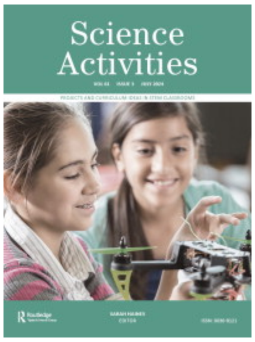

Science Activities

Projects and Curriculum Ideas in STEM Classrooms

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RESEARCH ARTICLE

The whole world in your hands: explorations in sustainability education using geospatial tools

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ABSTRACT

This paper describes the integration of geographic information system (GIS) technology in a high school environmental science classroom, specifically examining the impact of GIS technology on student engagement, critical thinking, and interdisciplinary learning for Education for Sustainability (EfS). This environmental science classroom utilized ArcGIS Online and StoryMaps to facilitate hands-on learning, enabling students to explore spatial relationships, analyze data, and communicate insights to foster engagement and critical thinking. This GIS technology promotes interdisciplinary learning by connecting essential environmental issues with location and other social factors. Students deepen their understanding of human-environment interactions by interpreting spatial data, empowering them to propose sustainable solutions to environmental challenges. Using ArcGIS Online and StoryMaps, students engaged in guided lessons, explored sustainability topics, and created their own StoryMaps based on the United Nations' (UN) Sustainable Development Goals (SDGs). The findings highlight positive engagement, critical thinking, and interdisciplinary learning impacts. Students demonstrated increased interest, understanding of complex issues, and developed analytical skills through spatial data analysis. The approach encouraged interdisciplinary thinking and expanded awareness of ongoing environmental challenges, supporting EfS goals.

KEYWORDS

Sustainability; environmental science; Geographic Information Systems (GIS); Sustainable Development Goals (SDGs); socioscientific issues; spatial reasoning

Introduction

Sustainability centers upon ensuring Earth's ongoing capacity to support life. For at least 35 years, researchers have conceptualized sustainability as encompassing three overlapping dimensions of life—economic, environmental, and social (Purvis, Mao, and Robinson 2019). Relatedly, the US Partnership for Education for Sustainable Development's K-12 Learning Standards (2009) define Education for Sustainability (EfS) as "a combination of content, learning methods, and outcomes that helps students develop a knowledge base about the environment, the economy, and society" (1). In addition, EfS helps students, "learn skills, perspectives, and values that guide and motivate them to seek sustainable livelihoods, participate in a democratic society, and live in a sustainable manner" (1). At its heart, EfS provides students, teachers, and community members with an awareness of the importance of sustainability and the disposition and tools necessary to act, locally and globally (Australian Education for Sustainability Alliance 2023). In 2010, the United Nations Educational, Scientific, and Cultural Organization (UNESCO) described Education for Sustainable Development as integral to students developing global citizenship, including an understanding of how to responsibly manage Earth's natural resources (Chung and Park 2016).

Sustainable Development Goals (SDGs) were created by the United Nations (UN) in 2015 with a target date of 2030. There are 17 SDGs: (1) No poverty, (2) Zero hunger, (3) Good health and well-being, (4) Quality education, (5) Gender equality, (6) Clean water and sanitation, (7) Affordable and clean energy, (8) Decent work and economic growth, (9) Industry, innovation, and infrastructure, (10) Reduced inequalities, (11) Sustainable cities and communities, (12) Responsible consumption and production, (13) Climate action,

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(14) Life below water, (15) Life on land, (16) Peace, justice, and strong institutions, and (17) Partnerships for the goals (UN 2015).

Standards developed by the US Partnership for Sustainable Development and the UN all provide K-12 teachers and students with a model for addressing global issues. These standards and pedagogical approaches serve as resources for educators to provide students with experience and knowledge related to systems thinking, civic action, and sustainable development (Hurd and Ormsby, 2020). Supporting teachers in these areas will help students learn to think critically, analyze issues related to sustainability, and provide potential solutions. EfS is paramount for ensuring that the Earth may continue to support life for generations to come.

EfS can be taught in a variety of ways, including embodied approaches that emphasize learning about local places through physical activities (Newton, Annetta, and Bressler 2023) as well as technology-based approaches that permit students to experience locales and access information that would otherwise be unavailable to them (Doering and Veletsianos 2008; Firestone and McMahon 2022; Kolvoord, Keranen, and Rittenhouse 2017). One example of technology for sustainability education is Geographic Information Systems (GIS) software, which allows users to layer maps that visually represent various types of information on one another to allow data analysis and insights that would be less fully synthesized if not combined in a visual space (Hwang 2013).

What is ArcGIS?

ArcGIS Online is a cloud-based mapping and analytic platform provided by the Environmental Systems Research Institute (Esri), a leading provider of (GIS) software and services. Geographers, educators, and public servants (e.g., city/urban planners, law enforcement, and conservationists) frequently use ArcGIS Online. It offers a vast array of publicly available geospatial data and analysis tools, as well as the ability for users to create, share, and use interactive maps. ArcGIS Online provides a range of features and tools for creating and working with maps. These features include a library of basemaps, such as satellite imagery, street maps, and topographic maps; a selection of visualization tools for maps, such as heat maps, dot density maps, and choropleth maps; and tools for creating and editing geospatial data with points, lines, polygons, and labels.

Educators can use ArcGIS Online to teach students the principles of mapping and spatial analysis. ArcGIS Online allows users to create interactive maps and analyze spatial data, which can be useful for a variety of applications in education, such as studying population patterns, analyzing environmental changes, and understanding spatial relationships. Using ArcGIS, students can better understand the world around them and develop critical thinking and problem-solving skills. Educators can also use ArcGIS as a valuable tool to create engaging, place-based, and interactive lessons, making the learning experience more enjoyable and relevant for students.

Esri's suite of ArcGIS products includes ArcGIS Online and other programs such as ArcGIS StoryMaps, a web-based application that enables teachers and students to build a digital story using interactive, multimedia maps and text. Users can combine text, images, videos, and maps with ArcGIS StoryMaps to produce interesting and educational narratives that can be shared with others directly or as a webpage. This application provides a variety of templates and customization options, making it easy for users to create professional-looking presentations without requiring coding or design skills. ArcGIS StoryMaps is especially helpful for identifying trends and patterns in data, visualizing data, and creating narratives about specific places or events.

