UC Santa Barbara

UC Santa Barbara Previously Published Works

Title

Cumulative Advantage in Sustainability Communication

Permalink

https://escholarship.org/uc/item/2c90c090

Journal

Science Communication, 38(6)

ISSN

1075-5470

Authors

Gustafson, Abel
Rice, Ronald E

Publication Date

2016-12-01

DOI

10.1177/1075547016674320

Peer reviewed

eScholarship.org Powered by the California Digital Library
University of California

Gustafson, A., & Rice, R. E. (2016). Cumulative advantage in sustainability communication: unintended implications of the knowledge deficit model. *Science Communication, 38*(6), 800-811. doi:10.1177/1075547016674320

[Note: there may be some small differences between this submitted manuscript version and the final published version cited above]

Abstract

The knowledge deficit model proposes that more information increases public knowledge levels about a given topic, and thus improved related attitudes and practice. However, research critiques the varying and limited ability of the deficit model. Further, the deficit model can also produce an unintended cumulative advantage system: growing inequality between and within the knowledge-attitude-practice (KAP) gap of individuals and groups due to a wide variety of possible moderators. Over time, these effects can exacerbate gaps between individuals' and groups' levels of KAP. We discuss the negative effects of increasing inequality in sustainability KAP, and provide recommendations for future research.

Keywords: cumulative advantage, sustainability, knowledge deficit model, knowledge gap, knowledge-attitude-practice, science communication

Cumulative Advantage in Sustainability Communication: Unintended Implications of the Knowledge Deficit Model

For several decades, the importance of general environmental care, sustainability, and climate change has stimulated research agendas, government policies, economic and infrastructure decisions, and media headlines across the globe (Boykoff & Roberts, 2007; IPCC 2007). Sustainability refers to behavior, policy, and development that "meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 43) and, as such, is socially, ethically, and economically motivated. "Effective" sustainability communication (SC) would improve knowledge about, change attitudes toward, and motivate improved practice in sustainability (Godemann & Michelson, 2011). However, despite massive efforts toward accomplishing these goals, the effectiveness of SC (e.g., concerning climate change) has been underwhelming.

This underachievement necessitates better understanding of the assumptions and factors affecting the relationships between SC and its effects. Thus, we explore diverse fields of research that converge on an alternative perspective about the effects of SC. We argue that the effects of deficit-based SC can form a cumulative advantage system, exacerbating the divides between and within the knowledge (K), attitudes (A), and practice (P) of individuals and groups.

The following sections discuss deficits between public and scientific knowledge about sustainability issues, the deficit model's goals and its assumptions, the relationships of K to A and P, divergences among these three, moderators of these relationships, the pervasiveness and generality of cumulative advantage systems, the disadvantages of cumulative advantage (even when the deficit model works), cumulative advantage in the knowledge-attitude-practice process, and future research directions.

Sustainability Science Communication

Public Opinion and Scientific Consensus

Sustainability and its associated buzzwords, such as conservation of resources, "green" products, climate change, and energy efficiency, have been increasingly prevalent in the media

(Boykoff & Roberts, 2007). Yet a recent poll shows large discrepancy between public's knowledge and opinion on science topics, and that of scientists (Pew, 2015). Almost all (98%) scientists think that "humans, and other living things, evolved due to natural processes," yet only 65% of non-scientists agreed. The interdisciplinary scientist population overwhelmingly (87% - around 98% of climate experts) supported the statement "the earth is getting warmer because of human activity"; only 50% of non-scientists agreed.

Public opinion on major sustainability issues – such as climate change – is divided. Large segments of the population are either uninformed about or even vehemently opposed to the scientific consensus by denying climate change or its human causes (Guber, 2012; Guy, Kashima, Walker, & O'Neill, 2014; Leiserowitz, Maibach, Roser-Renouf, Feinberg, & Howe, 2013; McCright & Dunlap, 2011). 42% of the adult US population feel that the seriousness of global warming is "generally exaggerated" (compared to "generally correct" or "generally underestimated") (Gallup, 2015).

Certainly, sustainability issues beyond climate change – such as green consumerism, sustainable agriculture, and resource conservation – may be less politicized and less divisive. Still, public opinion and understanding of diverse and major science issues are often laden with popular misconceptions and myths that do not reflect the relevant science. Of course, one might expect lay people and scientists to have discrepant knowledge – on any issue – simply because of the discrepant levels of training, awareness, access to information, and specialization. Thus, the reduction of public knowledge deficits has long been seen as an intuitive path toward affecting attitude and behavior change in sustainability issues.

The Deficit Model

Communication promoting sustainability knowledge, attitudes, and practice has long and often operated from this *knowledge deficit model*. Such efforts assume that insufficient or inaccurate knowledge are the best explanations for false beliefs and negative attitudes toward a science issue, and for under-involvement in the recommended behavior (Bauer, Allum, & Miller, 2007). The *modus operandi* of the decades of science and health communication campaigns has largely been to assume that social problems – ranging from smoking to recycling or water conservation – are largely caused or perpetuated by the public's insufficient or inaccurate knowledge about the relevant scientific evidence (Bauer et al., 2007; Hyman & Sheatsley, 1947). This model assumes that increased appropriate SC should therefore improve the public's general knowledge of the scientific basis, causal relations, likely implications, or relevant practices concerning sustainability issues (see Figure 1).

--- Figure 1 Goes Here ---

Complex Effects of SC on Knowledge, Attitudes, and Practice

Sustainability communication campaigns usually disseminate knowledge in order to change attitudes (such as increasing concern) and subsequently achieve practice goals ("green" behaviors). Theories of psychology and communication generally argue that knowledge increase has the potential to change attitudes (Valente, Paredes, & Poppe, 1998), and that attitudes can then change practice (Ajzen & Fishbein, 1980; Fishbein & Ajzen, 2011; Kim & Hunter, 1993).

The K-A-P Model

This knowledge-attitude-practice (KAP) progression (Figure 2) is grounded in social learning theory (Bandura, 1986), diffusion of innovations (Rogers, 2003), marketing (Ray, 1975), and health and development campaigns (Valente, Paredes, & Poppe, 1998). Understanding the causal relationships, and overcoming the difficulties of achieving strong linkages, from K to A to P, are central to the development of communication programs. While

some have posited alternatives to this general sequence of K-A-P (Bem, 1967; Chaffee & Roser, 1986; Valente et al., 1998), we focus on the traditional K-A-P path.

