Sustainability **2015**, *7*, 10620-10648; doi:10.3390/su70810620

OPEN ACCESS

sustainability

ISSN 2071-1050

www.mdpi.com/journal/sustainability

Review

Using Web 2.0 and Social Media Technologies to Foster Proenvironmental Action

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Academic Editor: Marc A. Rosen

Received: 12 June 2015 / Accepted: 3 August 2015 / Published: 7 August 2015

Abstract: Research from a variety of disciplines suggests that online technologies (*i.e.*, Web 2.0 and social media) have considerable potential for spurring proenvironmental action; however, relatively little work examines how to effectively capitalize on these communication and organization tools. This review paper describes the Technologies for Proenvironmental Action Model (TPAM), a conceptual framework that explicates how different functions of Web 2.0 and social media (*i.e.*, informational, relational, and experiential) can generate and/or facilitate personal, social, and contextual pathways to environmentally responsible behaviors. As derived from the TPAM, the likelihood of achieving practical goals of increasing proenvironmental behaviors is enhanced when technological functions are matched to the different pathways to proenvironmental action. For example, the relational function of technologies, as exemplified by Social Networking Sites (SNSs), should be particularly effective in communicating social norms supportive of environmentally responsible behaviors. The TPAM is intended as a guide to develop novel approaches, research questions, and methodologies in leveraging Web 2.0 and social media technologies to promote proenvironmental action. Results will contribute to basic theory development and work in applied settings (e.g., local environmental organizations) in order to effectively communicate and organize with different segments of the population to increase sustainable behaviors.

Keywords: online technologies; Web 2.0; social media; Social Networking Sites; environmental issues; behavior change; environmentally responsible behaviors; sustainable behaviors; proenvironmental action; sustainability education

1. Introduction

Increasing the general public's environmentally friendly behaviors is central to environmental education [1]. However, many citizens feel uncertain, disempowered, or ill-equipped when it comes to taking action on complex environmental issues, such as climate change [2–7]. Nonetheless, individual and collective action is needed to help preserve natural environments and mitigate environmental problems [8,9]. Web 2.0 and social media technologies are a set of communication and organizational tools that are increasingly gaining attention for their potential to heighten environmental concern and facilitate sustainable behaviors in the general public [10–23].

Web 2.0 (e.g., Google, blogs) refers to the array of contemporary web-technologies that allow users to interactively engage people and media content in different ways [24], such as participatory information sharing [25]. Social media (e.g., Facebook, Twitter) refers to "a group of Internet-based applications that build on the ideological and technological foundations of Web 2.0, which allows for the creation and exchange of user-generated content" [26] (p. 61). Social Networking Sites (SNSs) are one type of social media and particularly function to provide users with an "online space" or web address to interact and connect with other people (e.g., [27,28]). Together, Web 2.0 and social media involve the sharing of digital content among people all over the world, but social media tools and content more specifically focus on their active and co-constructing users [29]. These technologies permit users to navigate through a virtual world unbounded by time and space, as well as to influence and co-create rather than just passively observe or take in.

Web 2.0 and social media are increasingly becoming part of daily life. According to a 2015 report on usage of more than 240 countries across the globe [30], approximately 42% of the world's population are active Internet users (an increase of 21% from 2014) and 29% have an active social media account (up 12% from 2014). Of these users, they spent, on average, 4.4 h per day using the Internet on a computer, 2.7 h on a mobile phone, and 2.4 h accessing social media technologies. The top six regions with the largest percentages of Internet and social media users, respectively, are North America (88%, 44%), West Europe (81%, 45%), Oceania (69%, 45%), East Europe (58%, 45%), South America (56%, 47%), and East Asia (51%, 43%). Although East Asia has a lower proportion of users than other top regions, it represents the region with largest population of Internet and social media users across the globe. Thus, online technologies (*i.e.*, Web 2.0 and social media) have the potential to reach wide swaths of citizenry, and may represent primary (and as of yet under-researched [16]) mediums for encouraging action to protect the environment. In fact, the utility of Web 2.0 and social media is being tested in social science research seeking to build and organize communities (e.g., [31]) and for purposes of climate change communication (e.g., [14,16,20,32]) and environmental education (e.g., [11,23,33]). However, research has yet to establish the "best" technologies and how to maximize their effectiveness. In this

review, we offer a conceptual framework to guide future research and practice to begin harnessing the power of Web 2.0 and social media to promote proenvironmental awareness and action.

In focusing on proenvironmental action or engaging in ways to protect the environment, we refer to a wide range of environmentally responsible behaviors (ERBs) varying along several dimensions, such as the degree to which the behavior is active, public, regular, or broad in scope. For instance, active ERBs include environmental activism or participating in a forest cleanup, whereas relatively more passive behaviors include activities such as signing an online petition. In short, proenvironmental action is a multidimensional umbrella term referring to all environmentally friendly and sustainable behaviors, regardless of whether they are more or less impactful than others.

2. The Technologies for Proenvironmental Action Model (TPAM)

The Technologies for Proenvironmental Action Model (TPAM) is a conceptual framework describing how certain functions of Web 2.0 and social media technologies may be leveraged to (A) generate and/or (B) facilitate pathways to proenvironmental action (see Figure 1). That is, certain technologies and their functions can be used to drive the different mechanisms to ERBs (e.g., distributing information to promote awareness of climate change), and/or moderate these mechanisms to strengthen their link with proenvironmental action (e.g., posting a message to remind people of their connection with nature and the importance of protecting the environment). Although research has identified many specific mechanisms to proenvironmental action, they can be broadly categorized based on their source of influence. The pathways tend to differentially stress personal, social, or contextual influences that predict or produce proenvironmental behavior.

