Science, Technology, Engineering, and Mathematics —Teaching Space Weather Studies

Ronald H. Freeman, PhD
Chair, Space Operations & Support Technical Committee, AIAA

1. Introduction

Direct learning approach commonly used by Physics teachers does not really improve student ability to develop self-understanding as well as environment awareness [1]. In direct learning, especially used to teach Physics at senior High School, teachers give an explanation about the material, followed by examples of exercises, and end with students working on exercises. However, other learning strategies may hold an important role to improve conceptual understanding. Research-based active-learning instruction in physics involves students in their own learning more deeply and more intensely compared to that with traditional instruction [2]. The methods are very diverse sharing three common features: (1) they are explicitly based on research in the learning and teaching of physics; (2) they incorporate classroom and/or laboratory activities that require all students to express their thinking through speaking, writing, or other actions that go beyond listening and the copying of notes, or execution of prescribed procedures; and (3) they have been tested repeatedly in actual classroom settings and have yielded objective evidence of improved student learning. Simple observational experiments using no special educational technology includes the use only of paper and pencil, yet still engage students in learning activities that are demonstrably more effective than traditional lectures and homework.

A large body of peer-reviewed research indicates that typical learning gains for the majority of students on qualitative, conceptual physics questions, when engaged in “traditional” instructional activities, are around 10–15 percentage points on standard diagnostic exams [3]. This represents the pre-to-post-instruction gain, and corresponds to correcting 20% of incorrect pretest responses). By contrast, research-based active-learning materials and methods produce gains up to and often more than double that amount on similar questions. For example, in a recent study [4], a sample of more than 3000 students from ten universities showed gains from active-learning instructional materials to be more than four times those obtained through standard instruction. The active-learning methods also generally produce gains on traditional, quantitative physics problems that are equivalent or superior to gains observed with traditional instruction.1

2. Purpose

The aim of this paper is to explore other teaching modalities that would be more effective for student understanding and match a more diversified learning style.

3. Case Demonstration

Learning style differences have been attributed to student modality strengths (i.e. sensory channels that receive and give messages)---the visual, auditory, and kinesthetic [5]. Last year’s presentation “STEM ---Teaching Space Weather Studies” matched to a student’s auditory learning style is adapted for this year’s presentation “STEAM---Teaching Space Weather Studies” which is matched to a visual learning style. Whereas STEM adjoins science, technology, engineering and mathematics and applies academic concepts to hands-on, real-world activities, STEAM uses the same integrated approach but with a nod to arts education that captures visual learning. Last year’s auditory presentation was secondarily enhanced by visuals and charts; visuals (i.e. Powerpoint slides) were ordered correctly with respective narrations. In reverse, this case demonstration asks students to match visuals randomly ordered with their corresponding narrations. The primary modality is visual with figures and charts but secondarily enhanced with narrative per auditory modality. Student matching is facilitated with slides having relevant clues embedded that correspond to textual narrations. Reading textual narrations and critically evaluating the observed slides afford students the opportunity to learn subject matter through concrete experience (i.e. matching slides selected to corresponding narrations) and abstraction. As noted in Guild and Garger (1985), “While every person is able to use both sequential and random ordering, we each have a tendency to prefer and to operate most frequently and most successfully with one kind of ordering” (p.38).

Successful completion of this study module introduces students to the next module that explores space weather beyond Earth's ionosphere and magnetosphere onward to the Moon's exosphere where the upcoming Artemis mission will find formidable with unfiltered risks.

References

[1] Kade, A., Degeng, I., & Ali, M. (2019). Effect of jigsaw strategy and learning style to conceptual understanding on senior high school students. *International Journal of Emerging Technologies in Learning (iJET)*, *14*(19).
[2] Meltzer, D. E., & Thornton, R. K. (2012). Resource letter ALIP–1: active-learning instruction in physics. *American journal of physics*, *80*(6), 478-496.
[3] Hake, R. (1998)..Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses," *Am. J. Phys. 66*, 64–74.
[4] Thornton, R., Kuhl, D. Cummings, K., & Marx, J. (2009). Comparing the force and motion conceptual evaluation and the force concept inventory. *Phys. Rev. ST Phys. Educ. Res. 5*, 010105]
[5] Guild, P. & Garger, S. (1985). *Marching to Different Drummers*. Alexandria, VA. Association for Supervision and Curriculum Development

