Evaluating Images of the Environment for Educational Use: Exploring the Use of a Rubric Derived From Visual Information Theory

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ABSTRACT

This study explored whether a rubric based upon criteria from visual information theory and intended to facilitate selection of images for environmental education purposes would be robust among users of differing backgrounds. Five higher education faculty evaluated 40 images for the criteria of content, context, information density, and credibility of source. Cronbach's Alpha Reliability Coefficient was utilized to calculate internal consistency of user responses and findings indicated that the rubric was robust for the four criteria. Responses to different subject matter within environmental images were also considered using a qualitative interpretive methodology. Very different responses to the image categories of maps, terrain, plants and animals emerged. Images of terrain and of animals in terrain were highly ranked compared to map images and images of plants, likely due to relatively poor map understanding and lack of familiarity with plants. The majority of evaluator comments targeted human interactions with the environment, indicating a tendency to focus upon companion meanings of the images rather than environmental science content.

Keywords: *Evaluating Images, Environment, Rubric Derived, Visual Information Theory*

INTRODUCTION

Images mediate the environmental experience of many people (including students), and the term 'environmental images' conjures both compelling landscapes and depictions of actual or imminent environmental disasters or problems (e.g., oil spills and degraded rivers). However, this category of image is broad, as is the subject matter of environmental science and environmental education. In addition to fine art or photographic representations of landscapes or the causes and sustainable resolution of environmental problems, environmental imagery may include maps, technical illustrations of organisms that are intended for explanation and identification (such as in botanical watercolors and field guides to bird life) and diagrams of scientific phenomena such as the water-cycle and carbon cycle. Explicit and implicit content depicted by environmental imagery includes: matter and energy, water and soil chemistry, ecosystems and evolution, biodiversity, species interactions and population dynamics, water resources, waste and hazardous waste, energy issues, and the processes and technology of urbanization. Additionally, environmental concepts and issues in physical geography, geology, limnology, and oceanography may be addressed visually at a number of systemic levels. Such images fulfill a number of possible educational and cognitive functions as they engage the viewer aesthetically (Robin, 1992). They may describe and explain an organism or phenomenon, demonstrate cause and effect relationships, provoke inductive reasoning about the subject matter, teach visual classification skills by example, promote the development of explanations, and force the utilization of previously learned concepts in turn.

Thus there are many compelling reasons to give substantial consideration to selection of images for use in formal and informal environmental education settings. Conservationist Aldo Leopold understood this and utilized appealing illustrations of organisms in their natural habitat in *A Sand County Almanac* (1970/1949), a work that became influential in both the conservation movement and in environmental philosophy and aesthetics (Ito, 2008). More recently, images of the maned wolf in a traveling environmental cinema in central Brazil was one tool that proved effective in gaining support for conservation of the species in a rural area (Bizerril, Soares, & Santos, 2011). However, not all images are equal in potential and power to fulfill Robin's (1992) functions: an examination of images of the environment in more than 500 modern picture books about the natural world found that, exclusive of straightforward information texts, less than ten received the researcher's unreserved recommendation as contributing to the environmental education of young readers (Marriott, 2002). Marriott concluded, that although images of nature are plentiful, there are 'a few jewels, but a huge quantity of dross" (p.182), indicating that the reasoned and purposeful selection of images for environmental education is called for, and that use of a rubric based upon appropriate criteria might be appropriate and helpful in this process.

Although the cognitive and educational potential of any image naturally depends somewhat upon the visual literacy and previous knowledge of the viewer, the informational quality and design of the image is of paramount importance to the effectiveness of the image. In a four- volume work addressing data visualization and visual information theory, Edward Tufte (1983; 1990; 1997; 2006) expounds upon design strategies that maximize information representation, thus providing a potentially useful basis for image choice for environmental education use. Although many of Tufte's exemplars are from the fields of cartography, fine artwork and graphic design, recent refinements in image processing capabilities render photography amenable to adjustment to meet many of Tufte's criteria. The ability of a convincing photograph to transform and express a 'created' concept is consonant with the individual viewpoint and explanation of the subject matter offered by fine art painting (Gordin, 2013), and environmental images created by informed photographers have the potential to satisfy the criteria of visual information theory.

This study explores two questions. First, is it possible to develop a simple and robust rubric by which educators in environmental science or environmental education can evaluate images for their cognitive and educational power utilizing Tufte's (1983; 1990; 1997; 2006) visual information theory? Second, given that environmental imagery is so wide in scope and includes such a range of genres and subject matter, we examine how different categories of image (maps, terrain, and images of organisms) are perceived in terms of information extracted and responses evoked in viewers.

BACKGROUND: EDWARD Tufte's Visual Information Theory

Edward Tufte's (1983: 1996; 1999; 2006) visual information theory provides a framework for effectively evaluating images in general, and pictures with environmental science content in particular. Tufte (1983) insists that an educational graphic exceed the function of 'showing the obvious to the ignorant' (p.53) and posits a standard of excellence for images that rests upon two major axioms: that the maximum possible information about the subject is to be communicated as efficiently as possible, and that the image is 'relational', explicitly showing relationships between variables or different components of the illustration wherever possible. Relational images link two variables and encourage the viewer to assess possible causal relationships and respond to their visual experience with thoughtful and meaningful questions. Expectations underlying these axioms are expounded upon throughout the four-volume exposition of visual information theory, but for purposes of informing image evaluation relating to environmental science and environmental science education can be summarized by attention to six key elements: content, context, data-ink, integrity, causal reasoning, and visual hierarchies.

Content

Content describes the explicit and implicit information provided within the image. In terms of environmental images, this might refer to the presence of visually accessible information about the abiotic environment, organisms, ecosystems, populations, or sustainability. Tufte (2006) has proposed that the initial issue to be addressed in image selection is to determine the content reasoning task that the image is intended to assist. Clarification of essential reasoning tasks will suggest necessary content elements, of primary importance in the image selection process as "presentations ultimately stand or fall depending on the quality, relevance, and integrity of their content" (p.136).

