



# SDGs Learning Using Interactive Web-Based Satellite Imagery at SMAN 15 Semarang

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**Abstract:** The problem in teaching Sustainable Development Goals (SDGs) at the high school level is the lack of utilization of technology and the lack of contextual and interactive learning resources. This study aims to develop and implement interactive web-based satellite imagery as a learning media to improve students' understanding of SDG issues, particularly those related to the environment. The interactive web application was developed using the Google Earth Engine platform and Landsat 8, Sentinel-1, Sentinel-2, and Sentinel-5 data. The research method used was a pre-experimental design with a pretest-posttest group. The research subjects were 10th-grade social studies students at SMAN 15 Semarang studying geography lessons on maps, remote sensing, and geographic information systems. Data were collected through observation and tests. A science-based learning approach guided classroom teaching and learning. The results showed that integrating satellite image-based learning media into an interactive web platform increased students' understanding of the SDGs and remote sensing technology by 11%. These results indicate that using remote sensing technology and an interactive web provides an innovative and contextual

learning alternative in SDG-based geography education in schools.

**Keywords:** SDGs, Satellite Imagery, Learning Media, Interactive Web

## Introduction

Sustainable development goals are a plan designed to ensure that the development process can continue by meeting the needs of the current generation without reducing future generations' ability to meet their needs ([Nasution et al., 2024](#)). The SDGs serve as guidelines for countries facing various global challenges such as poverty, social inequality, environmental degradation, and climate change. The integration of the SDGs into school learning is a consequence of the Merdeka Curriculum, which gives teachers the freedom to manage learning by linking subject matter to sustainable development issues in a contextual manner. In this case, SDGs can be integrated with remote sensing material in classroom learning. The connection between remote sensing and SDG issues lies in the availability of satellite imagery for observation data that can be used to address sustainable development problems. According to [Estoque \(2020\)](#), remote sensing can address 70% of sustainable development issues. Therefore, integrating SDG content into remote sensing materials is an appropriate strategy for embedding it in contextual learning. This also addresses the

problem of applying SDG material in the social sciences, which often focuses solely on conceptual understanding rather than on application in contextual and participatory learning ([Ekawati et al., 2025](#)).

The application of remote sensing technology, through satellite imagery, provides visual representations of spatial phenomena occurring in students' surrounding environments. This is highly beneficial in helping students understand the environmental, social, and economic impacts of these phenomena ([Adaktylou, 2020](#)). In addition, [Amici & Tesar \(2020\)](#) state that the use of satellite imagery provides learners with new perspectives on the magnitude of impacts from events such as natural disasters. The advantages of satellite imagery, particularly its ability to map large areas, enable students to easily identify disaster-prone locations and subsequently explore the spatial associations between these locations and other factors, such as accessibility, population, and others. Furthermore, in other contexts, such as land-use change, students can use spatiotemporal imagery to detect patterns of land conversion and relate them to socio-economic factors, including industrialization and urbanization. This process supports students in developing critical thinking skills and spatial problem-solving abilities.

The application of remote sensing materials in classroom geography lessons poses a significant challenge: the lessons remain abstract, making them difficult for students to understand ([Zahra & Fariz, 2024](#)). This can actually be overcome by using satellite imagery in the learning process. However, using satellite imagery requires specialized skills in data processing. Mastery of such skills is one of the key challenges for teachers, as most encounter difficulties operating and processing satellite imagery with specialized software such as ENVI ([Harudu et al., 2024](#)). Therefore, it is necessary to provide learning media that enable teachers and students to easily access and interpret satellite imagery without requiring direct data processing. This can be achieved through the Google Earth Engine (GEE) platform, which leverages cloud computing.