--- Figure 2 Goes Here ---

Divergences between Knowledge, Attitudes and Practice

The knowledge deficit model, and KAP, both implicitly assume a direct and highly correlated relationship between knowledge, attitudes, and practice – that is, that they *converge* over time (Figure 2). For example, a recent Australian survey demonstrated a correlation between specific knowledge about climate science and agreement with the scientific consensus (Guy et al., 2014). Sturgis and Allum (2004) concluded that scientific and political knowledge are indeed significant predictors of favorable attitudes toward science, although they note many impeding factors. Blake (1999) argued for the intuitive and prevalent coupling of environmental attitudes and sustainable practice, but with similar qualifications.

However, early reviews cast doubt on the likelihood of convergence, showing little or no relationship between attitudes and behavior (Wicker, 1969). Later theoretical models highlighted the influence of myriad moderating and mediating factors that can motivate or impede the progression of K-A-P (Blake, 1999; Fishbein & Ajzen, 2011). Prominently, McGuire's hierarchy of effects model (2012) identified 13 steps in the persuasion process, including exposure, attitude change, and action. Each step has a varying likelihood of catalyzing the next step, with interactions, countervailing implications, and dependence on source, message, channel, and receiver characteristics. Thus, strong and lasting effects are very difficult to achieve (Ray, 1975). Indeed, meta-analyses of large-scale, formal, well-designed public communication campaigns show small effect sizes ($\bar{r} = .09$) of "interventions" (typically a knowledge provision) on "outcomes" (changes in attitudes or practice) (Snyder et al., 2004). Further, experimental research suggests the consumption of sustainability science information has only a small positive effect on attitudes such as environmental concern (Brulle, Carmichale, & Jenkins, 2012).

Moderators of Sustainability Communication Effects in K-A-P

Extensive research has identified many moderators of the K-A-P process, such as education, income, gender, social norms, resource availability, beliefs, values, ethnicity, culture, religion, authority structure, varying causal sequences, self-efficacy, response efficacy, complexity of the practice, time between attitude and practice, stage of life, and trialability of the practice (Bem, 1967; McPhee & Cushman, 1980; Rice & Atkin, 2012; Valente et al., 1998). The weak causal linkages and pervasive moderators in the K-A-P progression have motivated widespread critiques of the deficit model, arguing that it is a naïve solution to a complex problem (Ajzen, Joyce, Sheikh, & Cote, 2011; Hart & Nisbet, 2011). Thus, we should expect the effect of SC on the KAP progression to be inextricably moderated by powerful social, cultural, psychological, and economic forces, producing both small and non-uniform effects.

Such forces can suppress, reframe, or even reverse the intended effects of SC (Achenbach, 2015; Hart & Nisbet, 2011; Kahan, Jenkins-Smith, & Braman, 2011; Wolf & Moser, 2011). The formation of opinions about climate change, specifically, can be influenced by diverse factors such as perceptions of local weather and understanding of climate; culture; values, beliefs, and political identification (Leiserowitz, Maibach, Roser-Renouf, Feinberg, & Howe, 2013); trust (in science, government, or environmental groups); in addition to knowledge (Hoffman, 2015; Kahan, 2010; Marquart-Pyatt et al., 2011).

Because of the myriad factors that moderate relationships among K, A, and P, it is no surprise that while we see mostly positive public opinion about the general idea of sustainability

(Downing & Ballentine, 2007), that is much more prevalent than sustainability practice itself (Gallup, 2015).

There is no single moderating variable that explains the patterns of effects of any and all SC. Often, multiple moderators are in play simultaneously – compounding, interacting with, or suppressing each other – with some being more salient or influential, depending on the context or topic. The following sections constitute a brief sample of the many variables that research shows can moderate the relationships between K, A, and P in sustainability issues. Individuals and groups who differ on these variables likely experience disparate effects of SC on K, A, and P.

Group identification. In general, people are more accepting of information and persuasion from ingroup sources and confirmatory perspectives (Mackie, Worth, & Asuncion, 1990; McGarty, Haslam, Hutchinson, & Turner, 1994). Persuasive messages coming from an ingroup source (one that is perceived as sharing a salient group membership) are more effective in changing attitudes and behavior, compared to outgroup sources. According to self-categorization theory (Turner, 1985), when an advocated position represents the norms of an outgroup (often the case in SC, where the outgroup is a sustainability scientist, policy-maker, or advocate), the result is not assimilation toward the outgroup; instead, the result is polarization away from it (Hogg, Turner, & Davidson, 1990). Many sustainability attitudes and practices can be associated with certain social, ideological, political, or regional groups. The *degree* to which a SC receiver identifies as "that type of person" will moderate their tendency to adopt sustainability attitudes and actions.

Existing beliefs. Motivated reasoning (Kunda, 1990) proposes that individuals construe their perceptions of incoming information so as to support their existing attitudes. Thus, the link between K and A (or, even the formation of K) is moderated by existing beliefs. Many scholars suggest that a dominant source of continued polarization in attitudes about climate change or sustainability issues, despite the efforts of SC, is this motivated reasoning (Kahan, 2012). Hart and Nisbet (2011) argued that the motivated reasoning of SC audiences can cause an unintended "boomerang effect" under some conditions, leading those with oppositional beliefs to sustainability regulation policies to become even *more* opposed.

Ideology. Broader ideological orientations (which often underlie party affiliation) also have powerful influence on sustainability attitudes and practice. Individualism and belief in a free market economy are negatively related to agreement with the existence, anthropogenic nature, and danger of climate change (Guy et al., 2014), and thus with proposed appropriate practice (policies or behavior). For those with a more pro-environmental ideology, Corbett and Durfee (2004) found that context or controversy messages in experimental news stories had less effect on one's certainty about global warming. Other sustainability issues are not so famously polarized by party affiliation, yet even individuals' recycling behavior and bottled water consumption – as representing sustainable behavior – are significantly correlated with political ideology (Coffey & Joseph, 2013; O'Donnell & Rice, 2012). Kahan and colleagues (2011) found a small *negative* correlation between scientific knowledge (K) and general environmental concern (A) among those with a hierarchical ideology (social stratification and its associated access to resources as the natural order), but a stronger and *positive* correlation (and substantially higher mean level of concern) for those with a communitarian (interdependence and solidarity) or egalitarian (equal access to resources and opportunities) ideology.

Party affiliation. Unfortunately, knowledge of climate science is not the best predictor of an individual's attitudes toward the scientific consensus on climate change; instead, it's their political party affiliation (Guber, 2012; Roser-Renouf et al., 2014). Similarly, the "belief gap"

(Hindman, 2009; Nisbet, Cooper, & Ellithorpe, 2014) suggests that party affiliation is a stronger predictor of attitudes about climate change than education level. Thus in SC about politically charged topics, the effect of party affiliation is likely to outweigh the effects of SC on the K, A, and/or P (Nisbet, Cooper, & Ellithorpe, 2014; Nisbet, Cooper, & Garrett, 2015). Further, confirmation bias, selective exposure, and selective perception of information about politically charged topics can cause K and A to become increasingly polarized along party lines (Bennett & Iyengar, 2008).