While ArcGIS provides free accounts for schools, several challenges exist. The complexity of the software can present a barrier for both students and educators. Learning the software requires time and effort to achieve proficiency, often requiring training and support. Additionally, the resource-intensive nature of ArcGIS means that schools need to have a reliable internet connection to effectively run the software, which might not be feasible for all educational settings. Integrating ArcGIS into existing curricula can also be challenging, as educators need to align its use with learning objectives and standards. This requires careful planning and sometimes additional professional development for educators. Similarly, the dependency on a proprietary system can limit flexibility and adaptation, making it difficult to integrate with other educational tools and open-source platforms that schools may use. These factors can create hurdles in fully leveraging ArcGIS's capabilities within school learning environments.

Several other platforms similar to ArcGIS Online offer GIS capabilities, including QGIS, GRASS GIS, MapInfo Professional, and Google Earth Engine. QGIS and GRASS GIS are open-source alternatives, well-known for their adaptability, wide-ranging community assistance, and free availability. MapInfo Professional and Google Earth Engine offer commercial and cloud-based GIS solutions, each specializing in different areas, such as desktop mapping and environmental data analysis. However, ArcGIS Online continues to be a preferred option for numerous users because of its wide range of tools, smooth integration across desktop, web, and mobile platforms, and the extensive support and training resources Esri offers. ArcGIS Online provides robust capabilities for spatial analysis, data management, and high-quality map production. Its free access for educational institutions makes it a powerful and versatile tool for a wide range of GIS applications..

This article describes a high school project that uses Esri's ArcGIS Online for data analysis and StoryMaps to present findings *via* interactive maps, multimedia, and narrative. The class's teacher was a participant in a National Science Foundation-funded project designed to help high school teachers learn and use GIS technologies to explore and respond to environmental challenges while learning about careers that use GIS. In this case, the teacher and class used ArcGIS and StoryMaps to learn about the UN SDGs and investigate progress toward meeting those goals across the globe.

Why use ArcGIS to explore the United Nations' Sustainable Development Goals?

The UN's 17 SDGs are intended to be a blueprint for a more favorable and sustainable future for everyone (UN 2015). They cover a wide range of issues, including poverty, inequality, climate change, environmental degradation, and peace and justice. Each SDG has several indicators that measure progress toward achieving their goal. Using ArcGIS Online, students can explore and analyze the SDGs and their indicators to better understand the challenges and opportunities faced by different countries and regions. By creating choropleth maps, students can visualize data on various indicators and identify patterns and trends in the data represented through different colors. By selecting specific countries as examples, students can also compare the performance of different countries concerning a particular SDG.

Because StoryMaps are a useful tool for presenting the results of an analysis clearly and engagingly, students can combine interactive maps, narratives, and other multimedia resources to showcase their understanding of the assignment and illustrate the importance of sustainability in a way that is accessible to a wide audience. Overall, this class project allows students to learn about the SDGs and their indicators and develop data analysis, map-making, and storytelling skills. This project encourages students to think critically about sustainability and to consider their own role in creating a more sustainable future.

The project involves three different geographical regions: urban and rural Pennsylvania and Delaware (Lehigh University), suburban Washington state (Washington State University Tri-Cities), and urban Texas (Texas Christian University). At each of these sites, university faculty collaborate with teachers at two or more high schools (student ages 15-18) to design, develop, and implement activities embedded within the school's regular curriculum. These activities focus on social issues related to environmental science, are multi-disciplinary, involve decision-making based on the analysis of scientific data connected to relevant social science content, and have implications for social equity.

In this project, teachers design, develop, and implement socio-environmental science investigations (SESI) using a geospatial curriculum approach to promote the skills relevant for students interested in pursuing STEM-related careers. SESI investigations are designed to develop student STEM workforce skills. The SESI learning activities and investigations provide opportunities for students to collaborate, collect data, engage in analysis, problem-solve, master technology, develop geospatial thinking and reasoning skills, and practice communication skills essential for the STEM workplace. Throughout the project, teachers learn to use the suite of tools developed by Esri: ArcGIS Field Maps, ArcGIS Online, and ArcGIS StoryMaps

Classroom SESI projects focus on social issues related to environmental science and involve open-ended inquiry-based investigations, with students engaging in data collection and geospatial analysis. These investigations are multidisciplinary and involve decision-making based on the analysis of georeferenced geospatial data, examination of relevant social science content, and consideration of social equity implications. SESIs are based on the pedagogical frameworks of place-based education and socioscientific issues-based instruction. Place-based education focuses on local or regional investigations, is designed around engaging students in examining local problems (Sobel 2004; Yemini, Engel, and Ben Simon 2023) and utilizes fieldwork to gather evidence in that local setting (Semken 2005; Semken et al. 2017). Socio-scientific issues are socially relevant, real-world problems that are informed by science and often include an ethical component (Karahan and Roehrig 2017; Sadler, Barab, and Scott 2007), such as human impact on the environment, climate change, and questions related to economic and racial repercussions of urban development. They are sometimes controversial in nature but have the added element of requiring a degree of moral reasoning or the evaluation of ethical concerns in the process of arriving at decisions regarding possible issue resolution (Zeidler and Nichols 2009). These issues require the use of evidence-based reasoning and provide a context for understanding scientific information using an active approach to learning, placing science content within a social context in a way that fosters motivation for, and the ownership of, learning by the student (Sadler and Donnelly 2006; Zeidler and Nichols 2009). The following study will describe one teacher's approach to teaching students about socioscientific issues using geographic data in conjunction with ArcGIS software to help students achieve more nuanced understandings of global challenges and their relationship to sustainability initiatives.

Context of school, course, and classroom

The school in which these investigations occurred is a large secondary high school in the U.S. Pacific Northwest with approximately 3200 students. The school's student population reflects the local area's strong multilingual nature and Latine community, with 20% of students identified as multilingual learners and 65% of students who are Latine (WA OSPI 2023). This school serves students with significant levels of poverty and academic achievement; 65% of students are low income, with only 58% passing all their ninth-grade classes (WA OSPI 2023). The classes discussed here are part of the trimester-based environmental science course titled: Environment and Society. The students in these classes were likely to be more academically focused than the school average; the environmental science classes were offered as a high school and college dual credit course. Most students in this class were in either the 11th or 12th grade, while students in the 10th grade could register for the course if they were interested in the subject matter. This college-level course examined the physical and cultural components of environmental challenges, focusing on the interplay between ecosystems, essential resources, population dynamics, and culture. Students enrolled in this course gained skills in critical thinking, laboratory exploration, and environmental literacy appropriate for college-level work. The lessons discussed in this study took place over a two-week period in the second trimester. Despite the lingering impact of the COVID-19 pandemic, approximately 26 students consistently attended during this period.

Connections to NGSS

This paper closely aligns with the Next Generation Science Standards (NGSS), integrating specific science and engineering practices (e.g., engaging in argument from evidence, analyzing and interpreting data), crosscutting concepts (such as systems and models), and disciplinary core ideas (including Earth and human activity). The utilization of ArcGIS Online and StoryMaps in this high school classroom offers a dynamic and inquiry-driven approach to sustainability and environmental education that seamlessly aligns with NGSS principles.