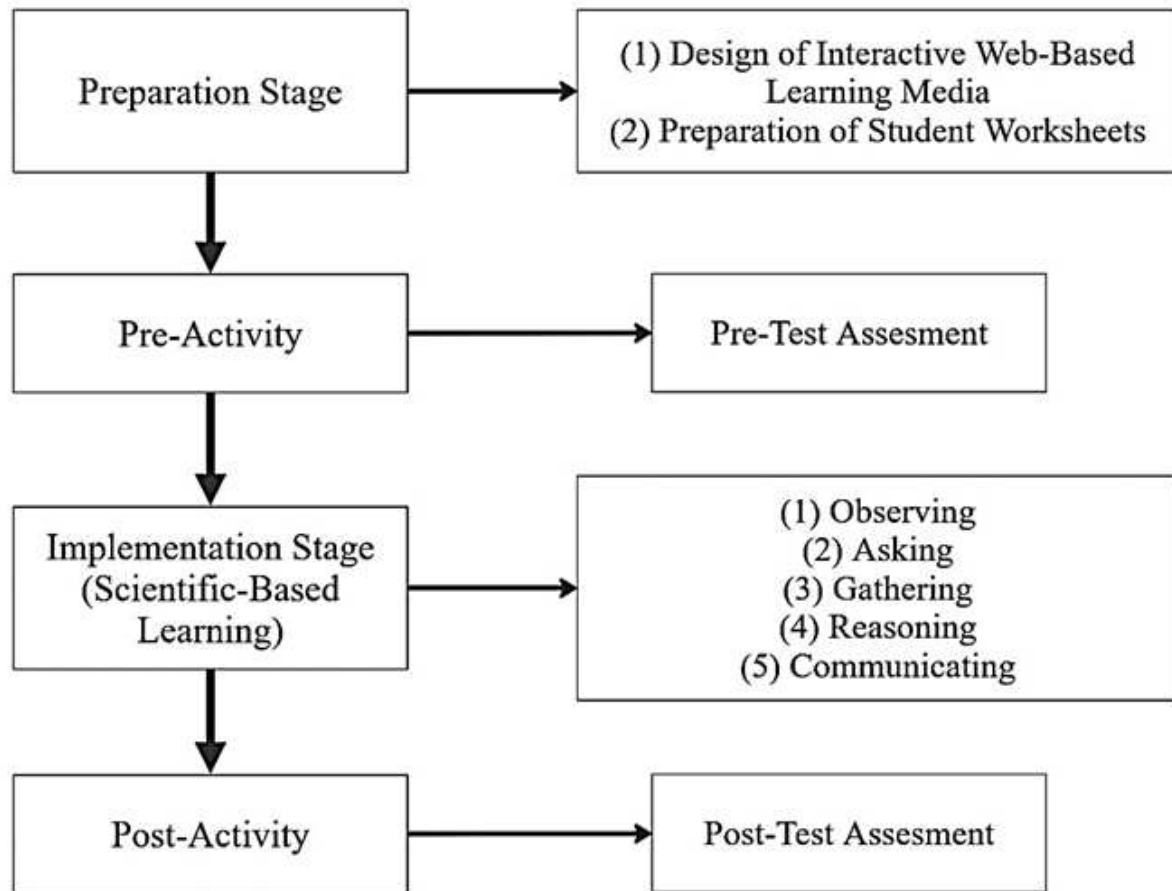
The application of GEE as a learning medium remains limited, as the platform is commonly used in geospatial research rather than in educational contexts. In fact, GEE has strong potential for application in education, particularly in teaching remote sensing. Several studies have explored the use of GEE in education, such as [Fahmi et al. \(2024\)](#), which integrated it into a teaching module on drought, and [Dema & Sivitkis \(2025\)](#), which applied GEE to teaching materials on wildfires. However, the satellite images in these studies were only single temporal images. In reality, remote sensing imagery is inherently multi-temporal, allowing the observation of dynamic changes on Earth's surface over time ([Zahra & Fariz, 2024](#)). The lack of exploratory and interactive features in these media is a research gap in this study. Therefore, this research introduces interactive web-based learning media developed through the Google Earth Engine platform. The media integrates SDG-related

content with satellite remote sensing data, enabling students to formulate solutions to sustainable development challenges using satellite-based information. This study is expected to serve as a reference for implementing technological innovations in teaching remote sensing in geography education, thereby supporting more contextual and meaningful learning.

## Methods

The research method used in this study is a quantitative, pre-experimental, one-group, pretest-posttest design. This research design was used to compare students' learning outcomes after receiving treatment during the learning process ([Sukarelawan et al., 2024](#)). The treatment used interactive web-based satellite image learning media in teaching and learning activities. Before treatment, students were directed to complete a pretest to assess their initial understanding. After the treatment, students completed a posttest to assess their final understanding. The differences between the pretest and posttest results completed by the students were then analyzed to determine whether students' knowledge increased after using the learning media.

This research was conducted at SMA Negeri 15 Semarang, located at Jl. Kedungmundu No.34, Sambiroto, Kec. Tembalang, Semarang City. The population used in this study was all 10th-grade students at SMAN 15 Semarang. From this population, 10th-grade students in class X-3 were selected as the research sample using purposive sampling based on students considered active by their teachers. The stages carried out in this study included four stages, namely (1) the preparation stage, which included the design of learning media and the preparation of student worksheets, (2) the pre-activity stage, which conducting a pretest assessment, (3) the implementation stage of learning media using a science-based learning approach which has five stages: observing, questioning, gathering information, reasoning/associating, and communicating ([Isroani & Nisa, 2022](#)), and (4) the post-activity stage, which conducting a posttest assessment. The flow of the research stages is shown in **Figure 1**.