Uncertainty portrayals. One of the cornerstone ethics of the journalism profession is balance – reporting "both sides" of an issue. As a result, television and print news coverage of sustainability issues such as climate change have offered both sides of the "debate," implying that support for each position is about equal, and framing the state of science as being uncertain regarding the anthropogenesis and threat of climate change (Antilla, 2005; Boykoff & Boykoff, 2004), thus substantially under-representing the overwhelming scientific consensus on both (IPCC, 2007; Oreskes, 2004). Uncertainty framing of SC can perpetuate or exacerbate the gap between public opinion and scientific consensus (Nisbet, 2009; Weber & Stern, 2011), which is a direct frustration of the goals of the SC. Those with existing pro-environmental ideologies are least affected by these portrayals of uncertainty (Corbett & Durfee, 2004). Thus, these moderation effects are non-uniform across (i.e., moderated by) different pre-existing ideologies.

Income. Green products – made in sustainable ways or with sustainable materials – are often more expensive purchases than their unsustainable counterparts. While solar panels, sustainably produced foods, hybrid or electric automobiles, or energy-efficient home renovations may be wise decisions (economically and ethically) in the long run, many individuals lack the overhead capital that is necessary to engage in these behaviors (though in the case of solar photovoltaics, innovative financing is reducing this obstacle; Dusonchet & Telaretti, 2010). In a more general sense, a hierarchy of needs perspective (Maslow, 1943) suggests that long-term, collaborative and collective goals such as sustainability are only likely to be given attention when immediate, personal survival goals are met. It is therefore no surprise that "green consumerism" and pro-environmental behavior and attitudes are positively related to income (Finisterra do Paco, Raposo, & Filho, 2009; Straughan & Roberts, 1999). Income may interact with ethics-based interpretations of and confusion about green advertising (whether incomplete, accurate, or deceptive) to increase the gap between sustainability attitudes and subsequent practice about "ethical" or "socially responsible" consumption of "green products" (Atkinson, 2013). Therefore, variation in economic resources can moderate the relationship between knowledge about the benefits of green consumerism and relevant attitudes or consequent practice.

Socio-economic status. SES is often measured by education level, but SES and income have a strong, positive (and often causal) correlation. Thus we can expect that SES functions similarly to income as a moderator of the links between K, A, and P. For example, In a study of immunization of children of migrant Chinese mothers, a mother's knowledge, attitude, and practice scores were significantly inter-correlated, and higher levels of knowledge, attitude, and practice about immunization were significantly associated with their child's being "fully immunized" (Hu, Luo, Lou, Zhang, & Li, 2016). However, significant disparities in the three scores existed across migrant mothers' socio-demographic characteristics (such as age, having an occupation, children in household, and education level). Therefore, SC about sustainability behavior recommendations or risk awareness may be understood (K), internalized (A), and applied (P) by those of high SES disproportionately *more* than those of low SES.

Visual and numeric literacies. Visual literacy (the abilities to think, learn, and communicate visually) plays a central role in the processing and retention of visual components of information (K) offered by science communication (Rebich-Hespanha et al., 2015; Smith & Leiserowitz, 2012; Trumbo, 1999), and may provide pathways to information for those with lower verbal literacy (Graber, 1990). Visuals may play an especially strong role as climate change representations may help to increase specific, individual, and current perceptions of the more abstract, global, and long-term processes and effects of such change (Doyle, 2011). As a somewhat related example, O'Neill and Hulme (2009) showed that focus group and survey respondents reported local and self-generated icons about climate change more meaningful if they had emotional connections with the visuals.

Similarly, numeracy (the ability to think in, and learn through, numbers) influences risk-assessment and knowledge-gain responses to health communication (Peters, Hibbard, Slovic, & Dieckmann, 2007). Low numeracy can sometimes facilitate *more* attitude change than high numeracy (Hart, 2013), arguably because of one's lower ability to critically evaluate quantitative evidence, inviting persuasibility. It follows that the effects of SC appeals that rely on visuals or numbers would be moderated by individuals' visual literacy or numeracy, respectively. For example, results from a national online survey concluded that those with higher numeracy scores had more accurate perceptions of their estimated household energy use and savings from engaging in 15 energy-saving activities (Attari, DeKay, Davidson, & de Bruin, 2010).

Summary. The deficit model assumes that SC efforts to increase K will result in related increases in A and P. But the relevant research identifies many powerful and consistent moderators of the effects of SC. Further, individuals and groups vary greatly in their respective levels of these variables. Thus, SC has non-uniform effects on K, A, and P, as well as on the progression from K to A to P. For example, the increase of knowledge through SC to those who possess a facilitating ideology (i.e., egalitarian) and adequate economic resources will lead to a significantly higher level of increase in attitudes – and, later, practice – than for those with an impeding ideology (i.e., hierarchical) and without adequate economic resources.

Next we extend the discussion past the inefficacies of the deficit model – the standard critique – to, instead, its potential *negative* effects. We argue that the non-uniform effects of SC – and the weak causal links within K-A-P – can compound over time to create a pattern of continually increasing inequality (gaps) between groups; that is, a cumulative advantage.

Cumulative Advantage

In 1965, *Sesame Street* debuted on American television as an attempt to use educational entertainment at home, after school, to boost the knowledge level of children who were underprepared for kindergarten or were underperforming in school. This was (and still is) an innovative implementation of the knowledge deficit model, with intended outcomes represented in Figure 1. And, indeed, *overall mean levels* of knowledge increased as expected. However, follow-up research found that the program also had a more surprising effect: the *difference* between initially high and low-performing children also increased (Figure 3; Bogatz & Ball, 1971). Later studies also confirmed that the gap in kindergarten performance between middle- and low-income students also increased as a result of the *Sesame Street* education attempt (Cook et al., 1975).

This set of relationships, often termed *the knowledge gap hypothesis* (Tichenor, Donohue, & Olien, 1970), posited that the result of information diffusion is not general individual increases, but, rather, differential gains, influenced by various moderators, especially SES (Figure 3). Further, over time, these differential gains represent a *cumulative advantage* (CA)

system – a pattern of effects also known as the *Matthew effect* (Merton, 1968) and its colloquial phrasing "the rich get richer." It describes a system where (even slight) initial advantages beget future relative advantages and, conversely, initial disadvantages beget further relative disadvantages. Power-law distributions – as seen in book sales, blog traffic, or the accumulation of wealth (Surowiecki, 2015) – are all examples of CA systems.