Moreover, these lessons highlight the practical implementation of NGSS-aligned pedagogical frameworks, notably the socioscientific issues-based instruction, which immerses students in exploring complex global challenges. These challenges are anchored in specific content areas, including environmental science (e.g., climate change, biodiversity loss) and human geography (e.g., socio-economic disparities, urban development), all significantly intertwined with sustainability and the United Nations' Sustainable Development Goals (SDGs). These lessons emphasize critical thinking, data analysis, and spatial reasoning skills, all essential components of NGSS. This approach fosters a comprehension of the complicated relationships between sustainability's economic, environmental, and social dimensions.

Sequencing of lessons

The teacher introduced students to ArcGIS Online for the first time through the classroom project described in this paper. To become comfortable using this new technology, students engaged in the following sequence of lessons that introduced creating maps in ArcGIS Online, visualizing large data sets in a meaningful way, analyzing data by joining layers, and comparing data from different countries. A data layer is a collection of comparable geographical features, such as houses, plots, cities, highways, and earthquake epicenters. These features may be points, lines, or polygons (i.e., larger areas). By using a data layer, a student can view, edit, analyze, and execute analyses against the features and their various attributes. Students also engaged in an introduction to StoryMaps by creating a Washington State Wildfire StoryMap containing multiple maps and other multimedia resources. Once students completed these introductory lessons, they were able to choose their own SDG to investigate, utilizing the same procedures for creating maps, joining layers, and interpreting the data. Finally, students demonstrated their understanding of their chosen SDG by creating a StoryMap that presented their analyses and conclusions. For more detailed instructions, please see: https://docs.google.com/document/d/1HHk_9GVG7f6Cjko6Ep-UmODpDN76CBWY/copy.

Examining global poverty

Students began their investigations into the UN's SDGs by completing an introductory lesson in ArcGIS Online, examining data regarding Goal 1: *End poverty in all its forms everywhere*. After logging into their ArcGIS organizational accounts, students added two data layers to a map. The first layer contained polygon information, denoting the boundaries of each country, and the second layer included the SDG data (i.e., Indicator 1.1.1: Proportion of population below international poverty line percent). This data layer represented the proportion of the population living below the international poverty line by sex, age, employment status, and geographic location. Next, students used the ArcGIS Online analysis function to merge the two layers. Adjusting the symbology of the newly created data layer to show the latest value (i.e., last year of reported data for each contributing country) enabled students to make a choropleth map (see Figure 1). From the color gradient of the map, students could easily conduct a visual analysis to identify countries with a large percentage of their population living below the international poverty line.

After students mapped global poverty, they mapped reported data of the percentage of children involved in economic activity, one of the measures used to determine a country's poverty level. This lesson began in a similar manner to the previous lesson. However, the students' newly created global poverty layer from the previous step was joined with another UN SGD layer, Indicator 8.7.1: *Proportion of children engaged in economic activity by sex and age* (percent). This data layer contains the proportion and number of children aged 5–17 years who are engaged in child labor. A second choropleth map was generated by combining these two layers and modifying the symbology to reflect the most recent value recorded (see Figure 2).

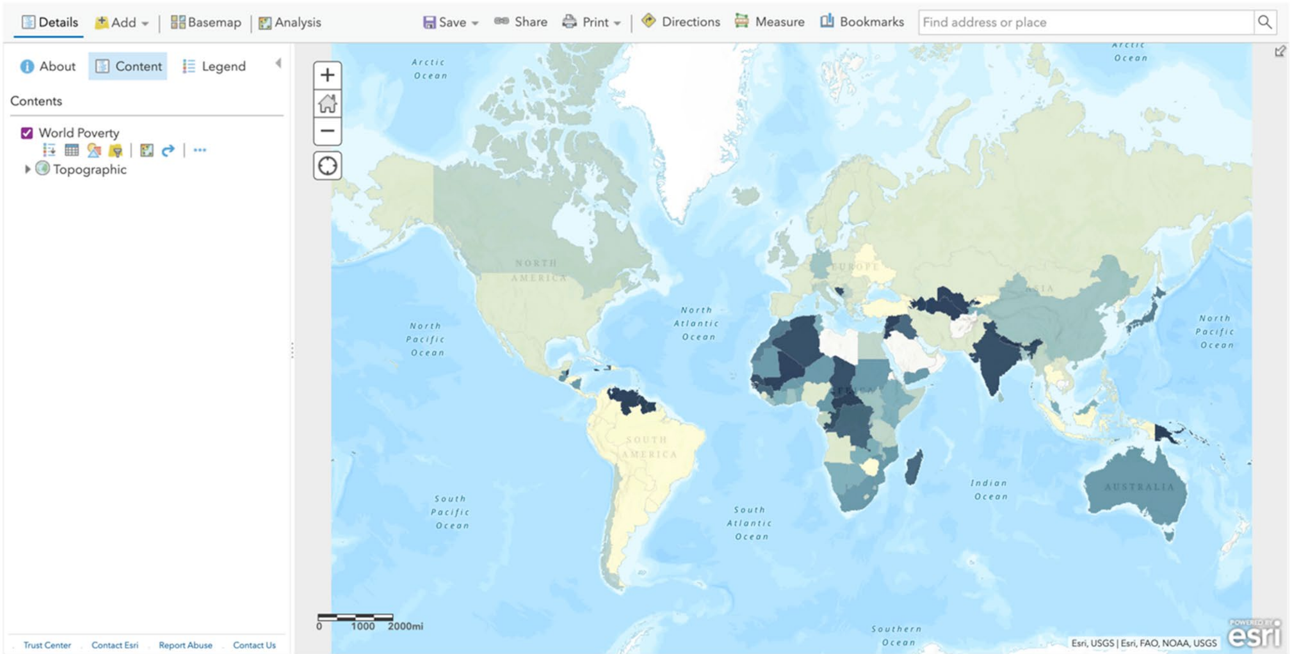

Figure 1. Choropleth map of world poverty.