**Figure 1.** Research Stages flow

The data collection techniques used in this study included test instruments, student response questionnaires, and documentation. The test instrument consisted of 10 multiple-choice questions covering basic remote sensing concepts, satellite imagery interpretation, and understanding of the SDGs. This instrument measured students' learning outcomes through pretest and posttest assessments. Meanwhile, the student response questionnaire used a Likert scale from 1 to 5 to collect information on students' perceptions of the learning media. The response indicators measured included accessibility, clarity of use, learning content, feature usability, and students' interest in learning. In this questionnaire, a score of 1 indicates a feeble response, two indicates poor, 3 indicates neutral, 4 indicates good, and 5 indicates excellent. The data analysis techniques applied were descriptive statistical analysis of students' learning outcomes and descriptive percentage analysis of students' responses to the learning media. Descriptive statistics were used to compare students' pretest and posttest learning outcomes by calculating the percentage increase in average scores. Meanwhile, descriptive percentage analysis was used to assess the feasibility of the learning media, as measured through students' responses.

## Results and Discussion

### A. Interactive Web-Based Satellite Imagery Learning Media for SDGs

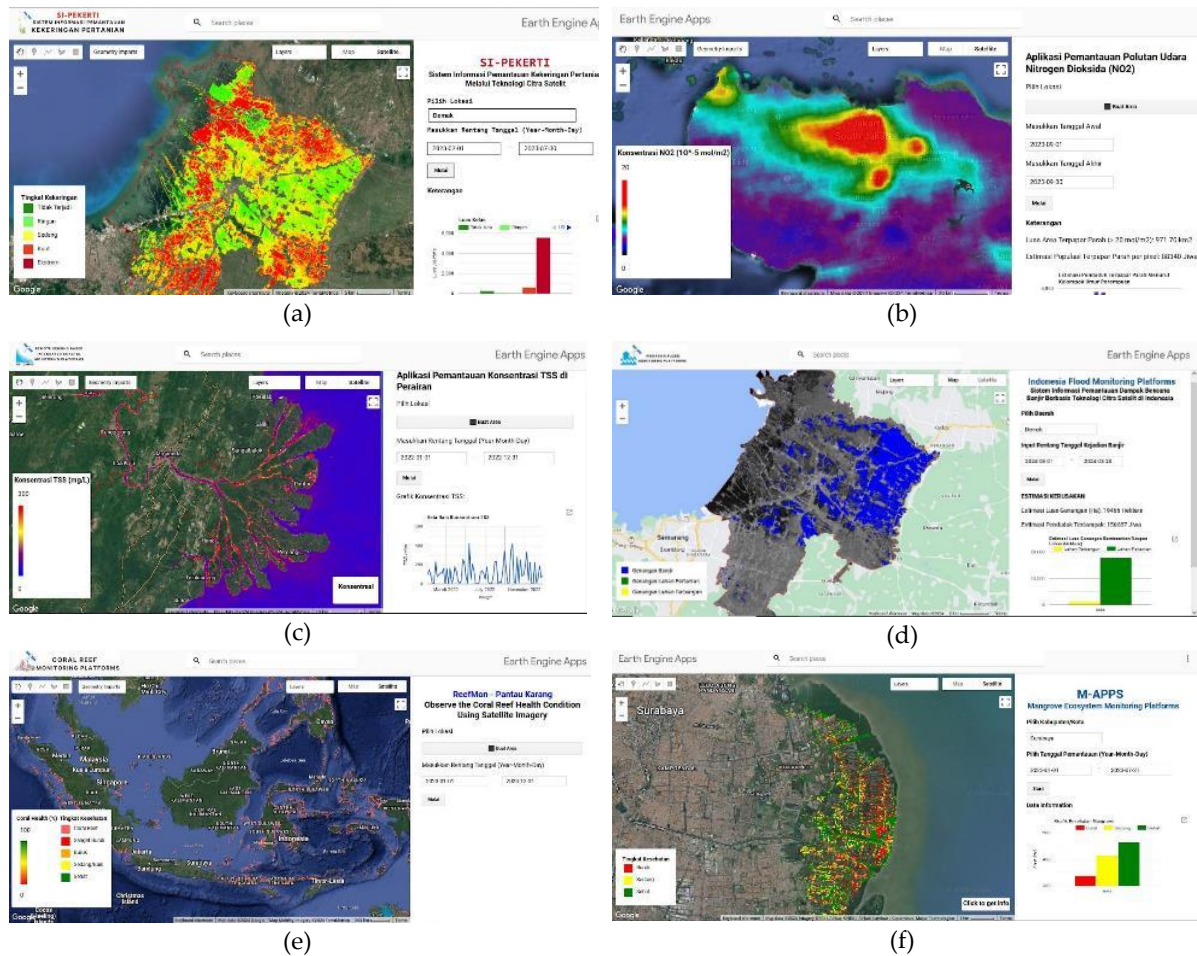
The design of SDGs learning media based on satellite imagery is entirely carried out in Google Earth Engine (GEE), a cloud-based platform for processing satellite imagery. With this cloud computing technology, GEE can process large amounts of satellite data and store it on cloud servers, so users only need to run the code in a code editor. In addition, GEE offers advantages for developing publicly accessible web applications. This advantage serves as the basis for developing SDG learning media using the Google Earth Engine platform. There are six SDG learning media applications based on satellite imagery, created using GEE, that represent the six SDG goals and themes, as shown in **Table 1**.