Context

A second criterion for an effective image choice is *context*. Environmental image selection requires that the targeted content is portrayed in authentic and accurate context (such as a cactus plant in a desert landscape), and that misconceptions are avoided. Context is an essential component of integrity in the illustration or image, and can be a difficult criterion to satisfy, as strict realism or authentic scenes that provide rich information while eschewing gratuitous detail (Tufte, 1983) are frequently not considered by artists and photographers to be pleasing or marketable. The principle of proper context in environmental imagery requires that illustrations of organisms provide direct answers to relevant questions about size, form, morphological and behavioral adaptations, and ecology (Hunt, 2006) and that images depicting multiple species of organisms indicate how the these are related, i.e., by taxonomy or by habitat. Modern illustrations in technical publications, such as field guides to birds, generally do organize their species according to a strict taxonomic arrangement (e.g., Kaufmann, 1990; King, Dickinson, &Woodcock,1975), while some field guides intended for the beginner, and many narrative paintings show organisms related by niche or habitat (e.g., Coe, 2001;

Lansdowne, 1968; Matthiesson, 1967).

Maps are a category of environmental image that illustrate how the power of an image can be enhanced by visual emphasis of causal and contributory factors to provide context: differences in of natural resources, population, rainfall, etc. are superb vehicles for geographic comparisons. The classic exemplar of this genre is Minard's figurative map of Napoleon's march through Russian in 1812 (Minard, 1869), in which both the advance and retreat of the army on and from Moscow are depicted with respect to six contextually relevant variables: environmental temperature, environmental hazards such as the crossing of the icy Berezina river, direction of movement of the army, the (decreasing) size of the army along the route, geographical coordinates, and dates at which the arm passed through key locations. Lesser known works of Minard include more than 50 thematic maps, most of which described and explained issues of economic rather than environmental geography, but which nonetheless demonstrate how maps with data shown in enriched context can summarize and convey impressive amounts of information (Friendly, 2013).

Information Density

A third element to be considered in image selection for environmental education is information density, or 'data-ink' (Tufte, 1983, pp. 91-105). Data-ink is the proportion of the image devoted to content, thus an image rich in information content will have a high 'data-ink' index (p.93). Data- ink can relay features of the environment that are explicitly portrayed or implied in the image. For example, the proportion of the image devoted to a nuclear reactor when illustrating energy sources, or to an urbanized river valley when the environmental topic is water conversation would be relevant to information density, or the data-ink index. Tufte (1983) has explained his concept of data-ink in more general terms:

> Data graphics should draw the viewer's attention to the sense and substance of the data, not to something else…graphics are instruments to help people reason about quantitative information (p. 91)… A large share of ink on a graphic should present data-information, the ink changing as the data change. Data-ink is the non-erasable core of a graphic, the non-redundant ink arranged in response to variation in the numbers represented (p. 93).

Thus when selecting an appropriate image for educational purposes, the percentage of the image area containing directly applicable content or information relevant to that content should be assessed: information density of the image increases with this percentage (Tufte, 1983;1997;2006).

Causal Reasoning

A fourth element Tufte (1997; 2006) to be considered in image selection is the extent to which it is likely invoke causal reasoning, encouraging viewers to ask reasoned questions about both the explicit content displayed and also that which is implied: "Scientific research involves causal thinking, for Nature's laws are causal laws.…principles of design should attend to the fundamental intellectual task in the analysis of evidence…causality, mechanism, explanation, systematic structure" (Tufte, 2006, p. 128).

Credibility

The element of integrity (Tufte, 1983, 1990, 1997) is described in terms of a number of dimensions, including design strategies that prevent the viewer from having to guess at missing information, or from being unintentionally deceived by misleading proportions or the optical plane in which the subject is depicted. However, integrity is primarily concerned with credibility: the scientific and historical credibility and the reliability of the source, this latter being of paramount importance when images are sourced from the Internet. Tufte (1997) is insistent on the matter of examination of image sources: "If images are to be considered credible, their source and history must be documented. And if an image is to serve as serious evidence, a more rigorous accounting should reveal the overall pool of images from which the displayed image was selected" (p. 25).

Visual Hierarchies

Tufte (1990) describes "confusion and clutter…as the failures of design" (p.53), impeding the comprehension of information. Thus the sixth and final element of image assessment generated from visual information theory is that of the provision of a visual hierarchy within the image. A visual hierarchy indicating the relative importance of content within the images can be provided by varying line weight, use of texture and patterns, color variation, and choice of compositional strategy. Color and line function in layering and separation of visual information, reducing noise and enriching the content of image by effective visual emphasis. Although beyond the scope of the current study, *Envisioning Information* (Tufte, 1990) also includes considerable attention to design strategies that sharpen the information resolution of illustrations.

METHODOLOGY

Criteria Employed

From the six criteria discussed throughout Tufte's (1983; 1990; 1997; 2006) work in visual information theory, four were identified that were judged basic to guiding image choice for environmental education purposes, and that were suitable for a non-specialist in visual information concerns to comprehend quickly. Content, context, information density, and credibility of the source of the image were the criteria selected. Causal reasoning and the provision of visual hierarchies were judged to be beyond the scope of this study.

Content (Criterion 1) required that the image be rich in explicit and implicit environmental content.

Context (Criterion 2) required that the image content be shown in an accurate environmental context and that content was not diluted by gratuitous decorative material.

Information density (Criterion 3)) was the percentage of the image containing relevant information about the environment (from Tufte's (1983) concept of Data-Ink).

Credibility of source (Criterion 4) required that the Internet source of the image be considered scientifically and historically credible**.**

To address the first question of whether a rubric for environmental image selection based upon visual information theory would be robust among users (i.e., that users would make similar judgments pertaining to our chosen criteria), we designed a questionnaire (see Appendix I) that was distributed to five evaluators, along with a 40 item image set. The questionnaire featured a Likert-type response to each of the four criteria, with a justifying written comment requested for each. For the criteria of content, context, and credibility of source we asked that the evaluator classify the images as fully, mostly, partly, or not met for each criterion and assigned each classification a numeric score (4 for fully met, 3 for mostly met, 2 for partly met, and 1 for not met.). The criterion of information density asked that evaluators estimate the proportion of the image that depicted environmentally relevant information, with available selections of 0 – 25%, 25% - 50%, 50% - 75%, and 75% - 100%.