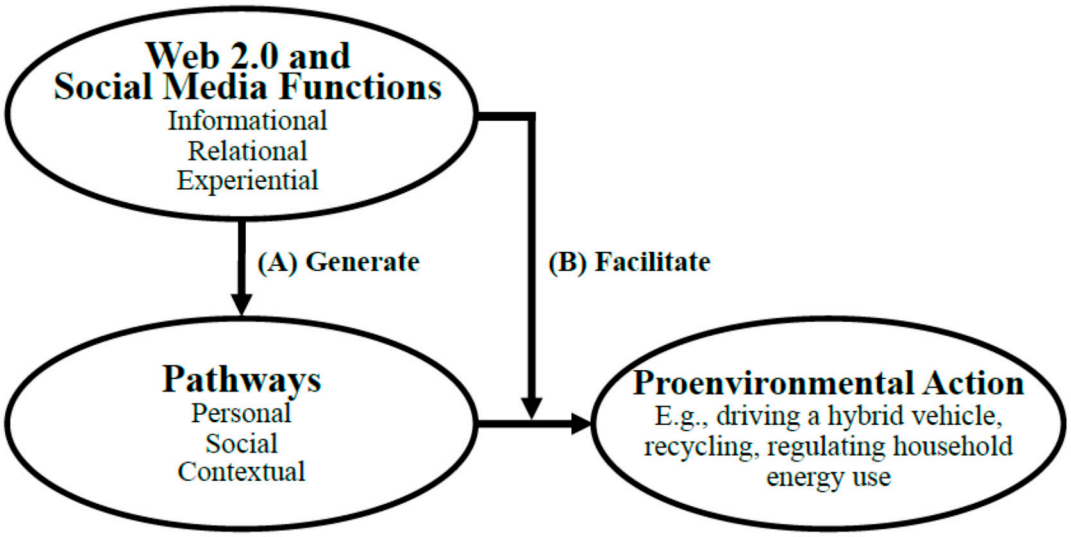

Figure 1. The Technologies for Proenvironmental Action Model (TPAM): A conceptual model linking the functions of Web 2.0 and social media in generating and/or facilitating pathways to proenvironmental action.

Personal factors refer to individual characteristics that influence the likelihood of caring for the environment and taking action to protect it. These factors include having a strong bond with the natural environment and positive attitudes toward taking care of it. Social factors refer to the influence of other

people (perceived, real, or imagined) in promoting proenvironmental behaviors. Thus, proenvironmental behaviors may be undertaken to enhance a social image or standing, or because of perceptions of what other people do and beliefs about their social correctness or appropriateness. Lastly, contextual factors are particular features of settings (e.g., communities, cultures, policies and regulations) that influence the likelihood and meaning of proenvironmental actions. These factors include either psychological and sociological (e.g., sense of community) or tangible and logistic (e.g., the existence and visibility of local recycling programs) features of settings. Thus, the TPAM proposes that Web 2.0 and social media technologies have functions that can be strategically used to generate and/or facilitate (*i.e.*, moderate) these factors of influence or pathways to proenvironmental action.

Web 2.0 and social media technologies have specific features characterized in terms of their broad informational, relational, and experiential functions. Technologies that serve informational functions have the capacity to produce, distribute, and collect knowledge and media content. These technologies put information at the user's fingertips and can be used to search for, read, and (re)post information and other material, such as the findings of environmental research. Relational functions focus on people's social goals, and include technologies whose primary purposes are to facilitate social network development, construction of social identities, or engagement in dialogue with others. Finally, experiential functions emphasize novel online experiences that are achieved through interactive and self-directed means. Technologies serving these functions might include online forums, blogs, interactive games, and web tools (e.g., ecological footprint calculator [34]). Many Web 2.0 and social media technologies possess features consistent with one or more of these functions; the functions are not mutually exclusive. Any overlap speaks to the flexibility and range of ways that different technologies can and may be combined and used.

To provide grounding for our conceptual framework, we begin by reviewing key theoretical and empirically supported pathways to proenvironmental action. Although there is no new data offered here, we summarize research on the functions of Web 2.0 and social media technologies. Then, we draw from this framework as well as other relevant research to speculate on the strategic use of technologies to generate and/or facilitate proenvironmental action via different pathways. Specifically, we consider ways of connecting people to the natural outdoors as well as different means of promoting participation in environmental programs. In the latter case, we focus on multidisciplinary, environmental Citizen Science programs, which seek to promote and involve the general public in environmental research locally or worldwide (e.g., [35,36]).

2.1. Personal Factors Promoting Proenvironmental Action

Among the personal factors associated with greater proenvironmental action are recurrent, positive childhood experiences in nature (e.g., [37]), accurate knowledge about the environment (e.g., [10,38,39]), personal norms or moral obligations (e.g., [40]), and positive environmental attitudes (e.g., [41,42]). Among the studied pathways, and a key driver of proenvironmental action, is a strong connection or relationship with nature [1,43–47].

Having a strong bond or sense of oneness with the natural environment has been conceptualized and assessed in a variety of ways in research, such as nature relatedness [44], connectedness to nature [1], and environmental identity [43]. The findings of one recent study suggest that the measures of these

concepts are strongly interrelated and that a multidimensional framework underlies people's relationships with nature [46]. Thus, we collapse these different conceptualizations into one multidimensional term: connections with nature. Connections with nature develop over time, especially from positive childhood experiences with nature, and are associated with empathic and protective behaviors toward the natural environment [37,48]. Connections with nature include a set of beliefs or cognitions tied to nature (e.g., people thinking that the natural world is a community to which they belong; [49]) as well as self-conceptualizations linked to nature (e.g., perceiving that personal welfare depends on the state of the natural environment; [46]). That is, connections with nature can become an important source of self-concept and identity (*i.e.*, environmental identity) in which people believe "that the environment is an important part of who [they] are" [43] (p. 46). In short, connections with nature can be central to how people view and define themselves.

Empirical research consistently shows that connections with nature are positively related to engaging in ecological behaviors as well as enhanced personal well-being (e.g., [1,46,50]). Research suggests that an environmental identity predicts proenvironmental action, even beyond environmental attitudes and social norms [51–54]. Moreover, environmental identity strongly predicts ERBs even when these behaviors are costly, effortful, and not extrinsically rewarding [55]. Not surprisingly, then, strengthening connections with nature is often advocated as an integral component in environmental education programs [1,56].

Different and specific individual motivations may be related to taking and maintaining proenvironmental actions [40,57–60]. As suggested by theory and research on volunteerism, personal needs and goals vary among people and are key to understanding what motivates people to get involved in causes and social action [61–64]. For instance, some people take action to meet other-focused motivations, such as concern for a community or expressing personal values (e.g., humanitarianism). To the extent that people perceive good correspondence between their activities and personal motivations and goals, they are likely to persist in those activities.

One study on urban conservation stewardship suggests that commitment to conservation volunteering depends on the match between motivations and perceived consequences of engagement [57]. In fact, results suggested that helping the environment was an important (significant) motivator of volunteer commitment only when efforts fulfilled salient personal, social, and community goals; and interestingly, helping the environment was less salient of a motivator than the other goals. Thus, it seems that performing ERBs can meet a range of motivations and goals other than environmental concern. For instance, people may engage in proenvironmental action to increase positive emotions [58] and participate in conservation efforts to interact with others and build community [57].