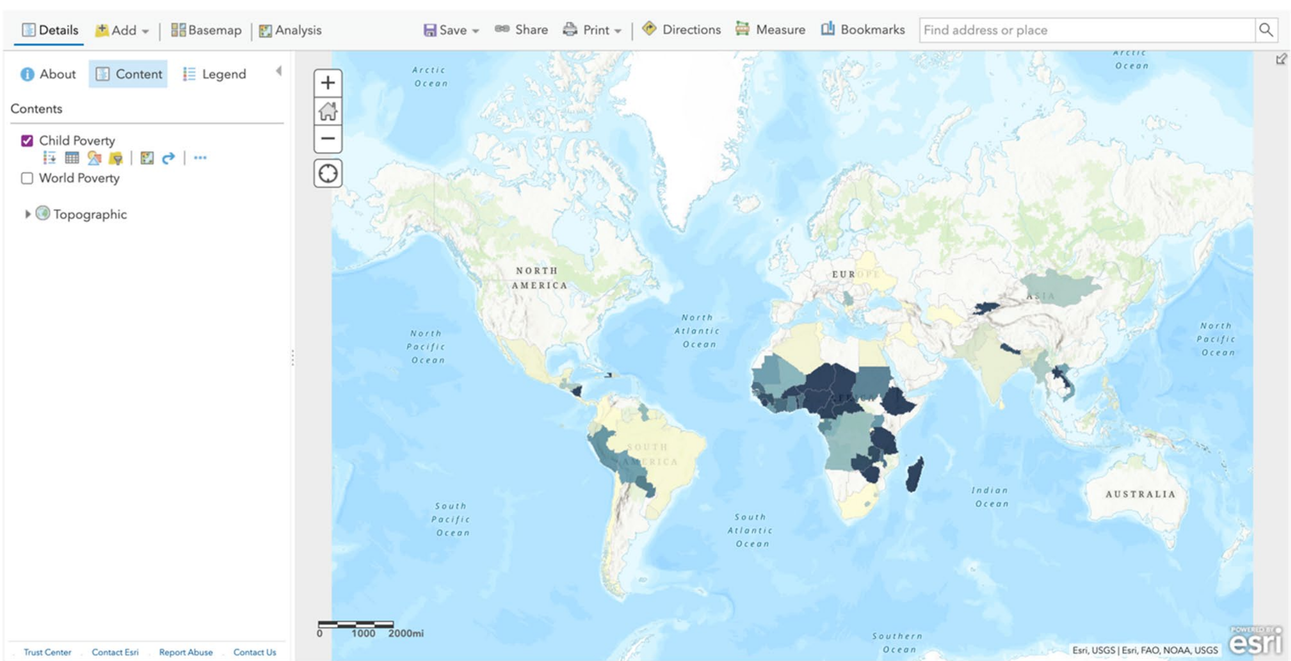

Figure 2. Choropleth map of child labor.

Students discussed which countries have high rates of child labor. However, by adding another attribute to display on the map by adjusting the symbology (e.g., the latest value recorded for the proportion of the population below the international poverty line), students created a choropleth bivariate map (see Figure 3).

A bivariate map combines two distinct sets of graphic symbols or colors to illustrate two variables on a single map, providing a straightforward approach for graphically expressing the relationship between two spatially distributed variables. A bivariate map can highlight relationships between variables more efficiently than

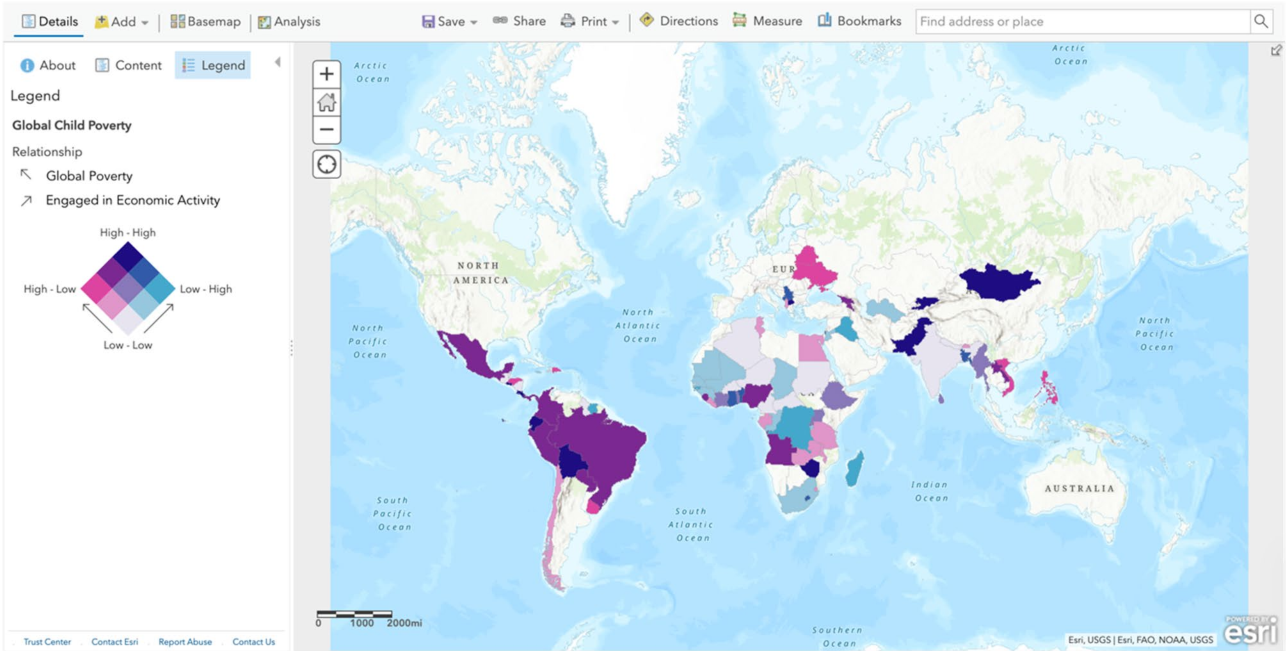

Figure 3. Bivariate map of global poverty and children engaged in economic activity.

comparing two univariate maps side-by-side, rendering it an essential cartographic tool. Having students create data layers in ArcGIS Online using extensive UN SDG data allowed them an easy way to visualize and compare relationships where data is present. The teacher used several questions to prompt a deeper analysis of the created data layers: (a) Which countries have the highest poverty rates? (b) Where does it appear that children are protected from labor? (c) Where do you see overlaps in patterns between the two maps that you have created for each indicator? (d) Where are the most affected areas where efforts should be focused toward helping improve the condition of children?

Measuring global hunger

Following the students' examination of global poverty, students examined Goal 2: *End hunger, achieve food security and improved nutrition, and promote sustainable agriculture.* This lesson started with students joining two data layers: UN's Indicator 2.1.1: *Prevalence of Undernourishment (percent) and Esri's World Countries layer.* Undernourishment is when an individual's dietary energy intake falls below the minimum requirements for maintaining a healthy and active life. The students accomplished this task by using the analysis function of ArcGIS Online. Once they adjusted the symbology to show the latest recorded value, the new data layer yielded a choropleth map of which countries have reported a high prevalence of undernourishment within their population. It is clear which countries do not have reported data, as the countries lacking contributing data will not have a polygon outline (see Figure 4).