Case Demonstration: STEAM Activity for K-12 Students

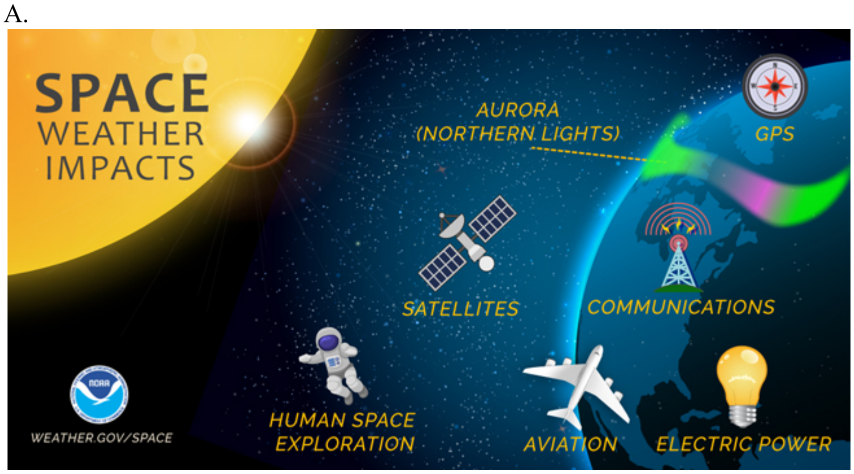
Chesapeake Section of American Association of Physics Teachers Conference
(Co-hosted and co-sponsored by the Virginia Tech Department of Physics and the University of Virginia Department of Physics).

Saturday, October 22, 2022
Falls Church, VA

The sun is the main source of space weather.

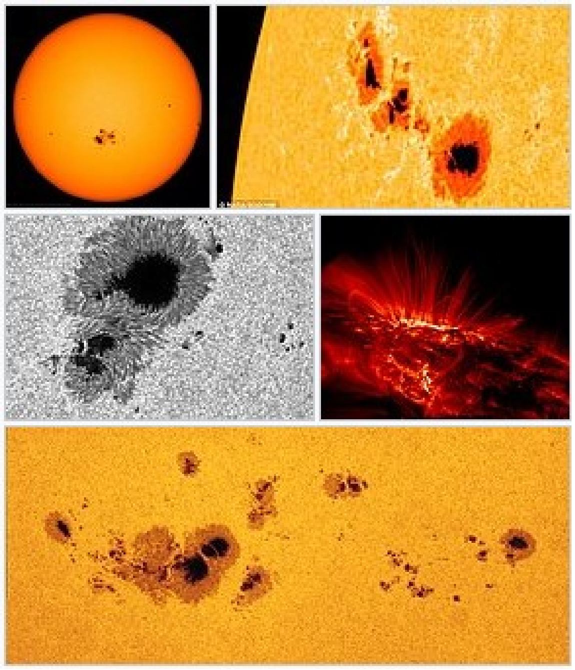
1. Naturally occurring space radiation is always with us. It occurs when atoms, ions, or subatomic particles are accelerated to high velocity by processes such as solar particle events from the Sun. Disrupted propagation of radio signals emitted by satellites, disruptions in telecommunications, GPS position, aviation, and sometimes Earth's ground electric power. Analyses of historical blackout events in the United States indicate that even short blackouts, which occur several times during a year in the United States, sum up to an annual economic loss between $104B and $164 B.

A.