In a conceptually similar vein, the Integrated Framework for Encouraging Pro-Environmental Behaviour (IFEP; [65]) describes multiple and sometimes conflicting motivations for ERBs, including hedonic goals (e.g., for pleasure), gain goals (e.g., to save money), or normative goals (e.g., to do the right thing). When proenvironmental actions involve a conflict (or mismatch) between goals, the likelihood of performing such actions decreases. For instance, using public transport may be perceived as less convenient and less pleasurable than driving a car [66]. According to the IFEP, motivational influences are central to proenvironmental behaviors, and changing actual or perceived outcomes of performing ERBs so that they align with salient goals is one way to mitigate the negative effects of motivational mismatch on action.

Taken together, connections with nature seem to be important personal factors associated with the tendency to act environmentally responsibly. Research also supports the importance of motivational mechanisms to proenvironmental action; ERBs are likely to be initiated and maintained to the extent that they meet people's salient motivations and goals. Importantly, people need not be motivated by care or concern specifically for the environment to engage in proenvironmental action as long as the behavior is perceived as addressing a pertinent reason for performing it.

2.2. Social Factors Promoting Proenvironmental Action

Empirical research documents the role of social influences in proenvironmental action including social status or reputation concerns [67], expectations of support from close others (*i.e.*, subjective norms [68]), and perceptions of descriptive and injunctive norms supporting ERBs [69–77]. For example, in three experimental studies, the salience of social status motives or being concerned about social reputation significantly influenced people's desire to make more proenvironmental ("green") choices, such as buying a hybrid car, than those who did not receive the social status manipulation [67]. This effect was only found when making the green choice was public rather than private. These results suggest that social influences are key to making proenvironmental decisions; they seem to be impacted by concerns of public image when others are around to be witness to the decision.

Moreover, descriptive and injunctive norms appear to be key drivers of proenvironmental action. According to the focus theory of normative conduct [71], descriptive norms and injunctive norms strongly influence how people act. Descriptive norms refer to perceptions of typical behaviors people believe are commonly enacted by others. Descriptive norms also can be tied to a specific social-physical context (e.g., a neighborhood) referred to as descriptive local norms [78,79]. For example, knowing that many neighbors are enrolled in renewable energy programs signals that it is commonplace among residents in a community. In comparison, injunctive norms are tied to value judgments about specific behaviors, and generally derive from cultural or societal sources and institutions. That is, injunctive norms describe the behaviors that are typically approved (or disapproved) of in a particular social context. People learn about descriptive and injunctive norms through positive and negative message frames, words, and social cues. For example, in encouraging recycling behavior, a descriptive norm might underscore that recycling is widespread among a certain set of (similar) people, whereas an injunctive norm would stress that recycling is generally approved of and valued by others.

Empirical research supports the importance of norms in facilitating environment-relevant behavior change and sustaining actions. For instance, the combination of descriptive and injunctive normative messages has been effectively used to deter the pilfering of petrified wood in a national park [70] and increase towel reuse in hotels [80]. Moreover, descriptive local (neighborhood) norms about recycling behaviors are positively and significantly related to recycling intentions [78,79] and behaviors [81].

However, in some cases, descriptive norms might paradoxically influence individual behavior to go against the norm. In a field-based experiment, Schultz and colleagues [74] provided Southern California households with feedback on energy consumption as compared to their neighbors (descriptive norm); specifically, they learned through the use of door hang tags that they consumed more or less than their neighbors. When the feedback indicated that energy usage was above the average of neighbors' usage, household energy consumption was subsequently reduced. However, when households with relatively

low initial energy consumption learned of their low consumption compared to their neighbors, they tended to increase their subsequent energy consumption. That is, the descriptive norm message produced a boomerang effect in increasing energy consumption among initially low-level consumers. This boomerang effect was eliminated in a separate condition in which the descriptive feedback was accompanied by an injunctive component; households received a hand-drawn sad face on the energy feedback when consumption was higher than the neighborhood average, or a happy face when consumption was lower than average. When the injunctive component reinforced the descriptive information, households initially relatively low in energy consumption maintained their low consumption.

These findings suggest the potent impact of descriptive normative influences on some environmentally relevant behaviors, as well as how descriptive and injunctive norms can work together in changing and maintaining proenvironmental actions (see also [75]). More generally, these studies provide evidence supporting the pathway to proenvironmental action that focuses on social, and especially normative, influences. Individual behavior can be strongly influenced by social image concerns, social cues, and what others are perceived to be doing, and norm-based messages that indicate what ERBs are socially valued or appropriate are effective in promoting proenvironmental behavioral change [73,74,82].

2.3. Contextual Factors Promoting Proenvironmental Action

Certain features of settings influence people's conceptualizations of environmentalism and their propensity to take actions to protect the environment; we categorize these as contextual factors. For instance, communities and people's psychological attachment to their communities are contextual influences on proenvironmental actions. Research suggests that people are likely to engage in ERBs to the extent that they have concerns about particular communities or believe that communities they belong to are affected by environmental problems [31,76,83,84]. Community connections also influence broader forms of social action and civic engagement [62,85–87].

Communities can be characterized in terms of the depth and breadth of social connections within them (a concept referred to as social capital), their physical make up and resources (physical capital), and the properties and resources of community members (human capital; see [87]). These different forms of community capital are interrelated and they individually and in combination predict engagement in environmental issues by community members. For example, the density of urban tree cover in a locale (a feature of physical capital) has been found to significantly and positively relate to social capital even after controlling for possible confounds [88]. Moreover, social capital is greater in more stable communities [87]. For example, residential stability is positively associated with community investment and other indicators of pro-community behavior, including donating money to support the maintenance of local nature habitats [86]. In a study of five communities in Ireland, greater social capital as indexed by community member reports of greater neighborhood cohesion, social trust, and community connection was related to recycling behaviors [89].

Communities need not be defined solely in terms of resources or geography (*i.e.*, communities of place), but can be defined by shared interests, concerns, or member attributes (*i.e.*, communities of interest). This conceptualization focuses on the psychological nature of communities rather than on physical boundaries; the community includes similar members sharing with each other, gaining personal

meaning from their connections, and developing strong emotional bonds with each other and the community at large (*i.e.*, sense of community; [62,90–93]). Directly relevant to Web 2.0 and social media technologies, online communities (*i.e.*, those developed over the Internet and with virtual interaction) are important sources of identity, relationships, and sense of meaning and connection for many members [94,95]. Furthermore, online communities can operate as a "public virtual arena" [19] (p. 1099) for the mobilization of collective action both online (e.g., signing online petitions) and offline (e.g., participating in local projects and protests). Online communities may also be made up of "personal publics" where users interact with web content by degree of "personal relevance for a known, networked audience in a conversational mode" [96] (p. 7). In other words, the public sphere online can become personalized; online communities can be tailored and co-created by groups of users allowing individuals to fashion their identities and articulate social networks for personal reasons.