Image Selection

The 40 images selected for evaluation (Muthersbaugh and Kern, 2012) were drawn from a set of 100 images, collected from Internet sources, that had previously been utilized in an elementary social studies and science study in which students explored the local (Pacific Northwest region of the United States) environment during the time of the Lewis and Clark expedition in the early 1800's, and compared this to current environmental conditions. For the current study, images were selected from this larger collection to fit four general categories of 'environmental image': maps, terrain (landscapes), plants, and animals. Ten images were provided for each of these four categories, and of the ten images in each category, five were historic images (from the 1800's) and five were contemporary.

Participants

Five educators were selected to evaluate the image set. These educator-evaluators had diverse professional lives, but all were positioned such that selecting images of the environment for educational purposes comprised part of their practice. All evaluators also possessed sufficient environmental science background to make a credible appraisal of the images. All individuals (four female, one male) were current or former higher education faculty with five to twenty-plus years of teaching experience at institutions in the Pacific Northwest region of the United States. Three have taught public schools and all have experience in science teacher preparation. The environmental science expertise of the evaluators varied from completion of relevant college coursework through actually teaching environmental science at the college level. One evaluator was employed in the private environmental sector, one was primarily a biological scientist, one was in engineering, one specialized in elementary education, and one was specifically science education faculty.

Data Analysis

To inform the first question of whether an image rubric would be robust to the subjectivity inherent in having different individuals evaluate images, Cronbach's Alpha Based on Standardized Items (SPSS) was employed to estimate the internal consistency of the different evaluators' scores for each of the criteria in the rubric for the 40 images (Cronbach, 1951). Scores were analyzed with n = 5, and an overall reliability agreement score of 0.700 preferred per criterion. Thus a Cronbach's alpha of 0.700 or greater would indicate that the evaluators reached an acceptable level of agreement for that criterion on the entire image set (see Table 1).

To address the second question of how different categories of image were perceived, the numerical values of the scaled Likert-type rankings (1 – 4) were averaged for each category of image for each criterion With five evaluators, and 10 images per category, the average of 50 responses was calculated for maps, terrain, plants, and animal images for the criteria of content, context, and credibility of source (see Table 2). The pattern of rankings for each image by each evaluator for each category was also visually inspected, and departures from the norm examined. In addition, for the criterion of information density, the number of images in each category receiving rankings of 75-100%, 50 – 75% etc. was tabulated and reported as a percentage of the 50 responses for that category (see Table 3).

Finally, given that this study was exploratory and descriptive in in nature, evaluator comments for each criterion were subject to interpretive qualitative analysis in an attempt to uncover how evaluators perceived the four categories of image in terms of our four criteria. Comments were analyzed by image category and criterion. An interpretive approach to the qualitative analysis of the comments was chosen, a methodology that positions the researcher as the vehicle by which reality is revealed (Andrade, 2009), with this 'reality' bounded by particular time and specific context, and is based upon the epistemological assumption that "findings are literally created as the investigation proceeds" (Guba & Lincoln, p.111). In the interpretive version of content analysis, the researcher's interpretations play a key role, bringing "subjectivity to the fore, backed with quality arguments rather than statistical exactness" (Garcia & Quek, 1997, p.459). Emerging themes that revealed understanding of how the evaluators interpreted the images were reviewed by two academics in the field of environmental science education.

FINDINGS

Reliability of the Rubric

Cronbach's Alpha for the four Likert- style responses from the five evaluators indicated that all criteria within the image rubric produced acceptable internal consistency of image ratings (see Table 1). The highest reliability coefficient occurred for credibility of the internet sources of the images (α = 0.869), followed by environmental content (α = 0.797), appropriate context (α = 0.761), and data ink or information density (α = 0.707). The closer that Cronbach's alpha is to 1, the greater the internal consistency of the ratings for each criterion. Guidelines for interpretation of Cronbach's alpha coefficient are: ≥ .9 – Excellent, ≥ .8 – Good, ≥.7 – Acceptable, ≥.6 – Questionable, ≥ .5 – Poor, and ≤ .4 – Unacceptable" (Gliem & Gliem, 2003. p.87.) These relatively high levels of agreement ('Good' for credibility of source and content, and 'Acceptable' for information density and context) in this initial attempt to develop a rubric of criteria for image evaluation are encouraging.

Table 1: Reliability Coefficients by Criterion Responses to 40 Images by Five Evaluators

Criterion	Reliability Agreement Score (Cronbach's Alpha)
Content	**.797**
Context	**.761**
Information Density	**.707**
Credibility of Source	**.869**

Responses to Criteria by Category of Image

Criterion 1: Content

Map images scored an average of 2.2 points (out of a possible 4.0) across the five evaluators, yielding an overall rating of 'partly met' for richness of environmental science content (see Table 2). Although certain evaluators had more experience with map interpretation than others, they were remarkably consistent in their ratings of individual images. As a group, evaluators were quite critical of the maps for this criterion: only one image received a rating of 'fully met' for environmental science content by one evaluator. Explicit and implicit environmental content of the maps generated 17 comments, with an overall indication that maps were richer in implicit than explicit content. Identified content included topography, geology, satellite imagery, vegetative cover, water resources, ecosystem variability, and abiotic aspects of environments, and political boundaries vs. ecological regions:

> An attentive viewer can extract a good deal of environmentally relevant information from this image...about topography, water resources, vegetative cover…
>
> Geology, and abiotic aspects of environment.
>
> Environmental variation is revealed if you can extrapolate.

