroom teaching practices that promote social justice and narrow the digital divide in an urban middle school. Computers in the Schools, 28(1), 5–26. https://doi.org/10.1080/07380569.2011.551086
Barton, A. C., Tan, E., & Greenberg, D. (2017). The makerspace movement: Sites of possibilities for equitable opportunities to engage underrepresented youth in STEM. Teachers College Record: The Voice of Scholarship in Education, 119(6), 1–44. https://doi.org/10.1177/016146811711900608
Blackley, S., Sheffield, R., Curtin University, Maynard, N., Curtin University, Koul, R., Curtin University, Walker, R., & Curtin University. (2017). Makerspace and reflective practice: Advancing pre-service teachers in STEM education. Australian Journal of Teacher Education, 42(3), 22–37. https://doi.org/10.14221/ajte.2017v42n3.2
Cirell, A. M., Kellam, N., Boklage, A., & Coley, B. (2020). Reimagining the thirdspace through makerspace. In M. Melo & J. T. Nichols (Eds.), Re-making the library makerspace: Critical theories, reflections, and practices (pp. 47–82). Library Juice Press.
Delli Carpini, M. X. (2000). Gen.com: Youth, civic engagement, and the new information environment. Political Communication, 17(4), 341–349. https://doi.org/10.1080/10584600050178942
Groves, R. M., Fowler Jr., F. J., Couper, M. P., Lepkowski, J. M., Singer, E., & Tourangeau, R. (2011). Survey methodology. John Wiley & Sons.
Heredia, S. C., & Tan, E. (2021). Teaching & learning in makerspaces: Equipping teachers to become justice-oriented maker-educators. The Journal of Educational Research, 114(2), 171–182. https://doi.org/10.1080/00220671.2020.1860871
Koehler, M. J., & Mishra, P. (2009). What is technological pedagogical content knowledge? Contemporary Issues in Technology and Teacher Education, 9(1), 60–70.
Lerner, R. M., Lerner, J. V., Almerigi, J. B., Theokas, C., Phelps, E., Gestsdottir, S., Naudeau, S., Jelicic, H., Alberts, A., Ma, L., Smith, L. M., Bobek, D. L., Richman-Raphael, D., Simpson, I., Christiansen, E. D., & von Eye, A. (2005). Positive youth development, participation in community youth development programs, and community contributions of fifth-grade adolescents: Findings from the first wave of the 4-H study of positive youth development. The Journal of Early Adolescence, 25(1), 17–71. https://doi.org/10.1177/0272431604272461
London, R. A., Pastor, M., Servon, L. J., Rosner, R., & Wallace, A. (2010). The role of community technology centers in promoting youth development. Youth & Society, 42(2), 199–228. https://doi.org/10.1177/0044118X09351278
Merriam, S. B., & Tisdell, E. J. (2015). Qualitative research: A guide to design and implementation (Fourth edition). John Wiley & Sons.
NASA. (2021). Landsat 9. NASA Landsat Science. https://landsat.gsfc.nasa.gov/satellites/landsat-9/
NASA. (2023, March 8). STELLA: A DIY Handheld Scientific Instrument | Landsat Science. https://landsat.gsfc.nasa.gov/article/stella/
NASA. (2024a). 50 years of Landsat science. NASA Landsat Science. https://landsat.gsfc.nasa.gov/
NASA. (2024b). Benefits. NASA Landsat Science. https://landsat.gsfc.nasa.gov/benefits/
Nichols, L., & Corum, K. C. (2023). Increasing teacher commitment to justice-centered mathematics through maker-enhanced social justice activities (E. Langran, P. Christensen, & J. Sanson, Eds.; pp. 411–416). Association for the Advancement of Computing in Education (AACE). https://www.learntechlib.org/p/221891/
Nichols, L., & Corum, K. C. (2024). Strategies for creating and sustaining inclusive makerspaces. In J. S. Briganti, J. C. Sible, & A. M. Brown (Eds.), Fostering communities of transformation in STEM higher education: A multi-institutional collection of DEI initiatives. Virginia Tech Publishing. https://hdl.handle.net/10919/117749
Nichols, L., Gorsky, R., & Corum, K. C. (2024). Conceptual and theoretical frameworks for leveraging makerspaces to encourage and retain underrepresented populations in STEM through learning by design. Educational Technology Research and Development, 72(1). https://doi.org/10.1007/s11423-023-10307-z
Saldaña, J. (2021). The coding manual for qualitative researchers (4th ed). SAGE Publishing.
Saraswat, I., Mishra, R. K., & Kumar, A. (2017). Estimation of PM10 concentration from Landsat 8 OLI satellite imagery over Delhi, India. Remote Sensing Applications: Society and Environment, 8, 251–257. https://doi.org/10.1016/j.rsase.2017.10.006
Sheridan, K., Halverson, E. R., Litts, B., Brahms, L., Jacobs-Priebe, L., & Owens, T. (2014). Learning in the making: A comparative case study of three makerspaces. Harvard Educational Review, 84(4), 505–531. https://doi.org/10.17763/haer.84.4.brr34733723j648u
Simons, J. D. (2021). From identity to enaction: Identity behavior theory. Frontiers in Psychology, 12, 679490. https://doi.org/10.3389/fpsyg.2021.679490
Twiss, L. (2017). How Urban Youth Use Digital Tools at Community Technology Centers to Support the Development of Civic Engagement Pathways: A Multisite, Multicase Study [Unpublished Doctoral Dissertation, Towson University]. https://www.towson.edu/coe/departments/edtech/grad/instructiontech/documents/twiss.pdf
U.S. Department of the Interior, & U.S. Geological Survey. (1997). Landsat data: A brief history of the Landsat program (USGSFact Sheet 084-97). https://pubs.usgs.gov/fs/1997/0084/report.pdf
US Environmental Protection Agency. (2024). Heat Island Impacts. EPA. https://www.epa.gov/heatislands/heat-island-impacts

Acknowledgements

This project is based upon work supported by the National Science Foundation under Grant Nos. 2243461, 2243462. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the view of the National Science Foundation.