Similar to the conceptualization of sense of community is the emotional attachment and shared meaning that people have with a specific geographic place (*i.e.*, place attachment [97]). Research generally supports that place attachment is significantly, positively related to proenvironmental action [43,97–99]. In one study, having an emotional connection to the natural aspects of a city was a stronger predictor of self-reported proenvironmental behaviors than attachment to the civic aspects of a city [99]. Moreover, this natural place attachment was significantly greater in the city with better environmental quality, a finding that is consistent with research showing stronger place attachment among people who have access to a natural area [100] or live in neighborhoods with distinct urban design or terrain [101]. These results add to the literature suggesting that physical (particularly natural) features of communities and places are associated with residents' connections with them, and these connections are related to a tendency to protect the environment.

Taken together, the real and perceived features of communities and also shared feelings of belonging and connection are key influences in the promotion of taking action in the community. It is not surprising, then, that emphasizing a shared sense of "place" and "community" is a key strategy for community outreach programs aimed at engaging people in community issues (e.g., [102,103]). Although more research needs to be conducted on sense of community as a mechanism to environmental involvement, findings to date suggest that the physical capital and social capital of communities as well as the strength of personal connections to communities encourage proenvironmental behaviors. It seems likely that community connections are reciprocally related to action that displays care and stewardship of resources; together they may work to produce "higher quality" communities that are environmentally and socially healthier, where community members have stronger bonds to the community.

To this point, we have reviewed some key pathways to proenvironmental action. We have sought to bring some order and "higher order" understanding to this set of pathways by broadly categorizing them in terms of their emphasis on personal, social, or contextual factors. Having reviewed some of the primary pathways to proenvironmental action, we now seek to link them with the functions of popular Web 2.0 and social media technologies.

3. Leveraging Web 2.0 and Social Media to Enhance Proenvironmental Action

Research on Web 2.0 and social media suggests that people have specific reasons and goals for using different technologies, and people make choices to start and continue using technologies to the extent that they perceive that these tools help them meet particular goals. For example, uses and gratifications (U&G) theory suggests that people actively select and consume media to meet individual needs and goals [104,105]. Although this theory was originally developed to explain the effects of traditional media (e.g., televised media, newspapers) on viewers [106], recent studies have expanded its scope to include newer forms of (social) media such as Facebook and Twitter [107–110]. For instance, social media technologies are used to diversify social networks and opportunities for interaction, and they enhance and complement traditional and offline modes of experience [19,111,112]. This suggests that Web 2.0 and social media use is strongly tied to social capital motivations; people seek to expand their social networks to increase mutual support, social trust, sense of community, and access to resources [112].

In short, Web 2.0 and social media technologies are not monolithic in their uses and capabilities, and people selectively use them to meet salient needs and goals. As indicated by the Technologies for Proenvironmental Action Model (TPAM), technologies can be broadly characterized to serve informational (e.g., disseminating knowledge content online), relational (e.g., forging social connections in online communities), and experiential (e.g., active participation in online forums) functions. In the following sections, we briefly describe some popular technologies as exemplars in terms of salient functions they serve (see Table 1). The following Web 2.0 and social media technologies are not meant to represent an exhaustive list (especially with the continual development of new technologies), and most of them function in multiple ways, thus indicating their mutability of use and dynamic capacity to meet a variety of user goals.

For each function, we consider how it might be optimally leveraged in cost-effective and targeted ways to inform people about environmental issues and to spur action. That is, according to the TPAM, we speculate on how the functions can be used to generate (*i.e.*, drive) and/or facilitate (*i.e.*, moderate) personal, social, and contextual pathways to proenvironmental action (see Table 2 for brief predictions in generating pathways). Because Web 2.0 and social media have varying levels of functions, we expect their application to be differentially effective when linked with certain pathways. Given the paucity of research on the topic, the ultimate aim is to stimulate interest in empirically testing propositions of the TPAM.

3.1. Using Informational Functions

There exists a wealth of Web 2.0 and social media technologies strongly suited to information distribution and knowledge collection. For example, podcasts are interpretive media in the form of audio or video files for computers or portable media devices (e.g., cellular phones and tablets) that users consume by streaming online or downloading to their device [113]. Podcasts serve informational functions in that they are used for learning, knowledge acquisition and sharing, and education [102].

Social Networking Sites (SNSs; e.g., Facebook, Twitter) also serve informational functions; some examples of this informational use include "viral" media or online social contagion [17,31] and disseminating information about petitions and social causes [114]. According to some researchers, Twitter is a microblogging technology that is used for information and opinion sharing across a social

network [115,116]. Twitter users post text (*i.e.*, "tweets") for their own network of followers, and at the same time can "follow" customized news streams and participate in public in-the-moment conversations [117]. Twitter also has the ability to connect posts to a particular trend or topic via the "hashtag" ("#" e.g., "#nature"), "retweet" other's posts, include hyperlinks to other material, and also "shout out" to another user by referencing their username (e.g., "@username"). Together, these features allow users to easily search and aggregate information on specific topics, while also allowing organizers or sources to quickly disseminate information via their network of followers [115].

Table 1. Exemplars of Web 2.0 and social media technologies and degree of functions.

	Description	**Level of Functional Capacity (High, Moderate, Low)**		
		Informational	**Relational**	**Experiential**
Blogs	Online journal used for reading and writing long-form narratives as well as inserting graphics, interface customization, and dialogue using the comments section.	High	Low	High
Online Groups	These include digital bulletin boards (e.g., Wikispaces), forums, and educational courses (*i.e.*, MOOCs) allowing for users to develop private online-based arenas for collaboration and learning.	High	Moderate	High
Podcasts	Audio and/or video files for computers or portable devices that users can stream or download and consume.	High	Low	Moderate
SNS: Facebook	Most widely used SNS that has a variety of uses (e.g., gaming, participating in groups). Users can post pictures, videos, text, links, and invitations.	High	High	High
SNS: Instagram	Online mobile photo- and video-sharing SNS that allows for users to upload pictures or videos and adjust them with filters.	Low	High	High
SNS: Twitter	Widely used SNS or microblogging technology that limits posts to 140 characters and is useful for instant conversations, customizable news feeds, and online networking.	High	High	Moderate
YouTube	Online video-sharing website that allows for users to upload, watch, and share videos (e.g., funny clips, video blogs).	High	Low	High

Note: Table is expanded from one presented in Bik and Goldstein [117].