The different ecosystems depicted in a large scale map drew evaluator attention:

> Different limiting factors are implied by the different environments.
>
> Variation in ecosystems (across the route) as mountain ranges, Great Plains, plateaus are labeled.
>
> Food webs and diversity implied…will be very different in marine, coastal, vegetated mountainous regions and high desert environments.

Implied interactions between humans and the environment were also a topic of comment for the set of map images:

> There are implications about the natural resources available to the (Lewis and Clark) expedition.
>
> Natural vs. anthropogenic change is suggested.

The 10 images in the category of 'Terrain' scored an average of 3.3 points across the five evaluators, an average rating between 'mostly met' and 'fully met' for richness of environmental science content (see Table 2). Ratings of individual images were consistent between evaluators and all provided comments (24 comments total) on the content identified in this category. Evaluator comments tended to emphasize human interactions with, and modifications to, the environment.

> Modifications of the environment based on the major highway.
>
> Diversity may have changed over time as humans monopolized the prairie.
>
> Negative results (on the environment) due to the dam and barge traffic.

Images in the 'Plants' category scored an average rating of 'partly met' (2.1 out of a possible 4.0) for depiction of explicit and implicit environmental science content. Ratings were consistent between images, and moderately consistent between evaluators, although two individuals (one with a 'naïve' interest in botanical illustration, and one with some academic background in this area) gave the plants images higher ratings for content. These two evaluators were the only individuals to offer comments on the content of the plant images. Most of the comments made by the more 'naïve' evaluator keyed on flowers and fruiting structures or focused upon human interactions with plants, while the 'informed' evaluator appeared to be searching for ecological content:

Examples of 'Informed' comments:

> Plant appears to be in a woody landscape where it will be competing with other plant species for resources. It is providing a food source, which is beneficial to other species.
>
> Cottonwoods increase biological diversity in riverine environments by providing food and shelter for other organisms.

Examples of 'Naïve' comments:

> The seed pods are intriguing.
>
> Humans affected the plants' environment in some way as they harvested wood.
>
> Plant used by humans for utilitarian and medicinal functions.

Evaluators indicated that depictions of unfamiliar plants such as wildflowers are more useful when an informative label was provided:

> The accompanying explanation brings the missing content to the image.
>
> The image alone does not provide much information – photos of flowers and foliage have limited usefulness.

Images of 'Animals' scored an average rating of 2.95, or 'mostly met' for environment science content (Table 2). Ratings of individual images followed a consistent pattern among the evaluators, although three individuals tended to score all animal images somewhat higher than did the other evaluators. The majority of content identified in the 'animal' images was broadly ecological, rather than specific to the organism depicted:

> Use of old growth forest by humans is depicted.
>
> Woody plants in background (of bird portrait) provide habitat, food source, and nesting sites.
>
> Showing pictures of several species implies food webs and life cycles.

Herbivory, over-harvesting of buffalo, habitat fragmentation, and loss of habitat to agriculture, food webs and life cycles implied by multiple species' depictions, population plunges, piscivory, and competition for resources were identified.

> A dramatic population plunge due to the loss of open prairie habitat is implied…we do not see massive herds of buffalo today.
>
> The label states that the salmon population was once thriving…overfishing and habitat degradation since the time of the Lewis and Clark expedition are implied.
>
> Crash of woodpecker populations due to the loss of large tracts of old growth forest is implied.

Table 2. Average Ratings for Three Criteria Across Four Categories of Image**

Criterion	Maps	Terrain	Plants	Animals
Content	2.20	3.30	2.10	2.95
Context	2.52	3.42	2.02	3.09
Credibility of Source	3.60	2.30	2.00	2.28

** 1.00 = criterion not met; 2.00 = criterion partly met; 3.00 = criterion mostly met; 4.00 = criterion fully met.

Criterion 2: Context

Maps received an average score of 2.52 points (see Table 2), a rating between 'partly met' and 'mostly met' for showing environmental content in an appropriate context. One evaluator felt the question was not suited to images of maps and rated all ten images as 'not met' for context. The remaining four evaluators tended to rate images similarly, judging the maps as showing appropriate context with respect to geography and geology:

> Shows appropriate natural features accurately.
>
> Topography is accurate.
>
> Geological phenomena only shown, these are depicted in correct context.

Maps with extensive legends, particularly those showing types of vegetative cover, were ranked most favorably:

> The variations of color depicting vegetative cover is useful.
>
> Lack of a legend reduces the usefulness of this map.

The one map image containing labels or illustrative embellishments of organisms drew favorable responses:

> Plant groups are appropriate to biome.
>
> Deciduous trees of the eastern forests, the western evergreens, and prairie grasses are shown in appropriate locations.
>
> Representative birds are a nice touch.

Even where plants or animals were not referenced, either by legend or direct illustration, some evaluators interpreted topographic features in terms of implications for organisms:

> Narrow continental shelf of Pacific coast has implications for marine life.

Images of terrain were highly ranked for display of environmental content in an appropriate context, scoring an average of 3.42, a rating between 'mostly met and 'fully met' (see Table 2). Evaluators appeared more confident about evaluating environment context when presented with images of landscapes, and rankings were similar across all images and all five evaluators.

Evaluators cited details to support their high rankings for accurate context:

> Moisture loving herbs at the feet of fishermen, salmon in stream, the trees growing in rock crevices smaller than those on riverbank.
>
> The banks of the river show rising and lowering of water level, probably dependent of release of water from the dam (depicted).
>
> The flowers are consistent with the prairie ecosystem.

Images of individual plants were not ranked highly by the evaluators for showing accurate and appropriate environmental context, receiving an overall score of 2.02, or 'partly met' for this criterion (see Table 2). A number of these images were field plates, or illustrations of plant parts, and evaluator comments indicated the need for a full narrative background to be included in order that the plant be placed in context:

> Images in this section are beautiful, but not particularly environmentally contextual.
>
> An accurate depiction of the plant, but not shown in its environment.
>
> Camas depicted correctly, but hard to discern surroundings.