The students repeated the procedure for Indicator 2.1.2: *Prevalence of moderate or severe food insecurity in the adult population (percent)* and the world countries layer to produce a choropleth map of food insecurity in the world (see Figure 5). Food insecurity is when people lack reliable access to sufficient, safe, and nutritious food that meets their dietary needs for an active and healthy life due to limited economic resources or other barriers. The teacher's plan was to use the two data layers that the students created to create a bivariate map similar to the one in the Examining Global Poverty lesson; however, due to time constraints, this was not included in the lesson on Measuring Global Hunger.

Students used the following guiding questions to aid them in further investigating their ArcGIS data layers and pop-up information (information

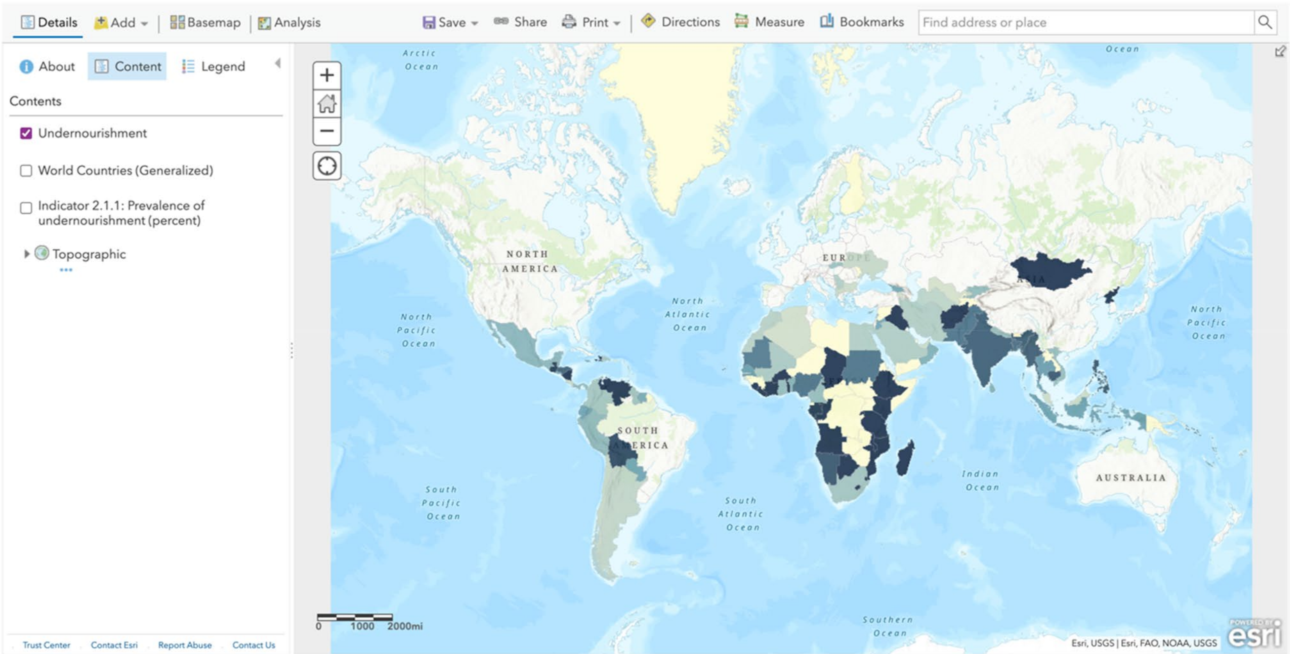

Figure 4. Choropleth map of undernourishment.

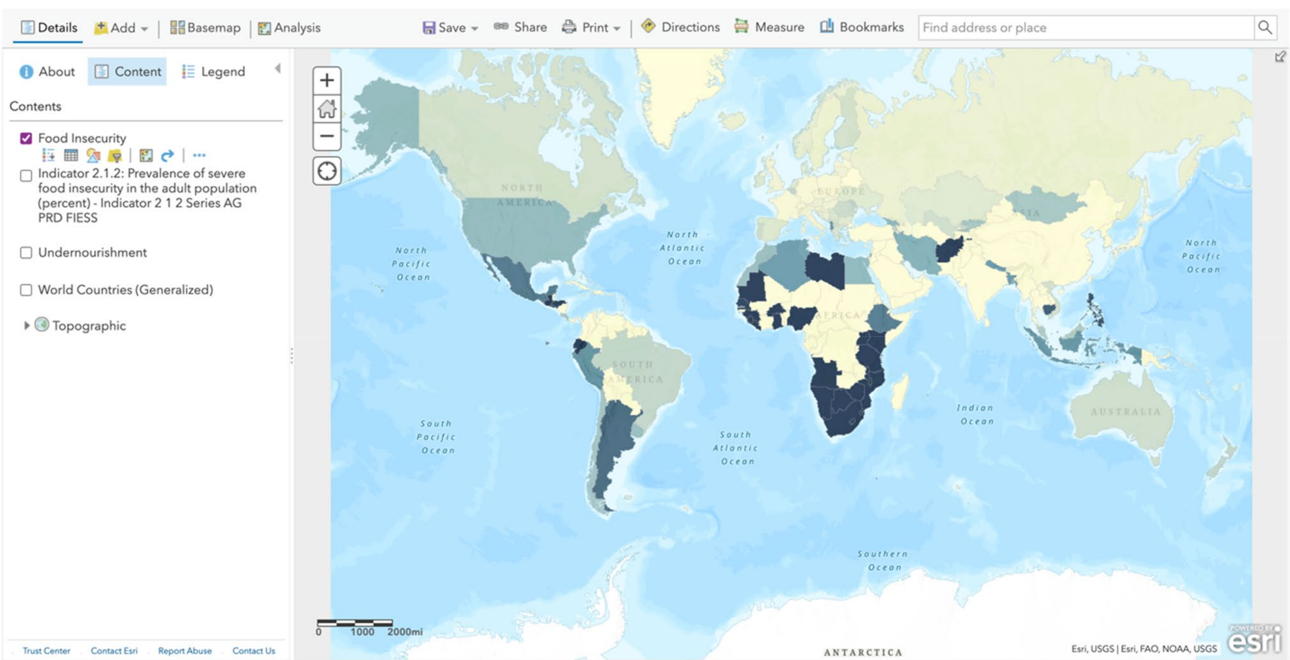

Figure 5. Choropleth map of food insecurity.

that appears in a small window when one hovers over data points on a map): (a) Which countries look like they suffer most from undernourishment (list at least three)? (b) Were any of these countries or rates surprising? (c) Which countries are missing data (list at least three)? (d) Why might it be hard to collect these data from all countries? (e) Which countries look like they suffer most from food insecurity (list at least three)? (f) Were any of these countries or rates surprising? (g) Which countries are missing data (list at least three)? (h) Was it the same countries as before or different ones? Why? Through these questions, students were able to identify countries most at risk for food insecurity and suggest policies in their presentations to best combat this.