Table 2. Hypothesizing on different technological functions generating pathways to action

	Personal (e.g., connecting people to nature, increasing motivation to participate in Citizen Science)	**Social (e.g., normatively influencing others to act proenvironmentally)**	**Contextual (e.g., building community connections)**
Informational	• Disseminate information via Twitter, Facebook, or blogs to communicate importance of connecting with nature or use to recruit participants in a Citizen Science project. • Post pictures of local nature spaces to visit to promote connecting with nature.	• Information posted on Facebook or Twitter can be "Liked," "reshared," or commented on providing social cues to other people about approval of the information. • Post information about what locals are doing to help the environment.	• Information can be explicitly tied to the local community using words like "we" and "our" to underscore a joint sense of purpose • Post information on multiple technologies to promote greater exposure to the "community in action."
Relational	• Spark dialogic conversation with and between "friends" or followers (e.g., "What's your favorite #flower?") • Encourage users to upload pictures and "check-in" to a natural setting or park, and offer incentives in return (e.g., raffle entry)	• Broaden online networks by Facebook "friending" or Twitter "following" to enhance the image of the organization. • Encourage others to post content about what they are doing to connect with nature and "Like" or "@mention" them.	• Offering an online arena (e.g., Facebook group) for dialogue can connect community members together. • Citizen Science programs can use SNSs to network with participants, community members, and local organizations.
Experiential	• Create a photography contest of local ecology for users to post pictures on Instagram or Facebook. • Use "green blogs" to promote reflective writing about experiences in nature.	• Experiential uses (e.g., nature photography contest) can be made public so that other users are aware of others' activities. • Promote perceptions of desired behavior by acknowledging proenvironmental activities.	• Construct online interactive contexts (e.g., Wikispaces) to collaborate with community members. • Online contexts might build communities of shared concern, which might lead to community action offline.

The informational functions of technologies might be best matched with the goal of spreading awareness on a particular environmental issue. For example, research indicates that greater use of online technologies to distribute information (e.g., frequent blogging) is associated with increased readership of the knowledge content [20,117]. Environmental non-governmental organizations (ENGOs) use a variety of technologies (e.g., Facebook pages, YouTube videos, Twitter accounts) to foster visibility, raise awareness, and circulate relevant information and resources [14,118]. Technologies that allow for images to be shared and posted (e.g., Instagram, Facebook, blogs, Twitter) should be particularly effective and more captivating than text-only technologies (e.g., [20,119–121]).

In terms of generating personal pathways to proenvironmental action, for instance, disseminating information on ways to connect with nature (e.g., posting news and pictures on actual nearby locations) and their associated benefits (e.g., positive well-being) on sites such as Facebook and blogs might be effective ways to encourage people to participate in such activities. Including pictures of local nature spaces in these posts (tailoring to people's "home") are also effective forms of environmental

communication [6,122], and thus might be particularly useful in encouraging visits to a location to generate connections with nature. The pictures of local places of nature might also make people's connections with nature (and their community) salient, which can facilitate its link with ERBs, such as donating to a local environmental organization.

Another effective strategy should be disseminating information that frames the pathways to ERBs in terms of meeting specific (and perhaps multiple) personal goals, such as connecting with nature for health reasons or personal development. For example, online messages promoting awareness of local environmental programs/events can include reasons on how participation can meet a variety of goals (e.g., a way to "give back" to society, make friends, connect with the community). By underscoring multiple reasons for participating or volunteering, informational functions can be capitalized on to make motivations salient and how involvement meets those motives. This information might generate participation in environmental activities or facilitate existing involvement.

The informational functions of Web 2.0 and social media can also enrich socially-rooted pathways to proenvironmental action. In one study, podcasts with multiple narrators (as opposed to single narrators) were shown to significantly enhance tourist experiences in a national park, and consequently positive attitudes and intentions toward protecting the park [113]. Perceptions of social presence represented a key mechanism in this process in addition to an enhanced nature experience. Podcasts might be an interesting add-on to data collection trips that are part of environmental Citizen Science programs, and even be used as a potential motivator to get people involved. As a result, they might introduce interactivity when visiting places of nature and facilitate the relationship between connecting with nature and environmental stewardship.

As another example, posting content via Twitter and Facebook about what other local community members are doing to connect with nature or protect the environment could be effective in conveying descriptive and injunctive norms that would presumably encourage others to take similar actions. Posts on many technologies (particularly SNSs) are accompanied by social information (e.g., Facebook "Likes" and comments) that can influence perceptions of the information content [24]. On Twitter, people can "@mention" (or publicly message) others and "retweet" posts from others thereby publicly indicating their approval or enjoyment of another post. Individually, but especially when aggregated, Facebook "Likes" and Twitter retweets provide signals about the degree of support or endorsement of information or action. In short, users learn how widespread certain actions are (*i.e.*, descriptive information) and also the valence or regard that other people have for posted actions or attitudes (*i.e.*, injunctive information). These posts might also indicate a positive social image and status that is socially valued, facilitating links between social status concerns and proenvironmental behavior.

However, there is a potential drawback to the dynamic and publicly visible functions of some technologies like Facebook and Twitter. The same content that is "Liked" may also receive negative comments [32], and depending on the extremity and number, create normative support against the espoused attitudes and behaviors. In one study, participants who viewed an online news article on risks related to nanotechnology followed by negative and relatively uncivil comments perceived greater risks and thought the story was more biased than participants who saw the same story followed by benign comments [123]. It may be prudent for individuals or organizations using these very public forums to carefully consider the potential impact of unfiltered comments.

An organization or intervention targeting the contextual pathway might use technologies for informational purposes to disseminate content that increases visibility and knowledge of community issues (e.g., posting daily updates, recognizing community members). Information should be explicitly connected to community by highlighting collective goals and a joint sense of purpose, and by using words such as "we," "family," and "community" [31,124]. Information disseminated to community members (e.g., through an electronic newsletter) might build collective perceptions of community concern and action, and thus generate a greater sense of community or connection to others.

3.2. Using Relational Functions

Social media and particularly SNSs exemplify the relational function, or the degree to which online technologies serve to promote social connections, social identities, and other types of relationship-oriented goals (both interpersonal- and group-based). For instance, SNSs act as "relational amplifiers," in that they accentuate existing social relationships, connections, and capital [20,29,114,125–129]. SNSs assist people in forging new social connections (*i.e.*, "bridging" social capital) as well as in developing and maintaining intimate relationships (*i.e.*, "bonding" social capital; see [130]). Institutions and organizations also use SNSs to connect with stakeholders [131] and foster social ties and sense of community online [132,133] and offline [18,114,134].