However, some less literally-minded evaluators felt it was possible to infer context from an illustration of a plant specimen:

> Painting depicts roots, a clue to typical environment (rocky soil in this case).
>
> Shows flowers low to the ground, appropriate for rocky soil.

Others either relied on a label to provide context, or felt that a label was needed to provide sufficient context:

> Environmental context given by label information (evaluator repeated this comment for three of the plant images).
>
> If context is not provided directly in image, it should be provided by a label.

Where a full background was provided, evaluators gave high rankings for context, and did not question the placement of the plant:

> Accurate depiction of prairie environment.
>
> The flowers are in a grassland setting, natural for this type of wildflower.

The images of animals received a moderately high average score of 3.09 for display of environmental content in an appropriate context, a rating of 'mostly met' for this criterion (see Table 2). Two of the evaluators considered behavior to be contextual:

> Social group (coterie); individuals in characteristic postures, shown on open prairie.
>
> Burrowing while two members of the coterie watch for threat.
>
> I have seen woodpeckers behaving like this so assume context is correct.

One evaluator examined the context of an image and reevaluated her own knowledge:

> I was not aware the buffalo lived so near mountain foothills but it does make sense for the northern route taken by Lewis and Clark.

Images of animals set against narrative backgrounds received higher scores for context:

> Prairie and mounds are consistent with typical prairie dog habitat.

Critical comments ensued when these (narrative backgrounds) were not provided or were judged insufficient:

> Inaccurate – white pine should be included for most correct context.
>
> Salmon not depicted in a natural habitat.

Greater familiarity with the behavior and ecology of specific animals on the part of individual evaluators increased ratings for context when a narrative background was absent. Comments of knowledgeable evaluators indicated that 'clues' to context were considered sufficient:

> Bird clinging to woody plant; both sexes and silhouette depicted in a configuration that would be observed in the field – artistic license used to good purpose here.
>
> Bird on lichen covered igneous rock is characteristic.
>
> Bird shown with a plant species with which it has a mutualistic relationship.

Criterion 3. Information Density.

Overall agreement between the five evaluators for the criterion of information density - the percentage of the image containing relevant environmental information - was acceptable (α = 0.707) although a dichotomy between evaluator responses was apparent. Three evaluators rated all maps as displaying less that 50% of environmental information for this criterion, while two individuals who were geologically knowledgeable and familiar with interpreting maps in environmental terms rated maps highly for information density (Table 3). This effect of prior knowledge appeared again in evaluations of the plant images. Responses to images of plants were very variable, and it seems that judgment of what constitutes 'environmental information' in plant images correlates with the knowledge of plant ecology possessed by the evaluator. One evaluator rated all plant images as having low information density (in the 0-25% range), whereas another with some knowledge of plant ecology rated all in the 75-100% range.

Images of animals scored the highest average ratings for information density. More than 60% of the images of animals were rated as containing 75-100% environmental information (See Table 3). Images of terrain were also highly rated for this criterion: 50% of terrain images presented were rated as containing 75-100% of environmental information. The animal images presented were for the most part situated against a full background of a contextual landscape, thus this category might be better described as 'animal in terrain' and we hypothesize that the presence of an engaging and familiar animal (buffalo, prairie dog, salmon, woodpecker) offered some personalized context that enabled evaluators to identify environmental information in the images.

Table 3. Information Density: Percentage of the image containing relevant environmental information

Category of Image	0-25 %	25-50 %	50-75%	75-100%
Maps	40.0	10.0	24.0	26.0
Terrain	6.30	10.9	32.8	50.0
Plants	32.0	12.0	27.0	29.0
Animals	14.6	10.4	12.5	62.5

Criterion 4: Credibility of source

Credibility of the internet sources of the images produced good agreement overall across all images and evaluators (α = 0.869). A breakdown of the average evaluator ratings of the images by category is supplied in Table 2. Federal agencies and sites that were 'household names' to our evaluators, such National Geographic and the Public Broadcasting Service were uniformly considered trustworthy and evaluators justified their rankings of 'fully met' for image credibility typically by naming the source:

> Dept. of Fish and Wildlife.
>
> National Park Service.

Maps, especially those from federal agencies, tend to be considered authoritative and were the most trusted of all categories of image in terms of integrity of source (See Table 2):

> USGS is a reputable source of maps.

'Rare Map Sites' were problematic for evaluators, as they appeared credible but were unfamiliar territory and tended to be low ranked for credibility:

> The title suggests reliability although I am not familiar with rare maps.
>
> Not familiar with 'Rare Map Sites.'

Commercial sites and Wikimedia were distrusted and images from such sites ranked low for credibility, even when the image seemed to be straightforward. Our evaluators were cautious about their rankings for all categories of image when they were unfamiliar with the source:

This is from a credible diary but Wikimedia is a problem.

The website is not necessarily a credible source but I recognize the image as accurate.

Appears historically credible but not enough information about source to trust.

Image is straightforward but a news source is not sufficiently authoritative.

Photographs of terrain, plants, and animals were treated with suspicion and ranked as 'partly met' or 'not met' (see Table 2), unless they originated from a source (such as National Geographic) that evaluators believed utilized scientific judgement:

National Geographic employs scientists and is a trustworthy source.

Appears to be a straightforward and untouched image but a realty is not a sufficiently authoritative source. The image is credible but the source is not

Not from an authoritative source but how important is this for an untouched photograph?

No reason to distrust a nursery photograph of a cultivar, but is not botanically authoritative.

The credibility of fine art illustrations of terrain and/or organisms was considered to be dependent upon the artist's scientific knowledge, which was unknown in most cases, thus some illustrations of plants and animals were ranked low for credibility:

We don't know how good a scientific observer the artist was.

Source is respectable but we don't know about the depth of the artist's knowledge.