"Advantages" can be of diverse natures – such as physical resources like income, or cognitive resources like intelligence and learning abilities, or opportunities for advancement in education or career. Individual and group differences on these factors produce non-uniform effects –paralleling the moderators of SC effects discussed above.

--- Figure 3 Goes Here ---

The Ubiquity of Cumulative Advantage

Diverse scholarship has shown the ubiquity and power of CA effects in myriad social contexts (DiPrete & Eirich, 2006), and in all three elements of KAP. In each case, the driving factor (individual or group differences in cognitive ability, SES, income, or party affiliation) is also a factor that was identified above as a moderator of the effects of SC.

Education. In addition to the *Sesame Street* social experiment, research has demonstrated that students who pre-test at a high cognitive ability level – relative to their peers – enjoy proportionately higher gains from subsequent instructional treatment (Walberg & Tsai, 1983). Essentially, the students who are most in need of benefit from the instruction benefit the least when it is provided. Similarly, variance in reading performance increases with grade level (Daneman, 1991).

Digital divide. Information and communication technologies are most often and most effectively used by those already socially, cognitively, or economically advantaged (DiMaggio, Hargittai, Celeste, & Shafer, 2004). These advantages accrue to earlier and more capable adopters (van Dijk, 2005), enabling access to more diverse resources and subsequent innovations, fostering a cumulative digital advantage. This "digital divide" originally described this growing gap between computer users and non-users in the U.S and often focused on socioeconomic differences (Selwyn, 2004). Other research expanded this to the use of the Internet and mobile phones, emphasizing both the gaps and the social consequences of such gaps (Katz & Rice, 2002; Mossberger, Tolbert, & Stansbury, 2003; Warschauer, 2004). Rogers (2003, Chapter 3) explained that the diffusion of innovations – in general – often results in unintended, long-term consequences such as CA systems. In addition to being subject to CA effects, (science-related) internet use may also be a moderator of the CA trend of science knowledge over time (Cacciatore, Scheufele, & Corley, 2014).

Public health. Analysis of lifetime health trajectories also shows a CA system, such that over lifespans, the gap in overall health between healthy and unhealthy people steadily increases (Willson, Shuey, & Elder, 2007). Inequality in public health can also be driven by income or education. *The Economist* (2015) reports that the upper quintile of SES *increased* their time spent in the gym by 50% between 2003 and 2014, while the bottom quintile of SES *decreased* their gym time. The cheery mean increase masks a darker CA system.

Civic participation. Economic and social disadvantage perpetuate a CA system in civic participation (Pacheco & Plutzer, 2008). In a vicious cycle, economic hardship stagnates voter turnout, which causes under-representation in the political process, which causes inadequate antipoverty policy, which causes increased economic hardship. Those who *most* need policy reform are the least likely to benefit from new policies. Similarly, Nisbet (2008) found that in the developing country of Mali, increasing overall media use in the population lead to a growing gap

in political participation, knowledge, and socialization between individuals with low, medium, and high education, resulting in increasing relative social and economic benefits for the already advantaged segments of the population.

Science communication. Most specific to sustainability issues, science communication researchers have applied the CA framework to the knowledge-gain effects of media consumption in controversial issues such as climate change (Hindman, 2009; Nisbet et al., 2014). Increased media consumption raises the population mean level of knowledge, but that increase is moderated by party affiliation (noted above), causing an increase in the discrepancy in attitude and knowledge between conservatives and liberals (Zhao, Rolfe-Redding, & Kotcher, 2016). These preliminary studies indicating CA systems in SC effects have investigated knowledge and attitudes only, not practice.

The Disadvantages of Cumulative Advantage

To some, CA systems and other inequalities in sustainability are expected and normal. For example, some ideologies hold that inequality is natural in any competitive system, including nature and the market economy (Kluegel & Smith, 1986). Further, if SC can positively affect the overall mean levels of materials consumed and emitted, why does it matter if inequality increases? We argue that inequality in sustainability KAP is inherently negative and counter-productive to the goals of SC.

One negative consequence of CA is a polarization or social segmentation of sustainability. For example, if a sustainability behavior required economic resources, this behavior would be practiced – to increasing disproportion – by high-income groups. Over time, that sustainable behavior would grow to be socially understood as a "rich person's thing," a stigma detrimental to low-income groups. Similarly, due to the increased political polarization of climate change opinions, climatologists and sustainability communicators face the Herculean task of convincing people that sustainability – as it relates to climate change – is *not* just a liberal's cause – it is a human, global cause. Further, the increased segregation of sustainability K, A, and P by income, ideology, or other groupings can reduce the likelihood of collaborative and interdependent efforts, due to the entrenchment of ingroup/outgroup categorizations like partisanship (Hoffman, 2015; McCright & Dunlap, 2011). These effects are devastating to fundamental sustainability goals, which require collaborative efforts at interpersonal, community, national, and global levels.

The inherent negative consequences of CA (and unsuccessful SC in general) are also clear when considering who bears the brunt of the potential consequences from sustainability crises or environmental threats (Roberts & Parks, 2007). Those who are most disadvantaged (in income, or health, for example) are most likely to be the most at risk (Adger, 2006; Mirza, 2003). One reason is that they are more likely to live in areas affected by environmental crises, such as areas with poor infrastructure and high vulnerability (Armah, Ung, Boamah, Luginaah, & Campbell, 2005). Thus, increased mean levels of KAP in the population does not justify the creation of a CA system.

Cumulative Advantage in KAP

This section describes how the deficit model's reliance on the K-A-P process perpetuates and exacerbates unintended effects. Specifically, groups with differing levels of a given relevant moderating variable would experience differential effects of SC, resulting in increasing *gaps* (CA) between individuals or groups in K, A, or P; the possibility of continued or increased pairwise and overall *divergence* within an individual's K-A-P progression; and *divergence gaps* between K, A, and P across groups.

KAP Gaps

The deficit model presumes that the causal sequence is K-A-P, and that increases in K are associated with subsequent increases in A and, later, P (Figure 4).

--- Figure 4 Goes Here ---

However, the standard cumulative advantage model (Figure 3) claims that while the overall mean of knowledge does increase, it increases more for those with a higher (h) existing level of a relevant knowledge, ability, or resource than for those with lower (l) levels of each, and over time these gaps are exacerbated. This CA effect can also happen to A or P directly.