Introduction to StoryMaps

Once students finished examining global poverty and hunger, they continued their introduction to Esri's technologies by creating a relevant StoryMap concerning the massive wildfires in the state of Washington during 2020. Students used an activity guide with explicit instructions on how to build a StoryMap containing maps, narratives, and other multimedia resources. This lesson enabled students to explore the different features and functions of StoryMaps before creating their own. The lesson started with students creating three maps in ArcGIS Online with Esri's USA Current Wildfire data layer and a Wildfire Hazard Potential. Wildfire hazard potential is an index that quantifies the relevant potential for a wildfire that may be difficult to control. After students saved three maps, they started creating their StoryMaps, seamlessly embedding them alongside other resources (see Figure 6). Various images, news clip videos, and written text accompanied these maps.

Sustainable Development Goals (SDGs) unit project

Through these introductory lessons, students had the opportunity to construct a solid understanding of the uses of ArcGIS Online and StoryMaps. Subsequently, students worked independently or in small groups to create a StoryMap concerning one of the SDGs. Students had the option of selecting any of the seventeen SDGs to investigate further, constructing various maps using indicator data while attempting to establish relationships between the SDGs (see Table 1). The students worked on their unit project for approximately two weeks, including two days of presentations.

After students identified their SDG to investigate, they started by searching through various maps and sifting through indicator data, or data layers in ArcGIS created and owned by UNstats_admin (the UN's GIS maps created and collected on the ArcGIS). Students had to include at least three maps of indicator data joined with the world countries layer and produce three choropleth maps. For example, one student who decided to investigate Gender Equality (SDG 5) chose to highlight the following three indicators: the proportion of seats held by women in national parliaments and local governments (Indicator 5.5.1), the proportion of women in managerial positions (Indicator 5.5.2), and the proportion of women aged 20–24 years who were married or in a union before the age of 18 (Indicator 5.3.1).

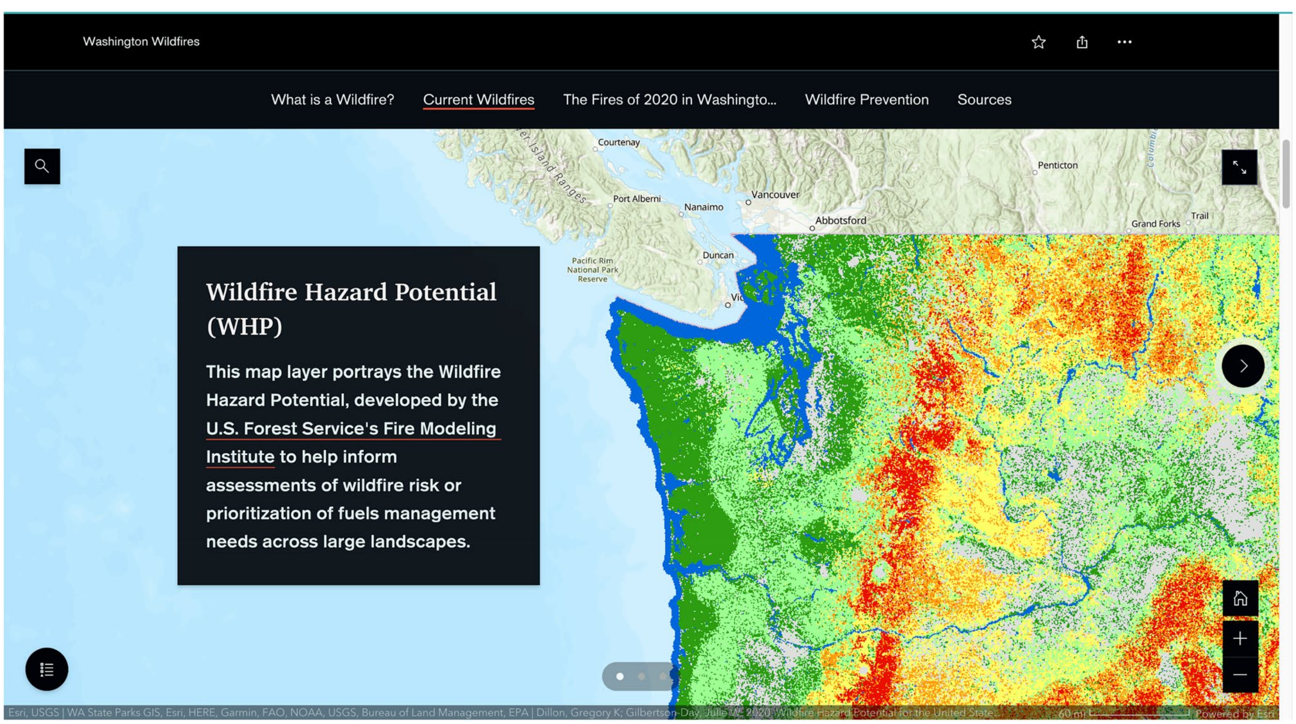

Figure 6. Example of Washington wildfire StoryMap.

Table 1. Sustainable Development Goals (SDGs) unit project outline.

Number of Class Periods	Classroom Activities
1	• Identified student groups for the assignment • Selected one of the seventeen SDGs to investigate. • Searched through various maps and indicator data in ArcGIS.
1	• Students created Choropleth maps (x3) on various indicators for their chosen SDG.
1	• Conducted a visual analysis to identify one country struggling with and one progressing toward the SDG. • Described the performance rating for each country, including population pyramids and demographic transitions.
2	• Created two choropleth bivariate maps to show relationships between their chosen SDG and another SDG. • Defined sustainability and how it relates to their chosen SDG.
1-2	• Compiled all information and maps into a StoryMap, supporting interactive maps with narrative and other media (e.g., population pyramids and demographic transitions).
2	• Ten-minute presentation on their maps, identified countries, and definition of sustainability.

Note: Each class period is an average of 60-minutes.