SUMMARY

This exploratory study utilizing 40 thematically linked images indicated that a rubric based on criteria derived from Edward Tufte's visual information theory has potential for guiding selection of images for use in environmental education and environmental science education. The use of a rubric to focus educators' attention upon explicit and implicit information contained in images, the context in which that information is presented, the information density of an image, and the integrity of its sources produced agreement within a group of five educators in higher education. Agreement was 'good' for image content and credibility of the image source, and acceptable for context and information density. Evaluator knowledge of environmental science, visual information theory and/or aesthetics appeared to some influence on evaluator response to an image, but not enough to undermine overall levels of agreement.

Of the four categories of image employed, images of terrain and images of animals in terrain appear to be rated most highly for environmental science content, appropriate context for the information, and density of information in the image. Images of animals lacking a full landscape background were rated less highly on all factors than when this was included/present.

Maps and images of plants, were rated as less rich in explicit and implicit environmental content and this content was less likely to be considered displayed in appropriate context. These two categories were also given mediocre ratings in terms of information density of the images. Maps were considered the most credible images of all categories, likely due to the tendency of these images to originate from governmental sources. An issue of credibility that seemed to concern evaluators was the knowledge of the artist in fine art illustrations, leading to doubts about the integrity of some images of plants and birds in particular.

All evaluators in this study appeared to be oriented toward issues of sustainability. Human interactions with the environment (use of resources, modifications to and corresponding effects upon) were a common theme that drew comments across all categories of image.

DISCUSSION AND CRITICAL REFLECTION

The results of the study were encouraging in terms of the potential of a rubric for selecting images for environmental education, and informative about viewer responses. However, it is recognized that more exploration is called for, particularly in terms of the criteria employed and the evaluator population. In this study, image criteria were limited to content, context, perceived information density, and credibility of source as the aim was to obtain some preliminary results to guide future efforts, and there was concern about the possibility of evaluator fatigue distorting results if additional criteria were added, particularly as a fairly large number of images were presented for evaluation here. One important criterion being investigated in a current study is that of the potential of images to stimulate reasoning and questions in the viewer (Hunt, Muthersbaugh, & Kern, in prep). This pertains to Tufte's (1997; 2006) criterion of causal reasoning, where the visual explanations and cause -and -effect relationships demonstrated within an image effectively stimulate inductive reasoning and content-relevant questions in the viewer.

Differences in evaluator populations are also likely to affect responses to rubrics. This sample of educators attained reasonable levels of agreement on the criteria employed, but it is recognized that this sample consisted of individuals who likely possess greater environmental content knowledge than other populations. An appropriate next step might be to evaluate agreement amongst practicing elementary school teachers and pre-service science teachers to discern whether gaps in environmental content knowledge (Dove, 1996; Mikhail, Stamou, & Stamou, 2006; Khalid, 2003; Summers, Kruger, Childs, & Mant, 2000) substantially affects use of the rubric and agreement levels.

One issue that emerged with evaluator responses concerns the perceived credibility of images. Although agreement about credibility of image source was the highest for any of the four criteria, evaluator comments initiated some concerns. A tendency for unquestioning acceptance of images produced under the auspices of government organizations, or household names such as National Geographic or the Public Broadcasting Service raises concerns that such 'automatically approved' images may not be subject to the degree of critical scrutiny that this sophisticated population of evaluators would be capable of. This effect may be even more pronounced amongst less educated evaluators. It was also evident that photographic images were accepted ("Not from an authoritative source but how important is this for an untouched photograph?") with less reserve than were fine art illustrations, which elicited some suspicion ("Source is respectable but we don't know about the depth of the artist's knowledge"). This distrust may eliminate some fine images from consideration: many of the most informative natural history illustrations originate from information and sketches in field notebooks, where the artist was intimately familiar with the habits and habitat of the organism. Examples of the former might include: Erasmus Darwin's detailed drawings of the fertilization process in the freshwater plant *Vallisneria spiralis* (Darwin, 1791), the illustrated diary kept by Charles Darwin during the five year voyage of the HMS Beagle (Keynes, 2001), and Maria Merian's entomological studies of Surinam (Merian, 1771; Tuft, 1962). More recently, two award-winning children's picture books - *My Season with Penguins* and *Looking for Seabirds: An Alaskan Voyage* – were created by ornithological artist Sophie Webb from illustrated journals of research expeditions in the Antarctic and Alaska (Webb, 2004; Webb 2000). Webb's watercolors are very far removed from technical illustrations, yet as Marriott (2002) commented, useful images of nature can be 'flamboyantly idiosyncratic yet accurate and effective" (p. 181). Similar illustrations are found in *The Tiny Seed* (Carle, 1987) in which a seed survives natural and man-made hazards before becoming a flower. It may be that this evaluator population, as higher education faculty, took a somewhat severe stance on the suitability of illustrations for use in education. It remains to be seen in further study with other populations if the use of credibility as a criterion will eliminate some categories of image from consideration for educational use.

The inclusion of maps as a category of environmental image was perhaps one of the more unusual and remarkable features of this study, and one that deserves some comment on evaluator reactions and also attention to the question of how maps could be employed in environmental education. In contrast to the other categories of image employed in this study, there exists a substantial body of research on understanding, interpreting, and teaching with maps as conventional representations of large scale spaces and their uses (e.g.: Anderson & Leinhardt, 2002; Rossano & Morrison, 1996; Schofield & Kirby, 1994; Ward & McCabe, 2000; Winter, 2007). The map images utilized in this study were rated as only 'partly met' overall for content, context, and information density, yet evaluator comments indicated that implied environmental content was plentiful. The rich implicit content suggests that maps might be more fruitfully employed with students who already have some background in the area of environmental science and are thus able to make inferences. A viewer might also benefit from a degree of geographic literacy about scales, symbols, keys, and legends and the ability to interpret maps in terms of this ' objective' knowledge before being able to understand them as environmental images. However, such prerequisites as preexisting environmental science knowledge and conventional cartographic interpretive skills might be circumvented by careful choice of the map image and also by encouraging a more constructivist approach to maps in the classroom. One middle level geography textbook, *Investigating Geography* (Grimwade and Durbin, 2002) has advocated adoption of a 'freer, more imaginative…perspective on map knowledge…within a more student centered pedagogical framework' (Winter, 2007, p.357) in which maps are interpreted more subjectively and the viewer is encouraged to decide what is important within the map. World maps within a section of *Investigating Geography* entitled 'Do Maps Tell the Truth?' show environmentally relevant phenomena such as lights from urban areas, oil production flares, and burning vegetation. In contrast, the map images employed in this study were somewhat conventional representations, and presenting users with more enticing and relevant images might result in better identification of explicit content and environmental context.