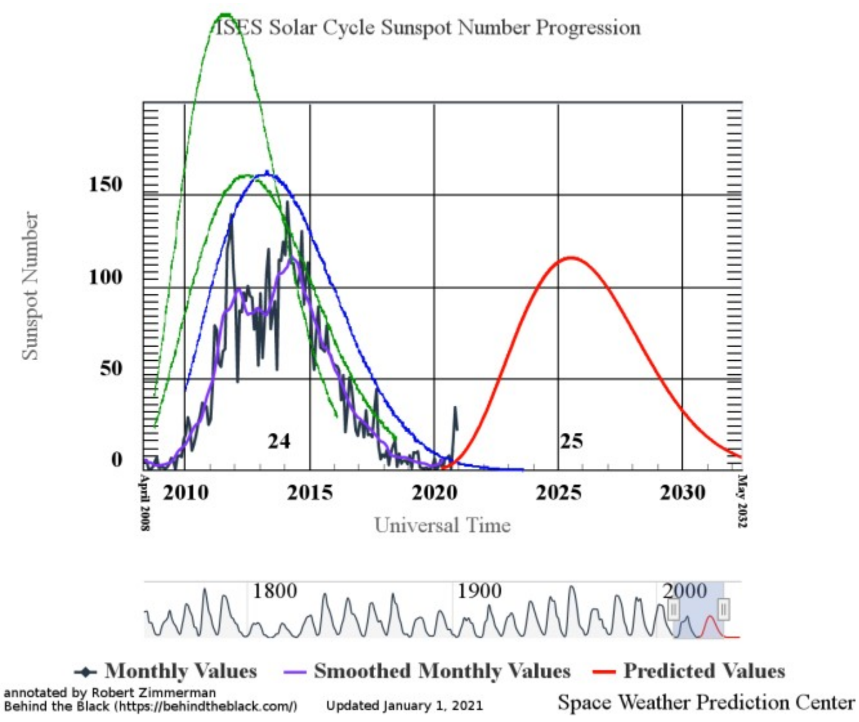
2. **Sunspots** are dark regions on the surface of the sun resulting from the interaction of the sun's surface plasma with its magnetic field.

B.



3. The total number of sunspots has long been known to vary with an approximately 11-year repetition known as the solar cycle. The peak of sunspot activity is known as solar maximum and the lull is known as solar minimum.

C.

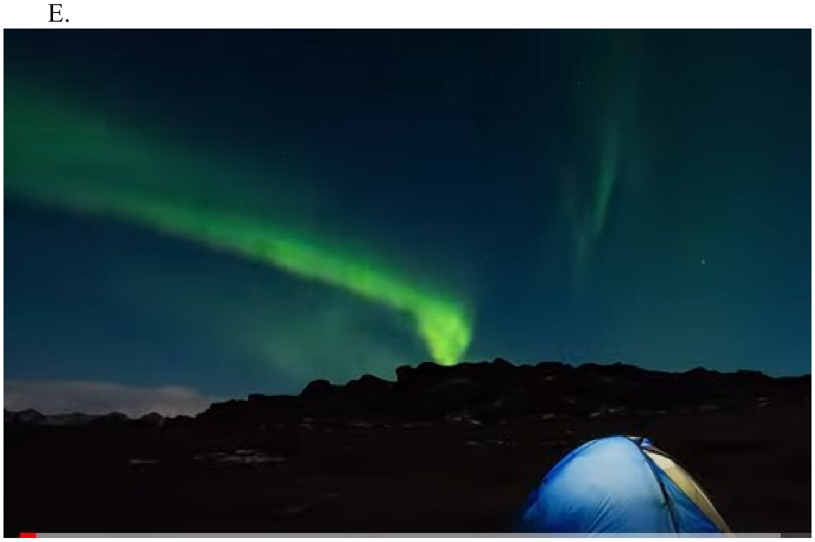


4. Electrons, protons, and other particles are blasted into space with kinetic energy between 0.5 and 10 keV. as a result of powerful activities within the sun; they appear as a **solar wind**, propelled in all directions throughout space.

D.

5. On Earth their energy may be absorbed in the atmosphere near the North , South Poles and show as "**auroras**" (e.g., Northern Lights)