Further, even non-uniform increases in K (only) can then produce CA effects in A and P, due the step-wise sequential nature of K-A-P. For example, if knowledge increase varies across groups (due to some moderator), then the gap between groups' attitude levels will also increase because (in the KAP model) ΔK drives ΔA. And the same would hold for practice gaps, whether directly affected by knowledge, directly by attitudes, or indirectly by knowledge through attitudes. Thus, beyond the initial K, A, and P gaps, there are also likely non-uniform increases *over time* between groups as knowledge effects progress to attitudes and to practice, resulting in further cumulative advantage (Figure 5).

--- Figure 5 Goes Here ---

KAP Divergence

In addition to KAP gaps between groups, there is also divergence within an individual's KAP relations, due to the moderators of the relationships between K, A, and P. For example, one's sustainability knowledge (K) is not fully reflected in one's attitude (A), which is not fully reflected in one's practice (P). Presume the scale in Figure 6 represents the percentage of the optimal level of K, A, or P, respectively. As constructed by the KAP model, knowledge is higher, attitude is lower, and practice is lowest.

--- Figure 6 Goes Here ---

The knowledge deficit model hopes that with appropriate K increase, A and P would then follow suit, *and* that individual divergence within the KAP levels would decrease (Figure 7).

--- Figure 7 Goes Here ---

But the literature shows, at best, moderate relationships between changes in knowledge and subsequent changes in attitudes or practice, or changes in attitude and subsequent practice, and thus *low reductions in divergence.* Hierarchical persuasion effects models (McGuire, 2012) emphasize that any given degree of change in an initial step (K) results in lower change in the next step (A and P), due to mediating, moderating and interacting factors. Thus the most reasonable conclusion is that if K is increased – as in the knowledge deficit model – we have no reason to *expect* an immediate, complete, or even noteworthy convergence between an individual's K, A and P, even if mean levels of K, A, and P improve (Figure 8). Rather, we expect *KAP divergence.*

--- Figure 8 Goes Here ---

KAP Divergence Gaps

Finally, we should also expect *KAP divergence gaps* – that is, variation across individuals or groups in the convergence of K, A, and P, due to the fact that SC recipients vary on levels of those very moderators that cause divergence. This, then, can also foster a cumulative advantage system. Groups with greater direct KAP gaps and more KAP divergence will systematically accumulate further relative disadvantage. Like all CA effects, this pattern compounds over time, because KAP divergence gaps create higher inequality in mean K, A, and P levels across

individuals/groups, and less convergence among K, A, and P relationships within some individuals/groups.

Summary

We have identified three relationships that are susceptible to effects not foreseen by the deficit model. 1) Increased *gaps* in K, A, or P between individuals/groups, even if overall levels of K, A, or P do increase. If changes in K, A, and P reflect *cumulative advantage* effects, then with increasing knowledge (assumed by the deficit model), gaps between groups in their K, A, and P are likely to continue to increase over time. 2) *KAP divergence*, or weak causal relationships among K, A, and P within individuals. 3) *KAP divergence gaps* between groups, which are likely to increase due to CA from the unequal levels of inhibiting or facilitating moderators. Figure 9 portrays these three sets of relationships.

--- Figure 9 Goes Here ---

Implications for Future Research

Surely, reductions in knowledge deficits are useful for improving population mean attitudes and practice. But some unintended and undesirable effects are likely *even if* the knowledge deficit model "works" on average.

To explain nuanced, unconsidered, step-wise, heavily moderated, time-lagged effects, we use the framework of the KAP progression. But the drastic effects of cumulative advantage are still present *even if* we only look at the simple direct effects of SC on K, A, and P separately. Indeed, preliminary emerging research has suggested CA effects of science communication on knowledge (Hindman, 2009; Nisbet et al., 2014) and attitudes (Zhao et al., 2016).

Most importantly, the purpose of this paper is to raise a new theoretical perspective on the over-time effects of SC that can develop from reliance on a simple deficit model that assumes an unmoderated, consistent, sequential, and homogenous K-A-P progression. Specifically, beyond the inefficacies identified by the prior critiques, through dependence on the K-A-P causal process, the deficit model of SC can create unintended effects in the forms of increasing *KAP gaps* between groups, continued *KAP divergence* within individuals, and increasing *KAP divergence gaps* across groups, all representing a general *cumulative advantage* system. These gaps, divergences, and cumulative advantages are contrary to, and unexpected by, the central goals of the deficit model and sustainability communication.

Thus, it is imperative to develop a program of research that accomplishes the following objectives. First, synthesize (through meta-analysis) and test (through longitudinal designs) the proposed relationship of the over-time CA effects of SC that cause increasing gaps and divergences through differing levels of relevant moderating variables. Second, measure the change in divergence within KAP when K is increased, while also assessing the effect of moderating variables. Third, test the possibility of increasing divergence gaps. Fourth, develop and test a more nuanced understanding of which moderating variables are most likely to produce CA effects (in gaps, divergence, or divergence gaps) across the diverse SC topics, methods, contexts, and audience groups. Sixth, develop practical modes of SC that can lessen gaps, divergences, divergence gaps, and CA effects. Finally, apply other models of science communication, such as the dialogue or participation models (Bucchi, 2008), or the rational choice or context models (Weigold, 2001). Bucchi (2008) thoughtfully argues how each of these models might be more or less appropriate for different problems and contexts, projecting the need to be open to moving across the various models as appropriate.

[what is there beyond the deficit approach? How do we avoid the trap?]

To ignore the cumulative advantage perspective when designing SC research and its resulting practice is potentially to perpetuate a pattern that systematically increases KAP gaps, divergences, and divergence gaps. Certainly, those most in need of increased sustainability KAP will not be adequately served by such a pattern of effects. Ironically – and similar to the *Sesame Street* edutainment efforts – the inequalities that are *increased* by this cumulative advantage system are what the knowledge deficit model and SC were designed to *reduce*.

References

Achenbach, J. (2015). Why do many reasonable people doubt science? *National Geographic Magazine*, March. http://ngm.nationalgeographic.com/2015/03/science-doubters/achenbach-text

Adger, W. N. (2006). Vulnerability. *Global Environmental Change*, *16*(3), 268-281.

Ajzen, I., & Fishbein, M. (1980). *Understanding attitudes and predicting social behavior.* Englewood Cliffs, NJ: Prentice Hall.

Ajzen, I., Joyce, N., Sheikh, S., & Cote, N. G. (2011). Knowledge and the prediction of behavior: The role of information accuracy in the theory of planned behavior. *Basic and Applied Social Psychology*, *33*(2), 101-117.

Antilla, L. (2005). Climate of skepticism: US newspaper coverage of the science of climate change. *Global Environmental Change*, *15*(4), 338-352.