Despite these caveats, a number of articles in practitioner journals have described successful routes to teaching about environmental science with conventional maps. Woolever (1956) describes use of local city, county, state, national, and world maps in teaching about foods, natural enemies, fisheries, insects, migrations, erosion, agriculture, natural parks, reclamation areas, sanctuaries, hunting areas, soil types, population changes, rainfall, watersheds, climate, altitudes and depths, natural barriers, and artificial boundaries by expanding the function of a map from 'what is where' to a vehicle for posing and answering questions about why, when, or how it got there. Locke (1963) employed road maps in biology teaching in elementary and middle grades by having students identify biological terms in town names (e.g., Parsley, Cotton, Buffalo, Coyote, and Salmon) and then tracking down their origin and relevance. Swab (2010) illuminates a college seminar with maps developed during the voyage of the HMS Beagle. Thus it seems that there are routes to developing uses of maps as environmental images , but this particular category of image may require its own carefully scaffolded rubric.

Plants as environmental images also seem somewhat problematic. Given the critical importance of plant life in a sustainable environment, the response of evaluators to the plant images was overall quite disappointingly unenthusiastic. The majority of evaluators had difficulty identifying environmental science content, ranked the plant images low for appropriate context unless placed in a narrative background, and considered few of the images information-dense. It is reasonable to suppose that less scientifically educated viewers would echo this negativity in their responses. This lack of engagement with this category may be a manifestation of the phenomenon of 'plant-blindness', defined and described by Wandersee & Schussler (2001) as "the inability to see or notice the plants in one's own environment—leading to: (a) the inability to recognize the importance of plants in the biosphere, and in human affairs; (b) the inability to appreciate the aesthetic and unique biological features of the life forms belonging to the Plant Kingdom; and (c) the misguided, anthropocentric ranking of plants as inferior to animals, leading to the erroneous conclusion that they are unworthy of human consideration" (p.2). Schussler & Olzak (2008) provided evidence in support of the plant-blindness model by demonstrating that plant images were recalled less frequently than animal images by undergraduates enrolled in psychology and biology classes at a large state university. These authors have proposed that plant-blindness be combated by biology teachers by presentation of equal numbers of plant and animal examples, and selection of the most memorable plant images possible to offset selective attention to animals. In this study, it is possible that the evaluations of content, context, and information richness of the plant images were affected by a zoocentric orientation on the part of the evaluators.

In addition to the overall poor evaluations of the plant images, the specific images rendered by botanical illustrators were also given low rankings for credibility, as the evaluators appeared uncertain of the artists' credentials in science. Given that botanical illustration as visual scientific description has a long and illustrious history (e.g., Sherwood, Harris, & Juniper, 2005), and is an area of scientific endeavor that is still emerging in the form of image-driven digital plant keys (Simpson, 2011: Valkenburg, Duisstermatt, & Boer, 2013), this response is curious. This lack of appreciation for the field by the evaluators in this study may be a further manifestation of plant-blindness, reflecting the lack of emphasis on botany in life science curricula in recent decades (e.g., Darley 1990; Hershey, 1993, 1996; Nichols, 1919; Uno, 1994): evaluators may simply not have been exposed to scientific botanical illustration. Evaluator comments on the plant images tended to focus on plant—human interactions (e.g., 'Used around encampments to deter evil spirits'), implicitly supporting the suggestion that 'plant-blindness' at all educational levels is most effectively countered by approaching plant study through ethnobotany (Babaian and Twigg, 2011).

The high rankings given by evaluators to images of terrain, and to images of animals situated within a landscape background reinforce the common perception that the allure of attractive landscape images '(nature pictures') increases engagement with the environment. A potential drawback of this response is that an emotionally charged aesthetic response to a landscape may distract and detract from a thoughtful and critical response to the environmental content. Popular concepts of the environment are frequently constructed from a vision of "nature as exotic and idyllic, enigmatic and inscrutable, precarious yet romantic" (Marriott, 2002, p.176) and the educator will not wish to further propagate such misconceptions in the images chosen for environmental education. Landscape images are undoubtedly engaging, but identifying environmental content from images in this category may be especially challenging for those viewers whose encounters with animals consists mostly of contact with domestic pets and zoo inhabitants, who are disconnected from natural landscapes outside of visitor-centers and highway way stations, who are 'plant-blind' (Wandersee & Schussler, 2001), and who have no sense of the role of abiotic forces such as water, wind, and sun (Marriott, 2002). Viewers of images intended to educate about the environment will benefit from a visual challenge to their preconceptions, and to be effective, the landscape images presented for this purpose (particularly those in which animals appear) might be deliberately selected to confront both romantic pastoralism and suburban familiarity.

Human interactions with the environment, such as medicinal use of plants, over-fishing, and diversion of water resources were the dominant theme of evaluator comments in all four categories of image, echoing and reinforcing other findings that many individuals, including students, are considerably aware of environmental problems due to human activity, although understanding of the mechanisms connecting cause to effect is frequently lacking. Empirical evidence across cultures - the United States, the United Kingdom, Mexico, Australia, Germany, and Russia - indicates that children and teenagers are aware of and concerned about environmental issues, most commonly those of pollution, global warming, lack of water, and deforestation (Barraza, 1999; Hicks & Holden, 2007; Hutchinson, 1997; Strife, 2012). Investigations into these environmental concerns of children and youth have indicated that feelings of helplessness and the ensuing pessimism engendered by this anxiety tends to result in a disengagement from environmental issues and impacts the willingness of youth to engage in pro-environmental behaviors (Barratt & Barratt Hacking, 2003; Connell, Fien, Less, Sykes, & Yencken, 1999; Sobel, 1999). Presentation of thoughtfully selected environmental images might assist in combating this resignation to environmental degradation: it is more difficult to disengage from a striking visual, and such may be effectively used in the classroom and other educational forums as a springboard to conversations that unearth pessimism and redirect this negativity into active engagement with possible solutions. Sobel (1999) has demonstrated in educational practice that children's connection with the natural world begins locally, in their own neighborhoods and towns. By extension, making environmental connection through images may also be best accomplished by choice of visuals that depict local and otherwise familiar environments and organisms.