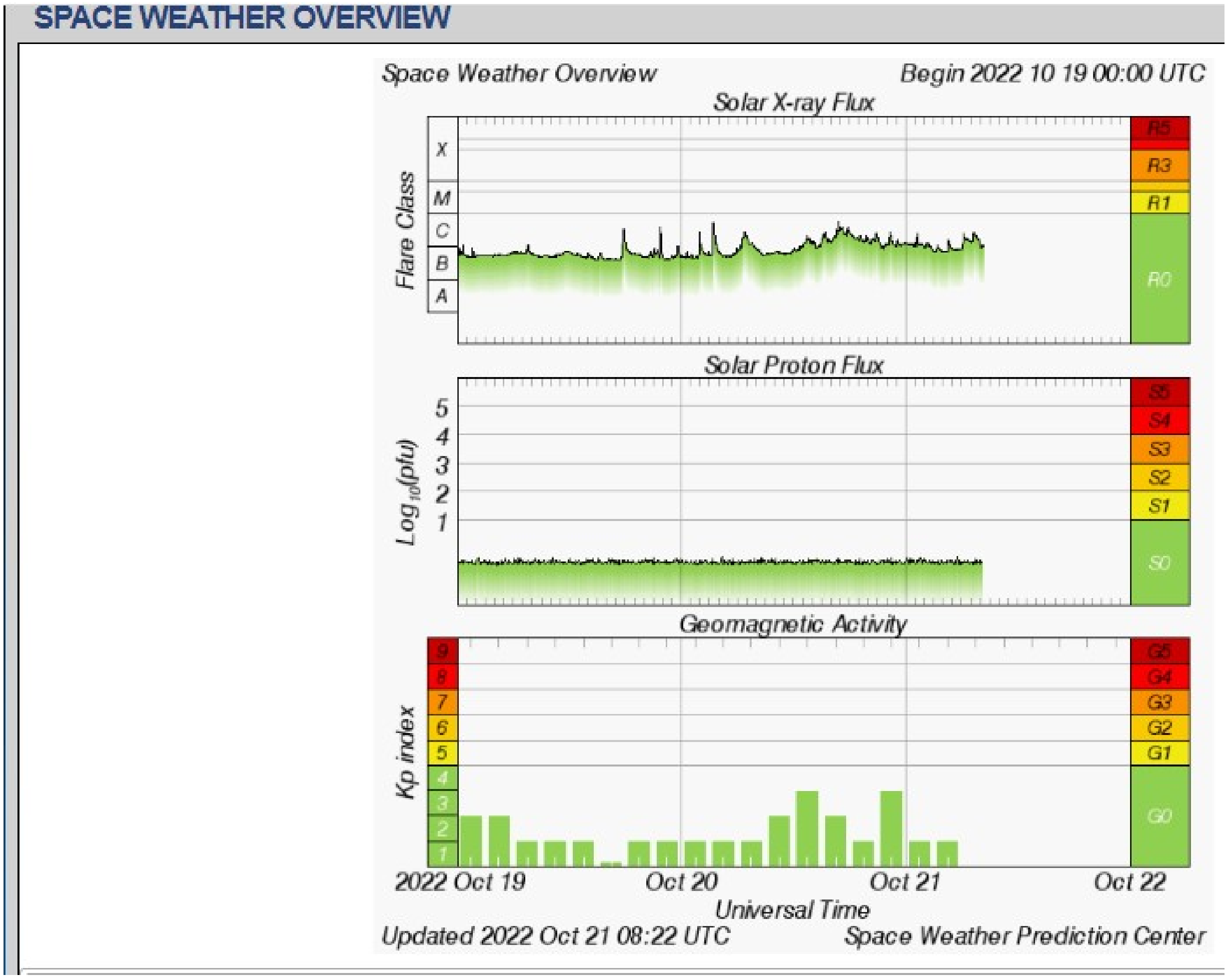
E.



6. When space weather hits and interacts with the Earth, **geomagnetic storms** occur. Geomagnetic storms caused by the Sun heat Earth's upper atmosphere, causing it to expand. The heated air rises and its density increases at the orbit of satellites. This overpowers the satellites' engines causing them to fall back down to Earth and eventually burn up. This happened in 1979 with Skylab, in 1989 with U.S. Navy's satellites, and again this past February with 40 0f 49 Space X satellites of Starlink Communications, costing about $50 M in losses.. Electrons penetrate shielding and accumulate within the spacecraft's electrons to disrupt telecommunications or GPS operations.