**Table 1.** Design of Satellite Imagery-Based Learning Media for SDGs

Goals and Themes of the SDGs	Satellite Imagery	Development Methods and Sources
SDGs 2 – Agricultural Drought	Landsat-8	Normalized Difference Drought Index (NDDI)
SDGs 3 – Air Pollution	Sentinel-5P	Nitrogen Dioxide (NO <sub>2</sub> )
SDGs 6 – Water Quality	Sentinel 2	TSS Algorithm (Liu et al., 2017)
SDGs 11 – Flood Disaster	Sentinel-1	Backscattering (UN-SPIDER)
SDGs 14 – Coral Reef	Sentinel-2	Coral Health Algorithm (Zaenuri et al., 2016)
SDGs 14 – Mangrove	Sentinel-2	Mangrove Health Index (Dharmawan, 2021)

The learning media design incorporates interactive features that allow students to explore and experiment with observing the studied phenomena. The interactive features include:

1. Select Region, allowing users to select the study area based on districts/municipalities. This feature is available in the learning media for SDGs 2, 11, and 14.
2. Select AOI, enabling users to define the study area as a polygon or rectangle. This feature is available in the learning media for SDGs 3, 6, and 14.
3. Select Date, allowing users to choose the acquisition or monitoring time independently.
4. Information Panel, which displays details related to satellite imagery data.
5. A graph that presents time-series changes in the data.
6. Legend, providing information on color symbols to help students identify and interpret objects.
7. Time-lapse Video, displaying animated changes in data over a specific time range. This feature is only available in the SDGs 3 learning media.



**Figure 2.** Design of Interactive Web-Based Satellite Imagery: (a) Agricultural Drought; (b) Air Pollution; (c) Water Quality; (d) Flood Disaster; (e) Coral Health; (f) Mangrove Health

The steps for using this learning media are as follows:

1. Select the study area by entering the name of the district/municipality to be examined or by clicking “Create Area” to define the study area as a polygon.
2. Input the observation time for the monitoring period.
3. Click the “Start” button to initiate processing.
4. The output is a satellite image displaying field conditions.
5. In the Information Panel, details related to satellite data will appear, such as the size of the severely affected area and the estimated impacted population.
6. Click on a specific location to display a time-series graph of data changes. The button in the upper-right corner of the graph can be used to enlarge the graph and download the data.
7. Users may also select the data displayed on the main screen via the “Layers” feature in the upper-right corner.

This satellite imagery-based SDGs learning media is integrated and disseminated through the Google Sites platform, enabling all components to be accessed through a single, user-friendly, publicly available web portal. Through this site, students can find information on SDG materials, including SDG goals, remote sensing methods, application usage guidelines, and group assignment instructions. In addition, this Google Sites website also includes assignments for creating digital maps using Canva. The purpose of these assignments is for students to present their satellite image findings through digital maps. By using Google Sites, the SDGs learning media developed not only emphasize satellite image visualization but also serve as interactive learning resources that support SDGs learning through data, technology, and exploration.

### **B. Implementation of SDGs Learning Media in Learning Activities**

The implementation of interactive web-based SDGs learning media in the learning process was carried out during three meetings on October 16, 23, and 30, 2024. The first meeting began with a presentation on the definition of remote sensing, the components and mechanisms of satellite imagery, and examples of its application. This first session aimed to provide students with an initial introduction to remote sensing. The second session focused on satellite image interpretation, guiding students to understand the visual information in satellite images, including color, texture, patterns, and object shapes. In this session, students were divided into five groups to complete an assignment involving the collection of information from satellite data, using interactive learning media developed for the session. The third session was the final session, in which students presented their findings in groups in front of the class. The teaching module and links to the learning media can be accessed at the following page: [bit.ly/MediaRS-SDGS](https://bit.ly/MediaRS-SDGS).

Implementing SDGs learning media in the classroom can be applied through teacher-centered and student-centered approaches. The teacher-centered approach emphasizes the teacher's role as a facilitator in delivering classroom material. In this context, teachers may use learning media to present SDG-related content grounded in data, such as the application of remote sensing technology to address sustainable development issues in the local environment. This approach is particularly suitable for schools or classes with limited learning facilities, such as computers, laptops, and internet access. This limitation arises because the SDGs learning media were developed using cloud computing technology, which requires adequate supporting infrastructure.

Meanwhile, the student-centered approach can be implemented through strategies, methods, or learning models that actively engage the students. In this study, the learning media were applied using a scientific approach within the learning process. The scientific approach emphasizes applying scientific principles through activities such as observation,

questioning, experimentation, data or information processing, and presentation of results ([Sunarko & Firdaus, 2021](#)). In geography education, the scientific approach is essential as it fosters students' creative, critical, and analytical thinking skills ([Rahayu et al., 2021](#)). In this study, implementing the science-based approach in the classroom followed five systematic stages, as outlined below.