Armah, F. A., Ung, M., Boamah, S. A., Luginaah, I., & Campbell, G. (2015). Out of the frying pan into the fire? Urban penalty of the poor and multiple barriers to climate change adaptation in Cambodia and Tanzania. *Journal of Environmental Studies and Sciences*. Online pre-print version: http://link.springer.com/article/10.1007%2Fs13412-015-0334-9#page-1

Atkinson, L. (2013). Clarifying, confusing or crooked? Interpretations of green advertising claims by ethically minded consumers. In M. Drumwright & S. Reese (Eds.), *Ethical issues in communication professions: New agendas in communication* (pp. 153-181). New York: Routledge.

Attari, S. Z., DeKay, M. L., Davidson, C. I., & De Bruin, W. B. (2010). Public perceptions of energy consumption and savings. *Proceedings of the National Academy of sciences*, *107*(37), 16054-16059.

Bandura, A. (1986). *Social foundations* of *thought and action.* Englewood Cliffs, NJ: Prentice Hall.

Bauer, M. W., Allum, N., & Miller, S. (2007). What can we learn from 25 years of PUS survey research? Liberating and expanding the agenda. *Public Understanding of Science*, *16*(1), 79-95.

Bem, D. J. (1967). Self-perception: An alternative interpretation of cognitive dissonance phenomena. *Psychological Review*, *74*(3), 183-200.

Bennett, W. L., & Iyengar, S. (2008). A new era of minimal effects? The changing foundations of political communication. *Journal of Communication*, *58*(4), 707-731

Blake, J. (1999). Overcoming the "value-action gap" in environmental policy: Tensions between national policy and local experience. *Local Environment*, *4*(3), 257-278.

Bogatz, G. A., & Ball, S. (1971). *The second year of Sesame Street: A continuing evaluation*. Princeton, N.J.: Educational Testing Service.

Boykoff, M. T., & Boykoff, J. M. (2004). Balance as bias: Global warming and the US prestige press. *Global Environmental Change*, *14*(2), 125-136.

Boykoff, M. T., & Roberts, J. T. (2007). Media coverage of climate change: Current trends, strengths, weaknesses. *Human Development Report*, 2007/*2008*, 3. http://www.researchgate.net/publication/228637999_Media_Coverage_of_Climate_Change_Current_Trends_Strengths_Weaknesses

Brulle, R. J., Carmichael, J., & Jenkins, J. C. (2012). Shifting public opinion on climate change: An empirical assessment of factors influencing concern over climate change in the US, 2002–2010. *Climatic Change*, *114*(2), 169-188.

Bucchi, M. (2008). Of deficits, deviations and dialogues: Theories of public communication of science. In M. Bucchi & B. Trench (Eds.), *Handbook of public communication of science and technology* (pp. 57-76). New York, NY: Routledge.

Cacciatore, M. A., Scheufele, D. A., & Corley, E. A. (2014). Another (methodological) look at knowledge gaps and the Internet's potential for closing them. *Public Understanding of Science*, *23*(4), 376-394.

Chaffee, S. H., & Roser, C. (1986). Involvement and the consistency of knowledge, attitudes, and behaviors. *Communication Research*, *13*(3), 373-399.

Coffey, D. J., & Joseph, P. H. (2013). A polarized environment: The effect of partisanship and ideological values on individual recycling and conservation behavior. *American Behavioral Scientist*, *51*(1), 116-139.

Cook, T. D., Appleton, H., Conner, R. F., Shaffer, A., Tamkin, G., & Weber, S. J. (1975). *"Sesame Street" revisited*. New York: Russell Sage.

Corbett, J. B., & Durfee, J. L. (2004). Testing public (un)certainty of science media representations of global warming. *Science Communication*, *26*(2), 129-151.

Daneman, M. (1991). Individual differences in reading skills. In R. Barr, M. L. Kamil, P. B. Mosenthal, & P. D. Pearson (Eds.), *Handbook of reading research* (vol. 2, pp. 512-538). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Dimaggio, P., Hargittai, E., Celeste, C., & Shafer, S. (2004). From unequal access to differentiated use: A literature review and agenda for research on digital inequality. *Social Inequality*, 355-400.

DiPrete, T. A., & Eirich, G. M. (2006). Cumulative advantage as a mechanism for inequality: A review of theoretical and empirical developments. *Annual Review of Sociology*, *32*, 271-297.

Downing, P., & Ballantyne, J. (2007). *Tipping point or turning point? Social marketing and climate change*. London: Ipsos-MORI.

Doyle, J. (2011). *Mediating climate change*. Surrey, UK: Ashgate.

Dusonchet, L., & Telaretti, E. (2010). Economic analysis of different supporting policies for the production of electrical energy by solar photovoltaics in western European Union countries. *Energy Policy*, *38*(7), 3297-3308.

Finisterra do Paço, A. M., Barata Raposo, M. L., & Filho, W. L. (2009). Identifying the green consumer: A segmentation study. *Journal of Targeting, Measurement and Analysis for Marketing*, *17*(1), 17-25.

Fishbein, M., & Ajzen, I. (2011). *Predicting and changing behavior: The reasoned action approach*. Taylor & Francis.

Gallup. (2015). *Environment*. Retrieved July 3, 2015, from http://www.gallup.com/poll/1615/Environment.aspx

Godemann, J., & Michelsen, G. (2011). *Sustainability communication–An introduction*. Springer.

Graber, D. A. (1990). Seeing is remembering: How visuals contribute to learning from television news. *Journal of Communication, 40*(3), 134-155.

Guber, D. L. (2013). A cooling climate for change? Party polarization and the politics of global warming. *American Behavioral Scientist*, *57*(1), 93-115.

Guy, S., Kashima, Y., Walker, I., & O'Neill, S. (2014). Investigating the effects of knowledge and ideology on climate change beliefs. *European Journal of Social Psychology*, *44*(5), 421-429.

Hart, P. S. (2013). The role of numeracy in moderating the influence of statistics in climate change messages. *Public Understanding of Science*, *22*(7), 785-798.

Hart, P. S., & Nisbet, E. C. (2011). Boomerang effects in science communication: How motivated reasoning and identity cues amplify opinion polarization about climate mitigation policies. *Communication Research*, *39*(6), 701-723.

Hindman, D. (2009). Mass media flow and the differential distribution of politically disputed beliefs: The belief gap hypothesis. *Journalism and Mass Communication Quarterly, 86*, 790-808.

Hoffman, A. (2015). *How culture shapes the climate change debate*. Stanford University Press.