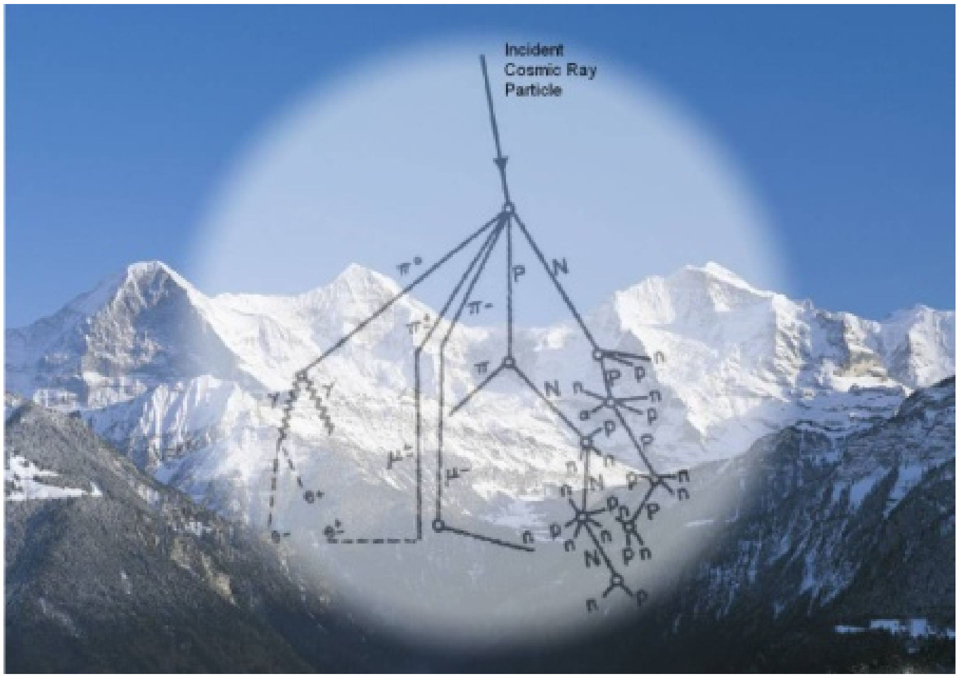
F.

7. Space Weather Prediction Center (NOAA) produces forecast expectations, and their respective measurements. **Forecasting** is the prediction of future events, based on analysis and modeling of the past and present conditions of the space weather environment.
G.



8. As the incident cosmic ray particle collides with an atom or a molecule of the air, it produces lots of secondary particles. If it is a heavy ion, it will be broken into lighter nuclei, protons, or neutrons. This generates a **cosmic ray cascade**. The primary cosmic ray after reacting with air atoms and molecules must have a minimum energy of about 450 MeV to produce a significant number of secondaries that can reach sea level. One has to go to high mountains or use air planes, balloons or spacecraft to detect traces of primary cosmic rays of lower energies. The secondaries rarely reach the ground.

H.



1. Naturally occurring space radiation is always with us. It occurs when atoms, ions, or subatomic particles are accelerated to high velocity by processes such as solar particle events from the Sun. Failures occur from disrupted propagation of radio signals emitted by satellites, disruptions in telecommunications, GPS position, aviation, and sometimes Earth's ground electric power. Analyses of historical blackout events in the United States indicate that even short blackouts, which occur several times during a year in, sum up to an annual economic loss between $104B and $164 B.
2. **Sunspots** are dark regions on the surface of the sun resulting from the interaction of the sun's surface plasma with its magnetic field.
3. The total number of sunspots varies with an approximately 11-year repetition known as the solar cycle. The peak of sunspot activity is known as **solar maximum** and the lull is known as **solar minimum**.
4. Electrons, protons, and other particles are blasted into space with kinetic energy between 0.5 and 10 keV as a result of powerful activities within the sun; they appear as a **solar wind**, propelled in all directions throughout space.
5. On Earth their energy may be absorbed in the atmosphere near the North , South Poles and show as "**auroras**" (e.g., Northern Lights)
6. When space weather hits and interacts with the Earth, **geomagnetic storms** occur. Geomagnetic storms caused by the Sun heating Earth's upper atmosphere, causing it to expand. The heated air rises and its density increases at the orbit of satellites. This overpowers the satellites' engines causing them to fall back down to Earth and eventually burn up. This happened in 1979 with Skylab, in 1989 with U.S. Navy's satellites, and again this past February with 40 0f 49 Space X satellites of Starlink Communications, costing about $50 M in losses. Electrons penetrate shielding and accumulate within the spacecraft's electronics to disrupt telecommunications or GPS operations.
7. Space Weather Prediction Center (NOAA) produces forecast expectations, and their respective measurements. **Forecasting** is the prediction of future events, based on analysis and modeling of the past and present conditions of the space weather environment.
8. As the incident cosmic ray particle collides with air atoms or a molecules, it produces lots of secondary particles. If it is a heavy ion, it will be broken into lighter nuclei, protons, or neutrons. This generates a **cosmic ray cascade**. The primary cosmic ray after reacting with air atoms and molecules must have a minimum energy of about 450 MeV to produce a significant number of secondaries that can reach sea level. One has to go to high mountains or use air planes, balloons or spacecraft to detect traces of primary cosmic rays of lower energies. The secondaries rarely reach the ground.