As a specific case example, consider Facebook, currently the most widely used SNS [14,30]. Facebook is strong in its capacity for dialogic communication (via messaging and commenting) and allows users to create pages or groups (private or public) for multi-person interaction. Moreover, Facebook allows users to "follow" other people, organizations, and social groups through customizable news feeds that maintain users' connections with others by keeping them up to date with other's posts and activities. Facebook also shares similar features to Twitter, such as "shouting out" to other users or friends to mention them in a post; and uniquely allows users to "Like" (or publicly show approval) as well as comment on content that others post. Together, the relational functions of Facebook represent how they can be used to engage in dialogue (publicly), build social identities through interacting with similar others, and develop social connections with other users in their network.

Technologies specialized with relational functions can enhance personal pathways through interacting with others and identity development, such as encouraging dialogue on SNSs to create or strengthen connections with nature, specifically environmental identities. This might occur by having an environmental organization initiate conversation with and between "friends" or followers on a SNS, such as asking users "What's your favorite #flower?" on Twitter, Facebook, or Instagram (an example derived from [115]).

In general, relational functions of technologies are likely best aligned with social pathways. SNSs should be particularly effective in promoting social pathways to ERBs because of their potential and ability to broaden social networks, communicate norms, and build perceptions of close interaction among users [28]. A local environmental organization might use technologies that allow for multiple users or user posts (e.g., Facebook, Twitter, or Instagram) and capitalize on their social network to elicit input on their page or site about how they are protecting the environment, what they are doing to connect with nature, or even where they are going (to hike, explore wilderness, *etc.*). Learning about where friends and associates are visiting could encourage similar visits by other social network members through social

(normative) pathways. Moreover, positive posts from users (e.g., Facebook "Likes") suggest that connecting with nature is common and desirable. In fact, some of these examples are currently employed by organizations centered on connecting the general public to the natural outdoors (e.g., visit [135–137]). As another example, environmentally-focused Citizen Science programs might encourage participants to post scientific articles or other relevant information online and the organization could publicly affirm these actions. In so doing, the organization would convey norms that sharing relevant content is welcomed and positively appraised, which might subsequently stimulate others to want to participate in the production of science.

Some SNSs also allow for direct exchanges among users, or what amounts to an online arena for dialogue. For example, a Facebook group can be developed to promote socialization with and among users (e.g., Facebook "friending") and also for open discussion of issues and projects. To the extent that these exchanges are about environmental issues and what individuals are doing to support and sustain the environment, they should engender greater participation in proenvironmental action. A recent study examined the impact of the Facebook application Hot Dish in promoting environmental information sharing, commentary, and ERBs around climate change [22]. This application offers many social channels for users to exchange information and get to know each other; some of its key functions include the capacity to share news stories, comment on stories, and participate in both online (e.g., signing petitions) and offline (e.g., volunteering for an environmental organization) team challenges. In this study, the number of challenges completed, comments made, and stories posted by Hot Dish users were made public. Compared to a pretest, post-participation ratings suggested significantly greater environmental knowledge and ERBs among participants. In addition, participants reported greater motivation to use the application to engage with like-minded people. Findings from focus groups of users also suggested that participants provided each other with alternative perspectives and new insights on environmental science while encouraging daily proenvironmental behaviors. Thus, the relational functions of this Facebook application (e.g., engaging in dialogue, developing a social identity) appeared as a key moderator of social influences (e.g., learning what others are doing) in performing ERBs and even continued participation on the application. As proposed in the TPAM, providing an online space for people to post about environmental issues and behaviors should not only moderate social pathways to action, but also fashion them in situations where they are absent.

A different and recent study further underscores the importance of using Web 2.0 and social media technologies to generate and facilitate social pathways, and particularly normative influences on proenvironmental action [7]. In this case, the Facebook application My Everyday Earth was used to promote energy conservation among university students as well as participation in activities both online (e.g., "vlogs") and offline (e.g., a photography challenge). Surveys and focus groups after participation suggested that peer influence (e.g., friends, dorm resident assistants) was most influential in both energy conservation and continued participation on the application (similar to Hot Dish). Extrapolating from these findings, active participation in an environmental Citizen Science program might be fostered by developing a Facebook group with incentives (e.g., an award system) for online participation as well as sending invitations to "friends" or "followers" to join the online community or group. It is assumed that online participation may lead to offline participation in the program, as shown in previous research on civic and social action [19,114,138–140].

Using relational functions to develop online communities geared toward environmental issues is also speculated to effectively promote contextual mechanisms to proenvironmental action, specifically through sense of community. Online groups provide arenas for people to connect and feel or imagine themselves as part of a broader collective or community [29], thus affording technologies with relational functions to help build a sense of (online) community, such as creating a Facebook group. Online communities operate as arenas for "community information exchange, social support, and sociability" [19] (p. 1107), or as a medium to increase social capital and community attachment. Online communities are also likely to be co-created by their members who share information and engage in conversation personally relevant to them [96]. From this perspective, the private and public sphere can blur together in online communities and communication becomes conversational rather than one-sided, which together may contribute to and maintain a sense of online community. As such, the mere development of an online space may not be sufficient for stimulating interaction and dialogue. Users setting up online spaces for the goal of building online communities should play a central role in stimulating dialogue among others [12] and making the community personally relevant to members by considering their sociostructural factors and subcultural variations, tailoring to their interests, and encouraging self-expression. Furthermore, users that are highly engaged with their community stay up to date with their network and "the pulse of the community" [115] (p. 64). These perspectives indicate that leveraging relational functions are key to generating an engaging online community, one that participants feel psychologically connected to. Then, these online communities can be drawn on to facilitate participate in online ERBs (e.g., support a proenvironmental initiative) or offline (e.g., volunteer for a Citizen Science event).

3.3. Using Experiential Functions

Web 2.0 and social media technologies also afford novel opportunities for interactive, self-directed participation and learning that users may not experience offline. A qualitative study of Web 2.0 and social media use by youth suggested that they use these technologies as an experiential medium for civic participation; they turned to these tools because they felt alienated from traditional public forms of civic and political participation and also lacked self-efficacy for engaging in in-person interactions in the public sphere [141]. Thus, Web 2.0 and social media can function to provide opportunities for (online) social participation and engagement, and may be especially appealing for educational purposes and people not otherwise engaged in the public sphere.

SNSs are capable of inciting individuals to participants in online social causes and collective action [14,17,18,31,140,142]. That is, SNSs serve experiential purposes in that they engage users as participants in social causes through online activism [7,14,19,134,143–147] and philanthropy [148,149]. For example, SNSs can be used for online petitioning of environmental causes and crowdfunding (*i.e.*, raising funds from a vast amount of people). In one study, Greenpeace used Facebook as a "mobilizing tool" to engage more people in environmental campaigns [14].

