Evidence-Based Design Principles for Online EE Programs
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Led by Eileen Merritt, Marc Stern, Bob Powell, Troy Frensley

Principle	Description
Designing content	
Relevance	Focus on topics or issues that matter to participants personally, to their communities, cultures and/or to broader society (e.g. issues or policies that are the subject of current discourse).
Socio-ecological connections	Focus on the connections between people and the ecological systems that surround them (e.g., human impacts on ecosystems, impacts of natural disasters on humans, relationships between people and the natural world).
Challenge	Provide content that builds on and extends learning beyond factual recall and requires higher cognitive processes, such as application, drawing connections among ideas, justifying claims with evidence, problem-solving, or generating ideas or solutions.
Positive framing	Emphasize the potential for positive solutions or outcomes that may arise from individual or collective efforts. Draw attention to what can/has/might be done.
Visual evidence of environmental change	Build awareness or draw attention to changes in organisms, populations or landscapes through the use of digital images, videos, data representations or simulations. Engagement with these artifacts may also include discussion or demonstration of cause and effect.

Supporting participants	
Preparation	Consider what skills or background knowledge students need at the start of a program. Add pre-activities or modules to prepare them for success, both in terms of the programmatic content and the technological tools that enable participation.
Use multiple modalities	Students are able to engage in the program through more than one modality (audio, visual and/or kinesthetic). Technology is used to represent concepts in a variety of ways that make content accessible for all learners (e.g., diagrams, videos, photos, maps, text, discussion, physical activities, models, figures).
Feedback	Participants receive iterative feedback from instructors, peers and/or through technology. This feedback can relate to technical guidance, understanding of concepts, or participants' performance. In the case of simulations or virtual environments, responses that guide student understanding can be built into the design of the technology.
Role models	Authentic characters share their knowledge and experiences as they teach about a topic, place or career. They may also model skills or behaviors. Stories can be useful in making personal connections with the participants. Diverse role models can help participants imagine themselves in the roles portrayed by the instructors.

Participant interaction	
Autonomy	Students have opportunities to make choices and direct their own learning experience.
Peer interactions	Opportunities are provided to interact with peers (e.g., group work, discussions).
Active involvement	Participants are prompted to engage with (or actively manipulate) materials or ideas. This may include engaging participants in generating ideas, asking/answering questions, posing solutions, developing models, or creating other products. When feasible, combining a virtual experience with a hands-on experience, such as a field trip or outdoor activity, can strengthen outcomes.

These principles came from a systematic literature review of research on digital environmental education activities published between 2010-2020.

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Contact us for more information about the research or our learning networks:
Eileen Merritt, Virginia Tech, egmerritt@vt.edu;
Marc Stern, Virginia Tech, mjstern@vt.edu;
Bob Powell, Clemson University, rbp@clemson.edu
Troy Frensley, University of North Carolina Wilmington, frensleyb@uncw.edu;

Related resources for educators:

Examples connected to some of our principles

Socioecological connections
Stroud Research Center: Model my watershed: https://modelmywatershed.org/

World without Fish – book by Mark Kurlansky:
https://www.betterworldbooks.com/product/detail/World-Without-Fish-9780761185000

Bald Eagle Relocation Story:
https://www.youtube.com/watch?v=Mi3l0qxdKcI&t=184s
(also shows positive framing)

Positive framing
Video about endangered species that shows a great example of positive framing, and led to shifts in students' attitudes about the Endangered Species Act
https://youtu.be/OUjHq2AFVlw?t=922

Visual evidence of environmental change
Book by Sagarin & Pauchard: *Observation and Ecology: Broadening the Scope of Science to Understand a Complex World*

Earth Images:
https://earthobservatory.nasa.gov/
Colorado River in 2000:
https://eoimages.gsfc.nasa.gov/images/imagerecords/1000/1288/aster_colorado_delta_lrg.jpg
Colorado River in 2020:
https://earthobservatory.nasa.gov/images/146839/green-lagoons-no-more

Challenge
A teachthought article that describes use of Bloom's taxonomy:

https://www.teachthought.com/learning/what-is-blooms-taxonomy-a-definition-for-teachers/

Use of multiple modalities

Source for short news articles at different reading levels: https://newsela.com/

WIDA English Language Development Standards, 2014

Article referenced:
Salmerón, L., Sampietro, A., & Delgado, P. (2020). Using Internet videos to learn about controversies: Evaluation and integration of multiple and multimodal documents by primary school students. *Computers & Education*, *148*, 103796.

Feedback

Articles:
Fauville, G. (2017). Questions as indicators of ocean literacy: students' online asynchronous discussion with a marine scientist. *International Journal of Science Education*, *39*(16), 2151-2170.

Wisniewski, B., Zierer, K., & Hattie, J. (2020). The power of feedback revisited: A meta-analysis of educational feedback research. *Frontiers in Psychology*, *10*, 3087.

Role Models

University Corporation for Atmospheric Research (UCAR) Meet the Experts
https://scied.ucar.edu/visit/meet-experts-live-qa-ncar-experts

Harvard article: This is what a scientist looks like

New Zealand Science Learning Hub:
https://www.sciencelearn.org.nz/

Example:
https://www.sciencelearn.org.nz/videos/729-working-as-an-ecologist
Related article:

Chen, J., & Cowie, B. (2014). Scientists talking to students through videos. *International Journal of Science and Mathematics Education*, *12*(2), 445-465.

General technology tools and resources mentioned by authors:

Free online book about blended teaching in K-12: https://edtechbooks.org/k12blended

Little Bird Tales – app for young children to create digital stories on topics they are learning about (used by a kindergarten teacher to make a virtual field trip WITH her students)

VoiceThread – allows you to have students respond to text, video, presentations, etc. in different formats, available in many university settings