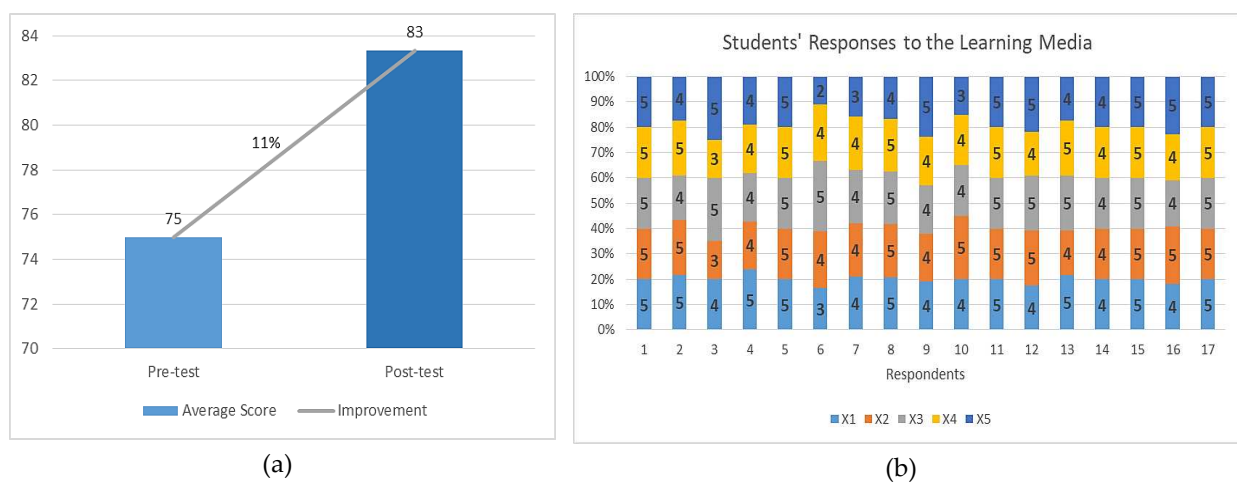
1. **Observing.** At this stage, students observe, read, and comprehend the teacher's explanation regarding remote sensing, satellite imagery mechanisms, applications in sustainable development, and image interpretation presented through slides. The teacher's presentation is expected to foster meaningful learning by providing real-life examples of satellite imagery applications to fulfill students' curiosity ([Isroani & Nisa, 2022](#)).
2. **Questioning.** At this stage, the teacher provides opportunities for students to ask questions about remote sensing material they do not fully understand. To make the class more interactive, the teacher may also provide stimulus questions related to remote sensing as prompts for students to respond to.
3. **Collecting Information.** At this stage, the teacher may divide students into groups and assign tasks to develop solutions for sustainable development issues using satellite data. The teacher may also introduce the learning media as a reference to help students find relevant information. Additionally, students are encouraged to access information from various sources, including primary sources such as interviews and observations, as well as secondary sources such as scientific journals, news articles, websites, and others. However, teachers can still facilitate learning activities, especially when students face obstacles when gathering information.
4. **Reasoning/Processing Information.** After the information collection stage, students process the information into written reports or papers. At this stage, they are expected to connect facts, data, and information to the issues under study. Students can also interpret satellite images and graphs, which can serve as supporting arguments in formulating solutions to the observed sustainable development issues. In this process, the teacher guides students who face challenges in analyzing and integrating information into a structured report or paper.
5. **Communicating.** Students can present their reports or findings to the class at this stage. This activity is a discussion in which students exchange opinions, ideas, and solutions. At this stage, the teacher acts as a facilitator or discussion leader while also harmonizing the information presented by the students. Through such scientific discussions, students' communication skills and critical and analytical thinking abilities are actively developed and enhanced.



**Figure 3.** Stages of Implementing Learning Media Based on the Scientific Learning Approach: (a) Observing; (b) Questioning; (c) Collecting Information; (d) Reasoning; (e) Communicating.

The results of implementing SDGs-based interactive satellite imagery learning media to teach remote sensing material to 10th-grade students at SMAN 15 Semarang showed increased student learning outcomes. The initial assessment of students' knowledge of SDGs and remote sensing showed an average score of 75. After implementing learning media, the students' results improved with an average score of 83. These average scores showed an

11% increase in student learning outcomes after implementing learning media. This finding aligns with [Fahmi et al. \(2024\)](#), who reported that using Google Earth Engine as a learning platform enhanced students' spatial knowledge and overall learning outcomes in remote sensing. Meanwhile, the results of student responses to the application of learning media showed a positive response rate of 89%, indicating that learning media can be very feasible to apply in the learning process. The feasibility was assessed based on several indicators: the ease of access to the learning media (X1), the clarity of the usage instructions (X2), the ease of understanding the material (X3), the user-friendliness of application features (X4), and the motivation and interest of students in the learning process (X5).