A well-designed rubric that takes into account all of the issues previously discussed might considerably facilitate the selection of the richest and most effective images for environmental education, but the ability of educators to utilize the rubric to its fullest capacity is also critical to the selection process. . The extent to which educators understand environmental science concepts, and the causes, mechanics, and effects of environmental issues affects their ability to identify images containing appropriate content, and gaps in knowledge and understanding have been documented at a number of educator levels. Khalid (2003) noted an array of misconceptions about the causes and effects of the greenhouse effect, ozone depletion, and acid rain in pre-service high school teachers. A study of 155 practicing elementary school teachers (Michail et al., 2007) found that although 70% expressed 'rather great' or 'great' interest in environmental issues, and could frequently identify the human activities contributing to pollution, climate change etc., many were fairly uninformed of the mechanisms of the problems (e.g., the names of specific gases contributing to the greenhouse effect). Other studies of teachers' ideas about anthropogenically initiated environmental concerns such as acid rain (Dove, 1996; Khalid, 2003)), biodiversity (Gayford, 2000; Summers et al., 2000), the greenhouse effect (Dove, 1996; Khalid, 2003), and depletion of the ozone layer (Boyes, Chamber, & Stanisstreet, 1995; Dove, 1996; Khalid, 2003; Summers et al., 2000) have indicated a similar lack of scientific understanding: findings indicate that many teachers have difficulty distinguishing between issues and separating causes and consequences. Likely contributing factors to this haphazard and inadequate knowledge of environmental issues are: poor quality of information in the mass media (which Michail et al. (2007) found to be the major source of environmental information for many elementary teachers), interference from a romantic image of nature that conceptualizes the natural world as a place of perfect harmony that is endangered by changes and fluctuations (Cooper, 2001; Cuddington, 2001), and a tendency to focus on companion meanings at the expense of cognitive meanings in science education (including environmental science) discourse (Michail et al, 2007). Companion meanings (Roberts, 1998) are the social and humanistic implications that accompany science content, and while these promote engagement and 'relevance' of the factual content, student focus on such connections may conceal that underlying content understanding is incomplete or faulty (Michail et al., 2007). It was apparent in this study that even higher education faculty were vulnerable to focusing upon these companion meanings, evidenced by the number of comments that focused on human interactions with the environment. Thus as the process of image selection is further developed and refined, it will be appropriate to develop a rubric designed specifically to orient teachers to the science content of the images rather than companion meanings.

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APPENDIX 1

Rubric for Environmental Image Selection

Criteria based on Tufte's (1983; 1990; 1997; 2006) Visual Information Theory

Reviewer Name ____

Image Title____ Image Number _______

<table>
<tr><td rowspan="3">Criterion 1: Content - The image is rich in explicit and implicit environmentally relevant science content.
Question: Does the image explicitly depict environmental science content?

Examples of possible content based on National Science Content Standards (NRC, 1996):

a) Interdependence of organisms.
___ The image depicts an ecosystem (biological and physical community of interacting organisms).
___ The image depicts organisms engaged in interactions beneficial to one or more of the participant species, by providing food, shelter, or some other resource.
___ The image depicts organisms competing or engaged in interactions, which have negative effects on one or more of the participant species (such as predation).
___ The image depicts modifications to the natural ecosystem by humans.
___ The image depicts or suggests negative results of ecosystem modifications by humans (E.g., pollution, over-harvesting, atmospheric changes).

b) Population growth and natural resources)
___ The image depicts an ecosystem reaching its carrying capacity (number of people in relation to resources able to support the given environment).
___ The image depicts humans using natural resources to improve quality of life.</td><td>Fully Met-4</td><td>Mostly Met-3</td><td>Partly Met-2</td><td>Not Met-1</td></tr>
<tr><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td colspan="4">Comments: Please note the content you identify in this image</td></tr>
<tr><td rowspan="3">Criterion 2: Context - The image shows content in an accurate environmental context.

Question: Does the image portray organisms in an accurate environmental context, and does the image emphasize environmental science content and data rather than decorative elements?

Examples of accurate contextual environmental content: (e.g., a giraffe in a savannah eating acacia leaves.)</td><td>Fully Met-4</td><td>Mostly Met-3</td><td>Partly Met-2</td><td>Not Met-1</td></tr>
<tr><td>☐</td><td>☐</td><td>☐</td><td>☐</td></tr>
<tr><td colspan="4">Comments:</td></tr>
</table>

Criterion 3 Information Density of Image - Amount of information and data shown or implied in the depicted image. Question: What is the approximate percentage of information and data related to environmental content shown or implied in the depicted image? What percentage of the image on the page transmits environmental information? _____ 0-25% _____ 25-50% _____ 50-75% _____ 75-100%	Comments:			
Criterion 4: Credibility of Image Source - The image source is considered scientifically and/or historically credible and trustworthy. Question: Is the image source considered scientifically and/or historically credible and trustworthy?	Fully Met-4	Mostly Met-3	Partly Met-2	Not Met-1
	☐	☐	☐	☐
Please check the one that applies: _____ 1. The image is not from a scientifically and/or historically credible source _____ 2. The image is from a somewhat scientifically and/or historically credible source _____ 3. The image is for the most part from a scientifically and/or historically credible source _____ 4. The image is from a completely scientific and/or historically credible source	Comments:			