Hogg, M. A., Turner, J. C., & Davidson, B. (1990). Polarized norms and social frames of reference: A test of the self-categorization theory of group polarization. *Basic and Applied Social Psychology*, *11*(1), 77-100.

Hu, Y., Luo, S., Lou, L., Zhang, B., & Li, Q. (2016). Knowledge, attitude and practice on immunization among migrant mothers: A questionnaire development and field application. *International Journal of Vaccine Immunization*, *2*(1). https://sciforschenonline.org/journals/vaccines/article-data/IJVI-2-106/IJVI-2-106.pdf

Hyman, H. H., & Sheatsley, P. B. (1947). Some reasons why information campaigns fail. *Public Opinion Quarterly*, *11*, 412-423.

Intergovernmental Panel on Climate Change (2007). *Climate change 2007-the physical science basis: Working group I contribution to the fourth assessment report of the IPCC* (vol. 4). Cambridge, UK: Cambridge University Press.

Kahan, D. (2010). Fixing the communications failure. *Nature*, *463*(7279), 296-297.

Kahan, D. M. (2012). Ideology, motivated reasoning, and cognitive reflection: An experimental study. *Judgment and Decision Making*, *8*, 407-424.

Kahan, D. M., Jenkins-Smith, H., & Braman, D. (2011). Cultural cognition of scientific consensus. *Journal of Risk Research*, *14*(2), 147-174.

Kahan, D. M., Wittlin, M., Peters, E., Slovic, P., Ouellette, L. L., Braman, D., & Mandel, G. N. (2011). The tragedy of the risk-perception commons: Culture conflict, rationality conflict, and climate change. *Temple University Legal Studies Research Paper* (2011-26).

Kahan, D. M., Peters, E., Wittlin, M., Slovic, P., Ouellette, L. L., Braman, D., & Mandel, G. (2012). The polarizing impact of science literacy and numeracy on perceived climate change risks. *Nature Climate Change*, *2*(10), 732-735.

Katz, J. E., & Rice, R. E. (2002). *Social consequences of Internet use: Access, involvement, and interaction*. Cambridge, MA: The MIT press.

Kim, M. S., & Hunter, J. E. (1993). Attitude behavior relations: A meta-analysis of attitudinal relevance and topic. *Journal of Communication, 43*, 101-142.

Kluegel, J. R., & Smith, E. R. (1986). *Beliefs about inequality: Americans' views of what is and what ought to be*. New Brunswick, NJ: Transaction Publishers.

Kunda, Z. (1990). The case for motivated reasoning. *Psychological Bulletin*, *108*(3), 480-498.

Leiserowitz, A., Maibach, E., Roser-Renouf, C., Feinberg, G. & Howe, P. (2013). *Global Warming's Six Americas, September 2012.* Yale University and George Mason University. New Haven, CT: Yale Project on Climate Change Communication.

Mackie, D. M., & Queller, S. (2000). The impact of group membership on persuasion: Revisiting "Who says what to whom with what effect?" In D. J. Terry & M. A. Hogg (Eds.), *Attitudes, behavior, and social context: The role of norms and group membership* (pp. 135-155). Mahwah, NJ: Lawrence Erlbaum Associates Publishers.

Marquart-Pyatt, S. T., Shwom, R. L., Dietz, T., Dunlap, R. E., Kaplowitz, S. A., McCright, A. M., & Zahran, S. (2011). Understanding public opinion on climate change: A call for research. *Environment: Science and Policy for Sustainable Development*, *53*(4), 38-42.

Maslow, A. H. (1943). A theory of human motivation. *Psychological Review*, *50*(4), 370-396.

McCright, A. M. & Dunlap, R. E. (2011). The politicization of climate change and polarization in the American public's views of global warming, 2001–2010. *The Sociological Quarterly*, *52*(2), 155-194.

McGarty, C., Haslam, S. A., Hutchinson, K. J., & Turner, J. C. (1994). The effects of salient group memberships on persuasion. *Small Group Research*, *25*(2), 267-293.

McGuire, W. J. (2012). McGuire's classic input-output framework for constructing persuasive messages. In R. E. Rice & C. K. Atkin (Eds.), *Public communication campaigns* (4th ed., pp. 133-145). Thousand Oaks, CA: Sage.

McPhee, R. D. & Cushman, D. P. (1980). Attitudes, behaviors, and messages: An introductory overview. In D. P. Cushman & R. D. McPhee (Eds.), *Message-attitude-behavior relationship* (pp. 1-42). New York, NY: Academic Press.

Merton, R. K. (1968). The Matthew effect in science. *Science*, *159*(3810), 56-63.

Mirza, M. M. Q. (2003). Climate change and extreme weather events: Can developing countries adapt? *Climate Policy*, *3*(3), 233-248.

Mossberger, K., Tolbert, C. J., & Stansbury, M. (2003). *Virtual inequality: Beyond the digital divide*. Washington, DC: Georgetown University Press.

Nisbet, E. C. (2008). Media use, democratic citizenship, and communication gaps in a developing democracy. *International Journal of Public Opinion Research*, *20*(4), 454-482.

Nisbet, E. C., Cooper, K. E., & Ellithorpe, M. (2014). Ignorance or bias? Evaluating the ideological and informational drivers of communication gaps about climate change. *Public Understanding of Science*, *24*(3), 285-301.

Nisbet, E. C., Cooper, K. E. & Garrett, R. K. (2015). The partisan brain: How dissonant science messages lead conservatives and liberals to (dis)trust science. *Annals of the American Academy of Political and Social Science,* 658, 36–66. doi:10.1177/0002716214555474.

Nisbet, M. C. (2009). Framing science: A new paradigm in public engagement. *Understanding Science: New Agendas in Science Communication*, 40-67.

O'Donnell, C., & Rice, R. E. (2012). A communication approach to campus bottled water campaigns. *Social Marketing Quarterly*, *18*(4), 255-273.

O'Neill, S. J. & Hulme, M. (2009). An iconic approach for representing climate change. *Global Environmental Change*, *19*(4), 402-410.

Oreskes, N. (2004). The scientific consensus on climate change. *Science*, *306*(5702), 1686-1686.

Pacheco, J. S., & Plutzer, E. (2008). Political participation and cumulative disadvantage: The impact of economic and social hardship on young citizens. *Journal of Social Issues*, *64*(3), 571-593.

Peters, E., Hibbard, J., Slovic, P., & Dieckmann, N. (2007). Numeracy skill and the communication, comprehension, and use of risk-benefit information. *Health Affairs*, *26*(3), 741-748.