**Figure 4.** (a) Improvement of Students' Learning Outcomes; (b) Students' Responses to the Learning Media

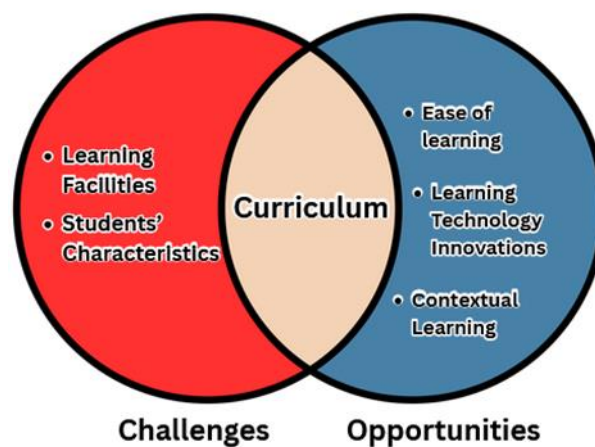
The utilization of interactive satellite imagery enables students to gain a spatial perspective that deepens their understanding of the location, patterns, and spatial relationships between phenomena occurring on Earth. This understanding not only helps students identify where an event occurs but also explains why and how these phenomena interact with surrounding factors, allowing them to build a deeper understanding of the dynamics occurring on the planet. When students work with satellite imagery, they are introduced to spatial thinking, which requires interpreting it, recognizing patterns, and connecting information spatially. Additionally, satellite imagery supports the development of geographic literacy by encouraging students to critically interpret spatial data. As students observe patterns of land cover change, such as urban expansion or deforestation, they learn that space is dynamic and constantly changing. This observation process enhances students' analytical skills in understanding the relationship between human activities and spatial change while also raising their awareness of environmental and SDGs issues.

### C. Opportunities and Challenges of Interactive Web-Based Satellite Imagery Learning Media

The application of interactive satellite image-based learning media using SDG content in remote sensing materials has advantages for overcoming challenges in mastering satellite image processing skills among teachers and students. With the design of learning media that uses interactive features, teachers and students can operate it without processing satellite image data. This advantage makes learning more effective and efficient by saving time and energy. In addition, the media is an innovative technological advancement in remote sensing education. This learning media can be used as an alternative to, or in addition to, tools such as Google Maps, Google Earth, and StoryMaps, which are generally limited to interpreting aerial photographs. In contrast, the interactive learning media not only focus on key elements of image interpretation but also emphasize the practical application of remote sensing by utilizing a wider range of satellite data, including multispectral, thermal, and radar imagery. Meanwhile, this learning media has the potential to address the main challenge of remote sensing material, which is abstract for students, by making the subject more accessible through contextual and data-driven learning. This approach provides a new learning environment for students by using satellite imagery to analyze and address sustainable development issues in the surrounding environment. Through this activity, students are encouraged to understand the direct connection between remote sensing and sustainability issues outlined in the Sustainable Development Goals (SDGs). As a result, the learning process becomes more meaningful, with students actively involved in analyzing satellite data, drawing scientific conclusions, and understanding the role of technology in addressing sustainable development challenges. Therefore, implementing this learning media indirectly fosters spatial literacy, critical thinking skills, and environmental awareness among students.

The main opportunity for implementing this learning media lies in its integration with the national curriculum, namely the Merdeka Curriculum. This curriculum emphasizes mastering and utilizing learning technologies in the classroom ([Humairoh & Ubaidillah, 2025](#)). For teachers, the Merdeka Curriculum provides flexibility to select learning media and apply various teaching styles, models, and approaches that align with students' characteristics. This opens opportunities for the media to be applied in remote sensing lessons and related topics such as disaster studies, environmental management, regional development, and other similar fields. Furthermore, the media can be integrated into other subjects, such as climate change topics within science education. On the other hand, this satellite image-based interactive learning media is highly relevant to the Merdeka Curriculum, which emphasizes project-based learning in which students independently explore how to solve real problems in their surroundings. Until now, remote sensing

material has often been abstract, making it difficult for students to understand because it is taught solely through theory and concepts (Fariz & Nurhafizah, 2021). Using satellite imagery, students can examine environmental issues related to the Sustainable Development Goals, such as climate change, deforestation, and urbanization. This process helps students tangibly understand remote sensing concepts and enhances their literacy, collaboration, and scientific communication skills. Thus, integrating this learning media into the Merdeka Curriculum creates opportunities for schools to adopt more modern, relevant learning methods in line with the times. By utilizing the latest technology, such as cloud computing, remote sensing material can be taught effectively without relying on teachers' or students' skills in processing satellite image data.