Instagram, another SNS, also appears to have a strong experiential function; it is an online mobile photo- and video-sharing phone or tablet application ("app") that allows users to take pictures or short video clips and upload them for others in their social network to see, "Like," and comment on. In two such cases, citizen naturalists in a city and across the globe share observations about natural species,

including their locations and appearance (e.g., visit [150,151]). Similarly, YouTube is an online video-sharing website that allows users to upload, watch, and share videos with others [26]. Instagram and YouTube serve experiential purposes for users because these technologies encourage them to act as photographers and filmographers by documenting valued moments and instantly sharing them with friends or a network of people from all over the world—a type of unique engagement they might not typically experience offline.

Online digital bulletin boards like Wikispaces function as experiential tools in which users create private internet-based spaces for brainstorming, working with others, and other forms of joint participation. Members of a Wikispace can add and edit content simultaneously making the technology dynamic and supportive of real time collaboration. Similar to online digital bulletin boards in their experiential functions are online forums and educational courses (*i.e.*, Massive Open Online Courses or MOOCs [23]). MOOCs provide free learning materials, instructional services, and support from experts and other learners within a certain timeframe. Because of their self-directed experiential functions (e.g., forums, lecture videos), they seem well-matched with environmental and sustainability curricula, as well as intercultural dialogue and interdisciplinary knowledge generation [11,23]. In short, these experiential Web 2.0 technologies set up a participatory arena for dialogue, social learning, and community building without requiring people to physically congregate in a specific location.

Blogs are another example of a technology that serves experiential purposes; they are online journals used for reading and writing long-form narratives and permit users to upload pictures, customize the interface, and engage in dialogue with others using the comments section [117]. Although blogs also function to circulate information or news [24], they afford writers with the opportunity to actively participate in this process of information sharing and use them for self-expression [152], thus demonstrating their experiential functions.

Experiential functions of technologies appear suited for generating and facilitating personal mechanisms to action, and may be especially attractive to youth who are often drawn to interactive technologies that give them power, tools, and efficacy to take ownership of issues [7,33,153]. For example, writing a "green blog" (*i.e.*, an online journal about nature experiences) can promote reflecting about personal experiences in nature [152], which is likely to strengthen feelings of connection with nature (e.g., visit [154]). In another example, youth might be encouraged to make their own YouTube videos (*i.e.*, "vlogs" or video blogs) about what they do to connect with nature (e.g., visit [155]). Similarly, youth can participate in a proenvironmental graphic design contest to create a message, such as "memes", around the importance of conserving their local environment as a means to moderate the relationship between connection with nature and proenvironmental action (e.g., visit [156]). Photography contests on Instagram (or other SNSs like Facebook) in which people take pictures of local habitats and share them with other people might encourage interactive visits to natural settings and consequently generate appreciation of and connections with nature. This latter example is often applied in environmental programs striving to connect the general public to the natural environment (e.g., visit [157]).

Other technologies serving experiential purposes (*i.e.*, interactive games and mapping tools) are also predicted to engage people in proenvironmental action [21,31]. A recent two-part study examined a game called Power House aimed at changing people's energy consumption behaviors [21]. The game's goal was to track a family of four around their home and turn on and off the appliances they would use (e.g., computers, lights) in order to keep the family from overloading electricity. During the game, players

were shown information about how much energy each appliance used. In the laboratory, participants who played the energy game (Power House) as opposed to an entertainment game (Diner Dash) were significantly more likely to turn off the laboratory's electrical appliances before exiting the room. In the field experiment that followed, findings suggested that participants who played the game (on average for 17 days) showed a significant drop in electrical usage in their home relative to 30 days before and after the game began. These findings link playing an interactive game to protecting the environment, though, the specific mechanism to action remains unclear. As proposed by the TPAM, the experiential function of Power House simulates real-life engagement and likely makes salient the motivation to conserve energy, thus facilitating the link between concerns about energy consumption and taking action to lessen use. The game's experiential function might also generate an otherwise absent motivation to conserve.

In another example, YardMap is a conservation-based SNS that allows users to visualize their local, environmental practices on a Google Maps interface [31]. Participants choose any location on the map (e.g., residential property, school, park) and specify characteristics for their location, such as whether they use pesticides on the vegetation. Then, participants virtually develop and manage the location, for example, by planting trees or building water features. To the extent that sustainable practices are adopted on YardMap, they are expected to transfer to offline practices of proenvironmental behaviors by users. Although this application has yet to be formally evaluated, in terms of the TPAM, the mapping tool simulates engagement in protecting the environment (an experiential function), and generates or facilitates personal links (e.g., strengthening environmental identities, making salient environmental concern motives) to performing ERBs.

Furthermore, YardMap participants know what and how much others are contributing; they can view their maps, leave comments, and "Like" and follow different sites. When participants change their maps and receive "badges" for adopting sustainable practices (e.g., having a healthy yard), these updates are publicly visible in the social network's news feed. These badges might signal social status in that having many badges suggests prestige. Similar to the normative feedback participants received in the household energy intervention study [74], YardMap allows participants to visualize their maps relative to other users' maps in terms of sustainable practices and to receive positive feedback (e.g., a happy face emoticon) if their practices exceed the norm. In short, users learn about both norms by participating in a virtual environment, which is also expected to promote awareness of positive (and negative) environmental impacts leading to a tendency to engage in conservation behaviors offline. Thus, in line with the TPAM, making participation and contributions public (leveraging both experiential and relational functions) should facilitate social, especially normative, pathways to proenvironmental action.

Online groups, such as bulletin boards (e.g., Wikispaces) and educational courses (*i.e.*, MOOCs), can be used for experiential purposes by simulating real-life interactions with others, and thus be capitalized on to build online communities of action (a contextual pathway). In a qualitative study of Wikispace use in a corporate setting, managers and collaborators were strongly satisfied with the technology for sharing knowledge and experiences [158]. Moreover, collaborators felt more motivated to participate and cooperate with one another than in usual face-to-face contexts, and they reported in interviews that participating on Wikispace increased their sense of community within their company. These results suggest that online groups (and their experiential functions) stimulate more interactivity and participation than in offline group contexts. As such, leveraging this function may be especially effective

when paired with contextual pathways to proenvironmental action revolving around generating a sense of (online) community specifically tied to environmental issues.