Students created a univariate choropleth map for each indicator and a narrative describing the data and included them in their StoryMap (see Figure 7). From these three indicator maps, students had to conduct a visual analysis and determine one country struggling to achieve the SDG and another more successfully progressing toward the SDG. For each country, students needed to describe how they determined these countries, including their performance rating for the SDG. In order to help illustrate this, population pyramids were embedded in the StoryMap as well as the country's stage of transition. Identifying a country's stage of demographic transition aided students in reasoning why they may be struggling or successful toward their chosen SDG.

For this unit's final project, students were expected to create two choropleth bivariate maps to show relationships between their chosen SDG and another SDG. These maps were the most challenging to create but held great value for the relationships they revealed. One student who chose to investigate SDG 12: Responsible Consumption and Production created a bivariate map with Indicator 12.3.1: Food Waste and Indicator 7.1.1: Access to Electricity from SDG 7: Affordable and Clean Energy. The reasoning this student used was that without electricity, it would be nearly impossible to keep food fresh and, therefore, produce a great deal of food waste. However, after creating the map, they saw that though this held for most countries, there were a few outliers in the data (Figure 8).

Finally, the unit project ended with students sharing what *sustainability* meant to them, how this definition was related to their investigated SDG, and how the SDG supports, is supported by, or otherwise interacts with other SDGs. Students compiled all their information and maps about their chosen SDG into a StoryMap. These StoryMaps were shared within the organization and their classroom groups, allowing students to look at their peers' creations and understandings. Students and student groups gave the class a ten-minute presentation on the maps they had created, the countries they identified, and their definition of sustainability. There was time added at the end of each presentation for questions from the teacher and other students.

Discussion and implications

Using ArcGIS software such as StoryMaps in a high school classroom can be an excellent way to engage students in learning about geography, environmental science, history, and other subjects. In terms of EfS, some of the benefits and challenges of using ArcGIS StoryMaps in a high school classroom are as follows.

Benefits

StoryMaps can be used to create interactive, multimedia-rich presentations that can engage students in learning and help them to retain information better. StoryMaps help students to visualize and understand complex spatial relationships, such as the impact of climate change on a particular region, or the historical events that shaped a city's development. StoryMaps can help to develop critical thinking, analytical, and communication skills as students design and create their own stories and present them to their classmates. Being able to visualize and understand such complex spatial relationships help students to develop their own understandings about the environment, the economy, and society as called

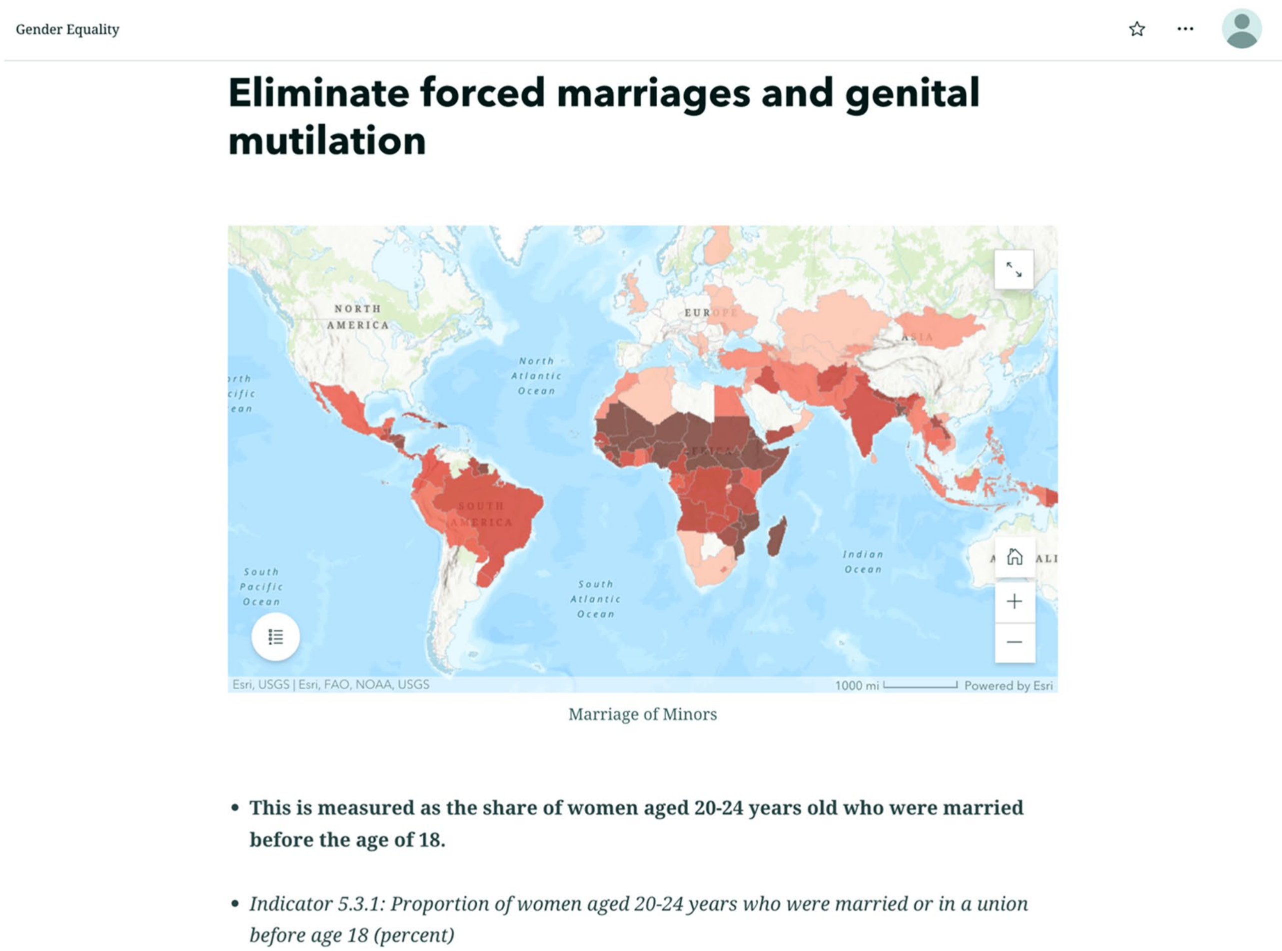

Figure 7. Student example of Indicator 5.5.2 map within a StoryMap.