**Figure 5.** Opportunities and Challenges in Implementing Interactive Satellite Image-Based Learning Media in Indonesia

The challenges in applying satellite imagery are also found in the current implementation of the Merdeka Curriculum. First, remote sensing material is combined with map and Geographic Information System (GIS) material in chapter 2 of grade X, making it difficult for teachers to discuss remote sensing in depth due to limited learning time, which must be shared with discussions on maps and GIS subjects. As a result, remote sensing is taught only at a conceptual level, without opportunities for practical application. This condition also leads to a lack of student understanding of the phenomena or issues being studied. For example, solving disaster or environmental problems using satellite data requires students to understand the issues. This aligns with the requirements for applying Google Earth Engine to drought-related material, as outlined by Fahmi et al. (2024), which require students to understand geosphere materials and disaster concepts, which will only be studied in grade XI. This problem can be addressed through the teacher's role in providing explanations of the phenomena under study. However, this approach requires a considerable amount of time in the learning process. This consequence arises from removing

the subject matter on the application of maps, remote sensing, and GIS, which was previously taught in Grade XII under the 2013 Curriculum. A possible solution would be to reintroduce remote sensing into the curriculum. This is important because remote sensing encompasses conceptual and theoretical aspects as well as skills-based aspects, such as analyzing and interpreting satellite imagery.

Second, the implementation of learning media must take into account students' characteristics. It is important to note that each student has different characteristics, whether active or passive, and varying levels of cognitive ability ([Almadani & Setiabudi, 2022](#)). Therefore, teachers should be able to apply strategies and approaches that can accommodate the diverse characteristics of their students. Third, there are limitations in school facilities, including the availability of computers and laptops, and adequate internet access. Without sufficient resources, it is difficult for teachers to apply this learning media in the classroom. The solution lies in the government's active role in providing and equalizing educational facilities, such as ICT infrastructure in schools, as well as improving internet connectivity. This ensures that all schools have equal opportunities to implement satellite imagery-based learning.

Training on using learning media for teachers in the Geography teachers' forum is essential before the media can be disseminated and applied in learning activities. In this activity, teachers can be given practical workshops to master using interactive web-based satellite imagery learning platforms through Google Earth Engine, enabling them to connect satellite image analysis with the issues under study. Through the forum, teachers can share experiences, design teaching materials, and develop collaborative projects according to the learning context. In this way, implementing learning media enhances students' knowledge of remote sensing and the issues under study and strengthens teachers' digital skills in guiding students and directly analyzing spatial data.

## Conclusion

The development of interactive satellite-image-based SDGs learning media using the Google Earth Engine (GEE) platform introduces a practical, interactive, and contextually relevant technological innovation in geography education. Interactive features such as study area selection, time range adjustment, time series graphs, and time-lapse animations provide students with a new learning experience. Implementing this media in remote sensing lessons at SMAN 15 Semarang improved students' learning outcomes by 11% and received a positive response of 89%, indicating that the media can be applied in the learning process. Integrating this learning media with the Merdeka Curriculum offers significant opportunities to realize project-based learning, which aligns with the characteristics of 21st-

century education. This media is relevant to remote sensing materials and can be applied to other themes such as disaster studies, environmental issues, regional development, and climate change.

This research has strong potential for implementation in other schools because the use of interactive satellite imagery is flexible, easy to use, and can be integrated with other subjects. To make it more accessible for teachers, learning media can be integrated into national digital learning platforms, such as LMS, allowing teachers across Indonesia to access materials, modules, and practice examples. This integration aims to support the equitable distribution of geospatial learning quality and ensure the long-term sustainability of learning media implementation in the classroom.

Nevertheless, the implementation of this media still faces several challenges under the Merdeka Curriculum, including the integration of remote sensing materials with map and Geographic Information System (GIS) content, which limits practical application opportunities, as well as students' limited understanding of the studied phenomena or issues, and the lack of adequate learning facilities in classrooms. This study also has limitations, as the learning media have not yet been fully assessed for suitability by the experts and have not been thoroughly tested in learning activities. Therefore, further research should address these limitations.

## References

- Adaktylou, N. (2020). Remote sensing as a tool for phenomenon-based teaching and learning at the elementary school level: A case study for the urban heat island effect. *International Journal of Educational Methodology*, 6(3), 517–531. <https://doi.org/10.12973/ijem.6.3.517>
- Almadani, R., & Setiabudi, D. I. (2022). Pengembangan kognitif pada siswa sekolah dasar dengan literatur harian. *Jurnal Riset Sosial Humaniora dan Pendidikan*, 1(1), 34–42. <https://doi.org/10.56444/soshumdik.v1i1.72>
- Amici, S., & Tesar, M. (2020). Building skills for the future: Teaching high school students to utilize remote sensing of wildfires. *Remote Sensing*, 12(21), 3635. <https://doi.org/10.3390/rs12213635>
- Dema, T., & Sivitskis, A. J. (2025). Using Google Earth Engine to teach burn severity mapping of wildfires across Bhutan. *The Geography Teacher*, 22(2), 74–82. <https://doi.org/10.1080/19338341.2025.2487456>
- Dharmawan, I. W. E. (2021). Mangrove health index distribution on the restored post-tsunami mangrove area in Biak Island, Indonesia. *IOP Conference Series: Earth and Environmental Science*, 860(1), 012007. <https://doi.org/10.1088/1755-1315/860/1/012007>