Taken together, Web 2.0 and social media technologies complement traditional forms of media consumption (e.g., reading newspapers), socialization (e.g., face-to-face networking), and social participation (e.g., activism), and are increasingly and widely used for communication purposes and to organize people for social action. More empirical research is needed not just on the relative effectiveness of the different technologies, but especially on how to leverage them so as to maximize the influence of personal, social, and contextual pathways in promoting social action, and more specifically, action that protects the environment and enhances sustainability efforts.

4. Discussion

Although there is considerable speculation in using Web 2.0 and social media to promote ERBs (e.g., [12,16,18,22]), research has yet to develop a framework for effectively using different online technologies for proenvironmental purposes. In this review, we have outlined several specific pathways for engaging people in proenvironmental action and broadly clustered them in terms of their emphasis on personal, social, or contextual sources of influence. In addition, we have reviewed several commonly used and specific Web 2.0 and social media technologies, noting the extent to which they seem to serve or focus on informational, relational, and experiential functions. Finally, we have offered the Technologies for Proenvironmental Action Model (TPAM); this is our attempt to conceptually link different Web 2.0 and social media to the pathways in generating and/or facilitating mechanisms to proenvironmental action. That is, the three different functions of online technologies can be strategically used to drive pathways and/or moderate the strength of their link with ERBs. Where possible, we turned to research findings to offer empirical support for matching the different technologies to specific pathways so as to enhance (if not maximize) their effectiveness. Although there is no original data presented here, the TPAM serves as a guide for identifying and testing promising directions for research and intervention.

For example, we suggest that capitalizing on the relational functions of Web 2.0 and social media, specifically SNSs, are especially effective in strengthening social influences on proenvironmental behavior. Also, Facebook might represent one of the most useful technologies to begin with because of its current widespread use [14,30] and its high levels of informational, relational, and experiential functions. As a specific example, Facebook posts and responses (e.g., "Likes") might be used to evoke social status implications, and descriptive and injunctive norms about what others are doing to protect the environment. Moreover, Facebook groups serving relational (e.g., building social identities) and experiential (e.g., participating in a thoughtful, interactive discussion) functions can be used to facilitate dialogue around environmental issues. In the context of organizations, such as nonprofits and advocacy programs, some researchers argue that dialogic strategies and relational functions of technologies have not been fully used to their advantage [12,116,159]. Therefore, the relational functions of technologies and their link with social pathways to action might represent important avenues for both research and practice geared toward environmental communication and organization.

Although our review has focused on the potential of different pathways and technologies, it is important to recognize that certain pathways and particular technologies have differential appeal and

effectiveness depending on people's access, preferences, needs, skills, and experiences. Said another way, we have stressed how certain technologies and their functions may be good matches to particular pathways, but likewise, there is selection bias involved and certain pathways and technologies may better fit certain people. For instance, engaging in technologies serving experiential functions requires a motivation and desire for interactivity [120]. Similarly, continued use also strongly depends on the technology itself [160]. There are also sociostructural factors related to disparities in technological access, skill, and use, conceptualized as the "digital divide" [15,29,111,112]. Although research suggests that inequalities in physical access to online technologies are narrowing, significant differences in skill and the nature of use remain [161]. It is pertinent for research to identify ways (e.g., via international agencies, governments, practitioners) to engage different groups of people in online technologies [15]. Therefore, communication and organizational efforts that capitalize on the primary functions specific to Web 2.0 and social media technologies can be expected to be most effective in promoting action when they are captivating, engaging, and simultaneously tailored to the populations (*i.e.*, targets) of interest.

Most importantly, effective environmental communication should have well-crafted messages (e.g., [20]) and speak to "place-based differences as well as to various dimensions of subcultural variation" [122] (p. 118). For instance, messages about climate change may be more effective if they depict personal relevance (e.g., framing it as a local problem; see [6]) and are familiar to people's perceptions of sustainability (e.g., using realistic visualizations and familiar landscapes to make climate change personal; [17,119,162–164]). Online environmental communication that conveys personal relevance can elicit strong emotional responses to sustainability issues potentially spreading across online networks to reach policy decision makers motivating them to implement change [17,164]. Clear messages accompanied with aesthetic visuals are likely to capture attention in the midst of the vast amount of information posted online, and thus attract more viewers [20]. In addition, communication efforts should be particularly effective when the message is legitimate, credible, and actionable [165,166], and when the source of communication builds trust and mutual collaboration with their audience [167]. For example, one study suggests that building an online presence or "brand" is very effective in promoting awareness and usage of an environmental program's resources [20]. In short, the message, media (e.g., visuals, videos), and messenger (or source) are all central to communication and organization processes in the online sphere [20,166,168].

5. Conclusions

Ultimately, the practical goal in offering the TPAM is to encourage greater use of Web 2.0 and social media to increase ERBs, and to do so using theoretically grounded and empirically supported pathways to environmental engagement. The ubiquity of Web 2.0 and social media technologies in the public sphere alone warrants continuing empirical research on their utility in communicating with and organizing users (e.g., volunteers, community members, stakeholders). Importantly, our suggestions about how specific technologies enhance the power or influence of particular pathways to proenvironmental action are based on an extensive literature review and need additional investigation to rigorously test predictions from the model and the differential impact of using various functions. Research examining technologies for proenvironmental action will promote basic theory development to better understand how and what technological functions can be "best" matched with the different

pathways, if they primarily generate or strengthen the pathways, and under what conditions and populations the effects occur. Research will also encourage greater development and use of innovative methodologies and measurement tools to collect and analyze data. Furthermore, research of this type is particularly relevant to applied settings, such as online environmental education programs, local environmental organizations, and programs using community-based social marketing (see [169]). Findings can provide them with empirically based strategies to test out with their networks in the online sphere, ultimately to improve their capacity to engage their community in environmental issues, and especially to reach out to different groups of people (e.g., differences in age, culture, socioeconomic status). Together, results may lead to more efficient and effective means of engaging new and different segments of the population in taking action. Findings may likewise encourage greater use of Web 2.0 and social media technologies in broader forms of social action. In short, we anticipate this review and integration of literature—including the conceptual framework and speculative hypotheses derived from the TPAM—will stimulate interest and further research on the use of Web 2.0 and social media technologies in fostering proenvironmental action.

Acknowledgments

This project and preparation of the article was supported by a Research Joint Venture Agreement with the USDA Forest Service, Pacific Southwest Research Station (#12-11272131-062).

Author Contributions

Matthew T. Ballew conducted the literature review, developed the model, and wrote the paper; Allen M. Omoto and Patricia L. Winter provided insight and edited the manuscript.

Conflicts of Interest

The authors declare no conflict of interest.

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