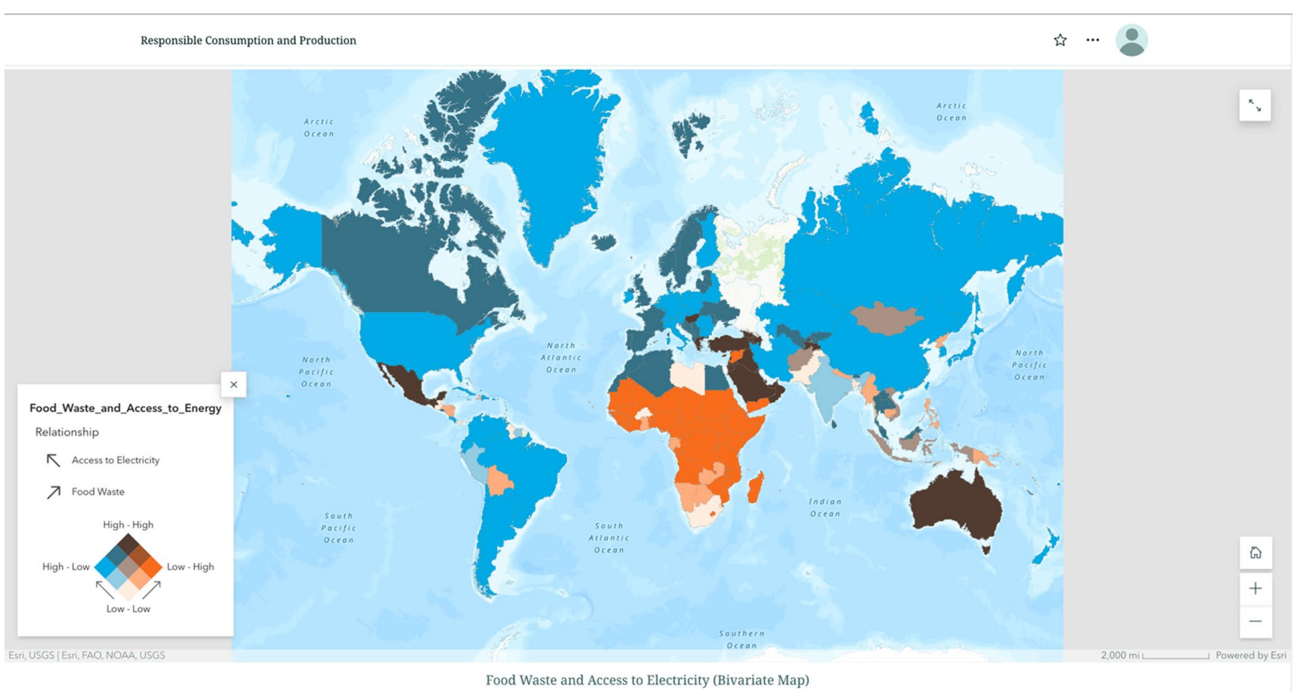

Figure 8. Student bivariate map embedded in a StoryMap – access to electricity (7.1) and food waste (12.3).

for by the US Partnership for Education for Sustainable Development (2009). Overall, an understanding of spatial relationships is integral to systems thinking and is important for analyzing interconnected issues across different disciplines (Meadows 1997). Such thinking helps students consider cross-disciplinary solutions (Hurd and Ormsby, 2020).

Using GIS in high school classrooms can also help to prepare students for college and careers in a wide range of fields. GIS technology is used in many different industries, including environmental science, urban planning, public health, and emergency management. By learning how to use GIS in high school, students can gain a better understanding of how GIS is used in real-world applications and develop skills that will be valuable in many different careers. Overall, GIS is an excellent tool for high school educators who want to provide students with a more dynamic and engaging learning experience with EfS.

Challenges

Students using ArcGIS Online may encounter a range of challenges. Firstly, there's the technical aspect; mastering GIS software can be daunting, particularly for students who may be less familiar with geospatial tools. Understanding the intricacies of GIS, with its numerous functions and tools, can also be complex. Interpreting spatial data and recognizing geographic patterns may take time and effort. Moreover, teachers face the challenge of effectively integrating GIS into the curriculum and aligning it with specific learning objectives and standards. Access to relevant and up-to-date geographic data can be another limitation, requiring guidance for students on data sources. Overcoming these challenges requires a holistic approach that includes proper training and support for both teachers and students, alignment of GIS activities with educational goals, ensuring access to technology, and the creation of engaging and meaningful assignments that promote critical thinking and problem-solving skills. Collaborative and peer learning can also help students tackle some of the technical and conceptual difficulties associated with GIS and ArcGIS Online.

StoryMaps can be time-consuming to create and require a certain level of technical proficiency to use effectively. Teachers often need to invest time to learn how to use the software or to find resources to help students learn the software. The platform can also be data-intensive, requiring access to large data sets and may require high-speed internet access to function properly. Teachers may find StoryMaps challenging to assess, as they are often creative, open-ended projects that do not have a clear right or wrong answer. However, it is this very ambiguity that makes them engaging for students as they navigate a plethora of possibilities.

To overcome these challenges, teachers can start by incorporating pre-built StoryMaps into their lessons to help students learn about a particular topic and gradually work up to having students create their own StoryMaps. Teachers can also provide resources, such as tutorials or online communities, to help students learn the software. Finally, teachers can use rubrics or other assessment tools to evaluate StoryMaps based on criteria such as accuracy, creativity, and clarity of communication. By incorporating this tool into their curriculum, teachers can help students develop critical thinking, analytical, and communication skills that will be valuable for their understanding of EfS and their place in the world.

Conclusion

Incorporating GIS into high school classrooms gives students a hands-on learning experience that enhances their understanding of complex geographical and environmental concepts. As demonstrated in the student case examples, GIS allows for analyzing geographic patterns and relationships, enabling students to explore spatial data sets and create their own maps and data visualizations. These activities make learning more engaging and interactive, as students can visually see how different factors and variables interact and affect their local surroundings or have impacts on a global scale. For instance, creating choropleth maps and building a StoryMap based on students' selected SDG, helped students understand complex socioenvironmental issues in a comprehensive manner. The platform's robust data analysis functions, user-friendly interface, and high-quality map production were crucial in facilitating these projects and providing students with a seamless experience.

Additionally, the unified integration of ArcGIS with various data sources provided students with a dynamic tool for their investigations. This approach reinforces the overlapping spheres of Education for Sustainability (EfS)—economic, environmental, and social—and empowers students with the tools and disposition necessary to support a sustainable future (Purvis, Mao, and Robinson 2019). GIS is uniquely suited to examine issues in these spheres as the platform allows students to use existing data to create and them visually share their insights. The importance EfS in terms of providing the tools necessary to act, and the disposition to support a sustainable future (Australian Education for Sustainability Alliance 2023) uniquely dovetail with the capabilities of GIS.

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Interested in ArcGIS online

ArcGIS Online and StoryMaps are freely available for educators and students. Teachers may request their free ArcGIS organizational accounts for student use at https://www.esri.com/en-us/industries/education/schools/schools-mapping-software-bundle.

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