- Ekawati, D., Adnyani, N. L. S., Widyantari, N. P. S. W., & Susiani, K. (2025). Mengintegrasikan perspektif SDGs (tujuan pembangunan berkelanjutan) dalam pembelajaran ilmu pengetahuan sosial untuk membangun kepedulian dan rasa tanggung jawab sosial. *JPGI (Jurnal Penelitian Guru Indonesia)*, 10(1), 56–61. <https://doi.org/10.29210/025727jpgi0005>
- Estoque, R. C. (2020). A review of the sustainability concept and the state of SDG monitoring using remote sensing. *Remote Sensing*, 12(11), 1770. <https://doi.org/10.3390/rs12111770>
- Fahmi, M. R., Purwanto, P., & Bachri, S. (2024). Integrasi Google Earth Engine ke dalam modul pembelajaran digital: Meningkatkan pemahaman fenomena kekeringan pada siswa geografi. *Geomedia: Majalah Ilmiah dan Informasi Kegeografian*, 22(2), 213–228. <https://doi.org/10.21831/gm.v22i2.78108>
- Fariz, T. R. (2021). Penggunaan animasi timelapse citra satelit sebagai media pembelajaran dampak perubahan iklim. *Proceeding Seminar Nasional IPA*, 416–422.
- Harudu, L., Irsan, L. M., Surdin, S., Kasmianti, S., Nursalam, L. O., & Hasanah, N. (2024). Pendidikan dan pelatihan aplikasi penginderaan jauh untuk meningkatkan kompetensi guru geografi. *Keyboard: Jurnal Pengabdian Masyarakat*, 1(2), 59–68. <https://doi.org/10.69688/keyboard.v1i2.146>
- Humairoh, S. W., & Ubaidillah, M. (2025). Implementasi pendekatan teknologi dalam pengembangan Kurikulum Merdeka pada pembelajaran bahasa Arab di MTs Matsaratul Huda Panempan Pamekasan. *AL-MUADDIB: Jurnal Kajian Ilmu Kependidikan*, 7(1), 186–193.
- Isroani, F. (2022). Implementasi pendekatan saintifik untuk meningkatkan hard skills dan soft skill siswa pada mata pelajaran PAI sekolah. *Journal of Education and Management Studies*, 5(3), 1–8.
- Liu, H., Li, Q., Shi, T., Hu, S., Wu, G., & Zhou, Q. (2017). Application of Sentinel-2 MSI images to retrieve suspended particulate matter concentrations in Poyang Lake. *Remote Sensing*, 9(7), 761. <https://doi.org/10.3390/rs9070761>
- Nasution, A. M., Ulfa, N., & Harahap, N. (2024). Strategi perencanaan pembangunan berkelanjutan. *Trending: Jurnal Manajemen dan Ekonomi*, 2(1), 208–216. <https://doi.org/10.30640/trending.v2i1.1943>
- Rahayu, P. S., Handoyo, B., & Purwito, H. (2021). Penerapan pendekatan saintifik dilengkapi LKS pada mata pelajaran Geografi untuk meningkatkan kemampuan berpikir analitis siswa kelas XI IPS 2 SMAN 8 Malang. *Jurnal Integrasi dan Harmoni Inovatif Ilmu-Ilmu Sosial*, 1(3), 336–349. <https://doi.org/10.17977/um063v1i3p336-349>

- 
- Sukarelawan, M. I., Indratno, T. K., & Ayu, S. M. (2024). *N-Gain vs Stacking*. Suryacahaya.
- Sunarko, A., & Firdaus, A. M. (2021). Pendekatan saintifik dalam pengembangan metode dan strategi pembelajaran agama Islam di Indonesia. *Citizen: Jurnal Ilmiah Multidisiplin Indonesia*, 1(2), 68–74. <https://doi.org/10.53866/jimi.v1i2.10>
- Zaenuri, A., Saputra, A. N., Kudiastuti, D. A., Fajria, I., Wijayanti, L. A., & Aryaguna, P. A. (2016). The relationship between the health of coral reefs and the damage of Jelateng Sub Watersheds in the northern coast of Sekotong, West Nusa Tenggara. *IOP Conference Series: Earth and Environmental Science*, 47, 012019. <https://doi.org/10.1088/1755-1315/47/1/012019>
- Zahra, D. F., & Fariz, T. R. (2024). Pembuatan video timelapse citra satelit berbasis Google Earth sebagai media pembelajaran dampak perubahan iklim. *Proceeding Seminar Nasional IPA*, 791–797.