Pew Research Center (2015). *Major gaps between the public, scientists on key issues*. http://www.pewinternet.org/interactives/public-scientists-opinion-gap/

Ray, M. L. (1975). Marketing communication and the hierarchy-of-effects. In P. Clarke (Ed.), *New models for mass communication research.* (pp. 1-43). Beverly Hills, CA Sage.

Rebich-Hespanha, S., Rice, R. E., Montello, D. R., Retzloff, S., Tien, A. & Hespanha, J. P. (2015). Image themes and frames in U.S. print news stories about climate change. *Environmental Communication*, *9*(4), 491-519.

Roberts, J. T., & Parks, B. C. (2007). *A climate of injustice: Global inequality, North-South politics, and climate change*. Cambridge, MA: The MIT Press.

Rogers, E. M. (2003). *Diffusion of innovations* (5th ed.). New York: Free Press.

Roser-Renouf, C., Maibach, E., Leiserowitz, A., Fein, G., Rosenthal, S. & Kreslake, J. (2014). *Global warming's Six Americas: Perceptions of the health consequences of global warming and update on key beliefs*. Yale University and George Mason University. New Haven, CT: Yale Project on Climate Change Communication.

Rice, R. E., & Atkin, C. K. (Eds.) (2012). *Public communication campaigns* (4th ed.). Thousand Oaks, CA: Sage.

Smith, N., & Leiserowitz, A. (2012). The rise of global warming skepticism: Exploring affective image associations in the United States over time. *Risk Analysis*, *32*(6), 1021-1032.

Snyder, L. B., Hamilton, M. A., Mitchell, E. W., Kiwanuka-Tondo, J., Fleming-Milici, F., & Proctor, D. (2004). A meta-analysis of the effect of mediated health communication campaigns on behavior change in the United States. *Journal of Health Communication*, *9*(S1), 71-96.

Spin to separate. (2015, August 1). *The Economist*. http://www.economist.com/news/united-states/21660170-sweating-purpose-becoming-elite-phenomenon-spin-separate

Straughan, R. D. & Roberts, J. A. (1999). Environmental segmentation alternatives: A look at green consumer behavior in the new millennium. *Journal of Consumer Marketing*, *16*(6), 558-575.

Sturgis, P., & Allum, N. (2004). Science in society: Re-evaluating the deficit model of public attitudes. *Public Understanding of Science*, *13*(1), 55-74.

Surowiecki, J. (Sept 24, 2015). Why the rich are so much richer. *The New York Review of Books*, Sept 24. http://www.nybooks.com/articles/archives/2015/sep/24/stiglitz-why-rich-are-so-much-richer/

Tichenor, P. J., Donohue, G. A., & Olien, C. N. (1970). Mass media flow and differential growth in knowledge. *Public Opinion Quarterly*, *34*(2), 159-170.

Trumbo, J. (1999). Visual literacy and science communication. *Science Communication*, *20*(4), 409-425.

Turner, J. C. (1985). Social categorization and the self-concept: A social cognitive theory of group behavior. *Advances in Group Processes: Theory and Research*, *2*, 77-122.

Valente, T. W., Paredes, P., & Poppe, P. R. (1998). Matching the message to the process: The relative ordering of knowledge, attitudes, and practices in behavior change research. *Human Communication Research*, *24*(3), 366-385.

Van Dijk, J. A. (2005). *The deepening divide: Inequality in the information society*. Thousand Oaks, CA: Sage.

Walberg, H. J., & Tsai, S. L. (1983). Matthew effects in education. *American Educational Research Journal, 20*(3), 359-373.

Warschauer, M. (2004). *Technology and social inclusion: Rethinking the digital divide*. Cambridge, MA: The MIT press.

WCED (World Commission on Environment and Development), UN. (1987). *Our common future*. World Commission on Environment and Development. Oxford, UK: Oxford University Press.

Weber, E. U., & Stern, P. C. (2011). Public understanding of climate change in the United States. *American Psychologist, 66*(4), 315-328.

Weigold, M. F. (2001). Communicating science: A review of the literature. *Science Communication, 23*, 164-193.

Wicker, A. W. (1969). Attitudes versus actions: The relationship of verbal and overt behavioral responses to attitude objects. *Journal of Social Issues, 25*(4), 41-78.

Willson, A. E., Shuey, K. M., & Elder, G. H. Jr. (2007). Cumulative advantage processes as mechanisms of inequality in life course health. *American Journal of Sociology, 112*(6), 1886-1924.

Wolf, J., & Moser, S. C. (2011). Individual understandings, perceptions, and engagement with climate change: Insights from in-depth studies across the world. *Wiley Interdisciplinary Reviews: Climate Change, 2*(4), 547-569.

Zhao, X., Rolfe-Redding, J., & Kotcher, J. E. (2016). Partisan differences in the relationship between newspaper coverage and concern over global warming. *Public Understanding of Science, 25*(5), 543-559.

Figures

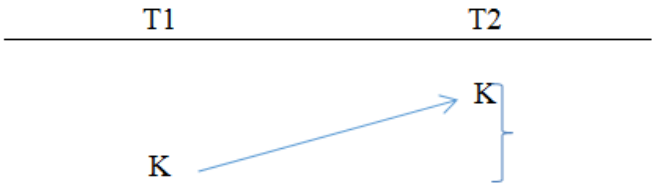

Figure 1. Knowledge deficit model: Knowledge increases after exposure to appropriate communication.
Note: Bracket indicates change in knowledge over time.

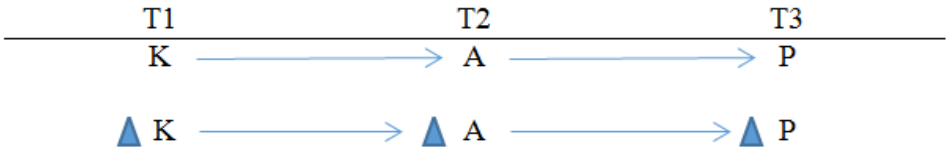

Figure 2. Knowledge deficit model's presumed causal relationships among K, A, and P, and among changes in K, A, and P, over time.

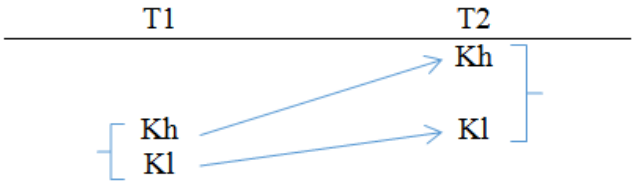

Figure 3. The knowledge gap.
Note: Brackets indicate difference between knowledge levels of high (h) and low (l) advantage individuals at each time period, T1 and T2, showing the increased knowledge gap.

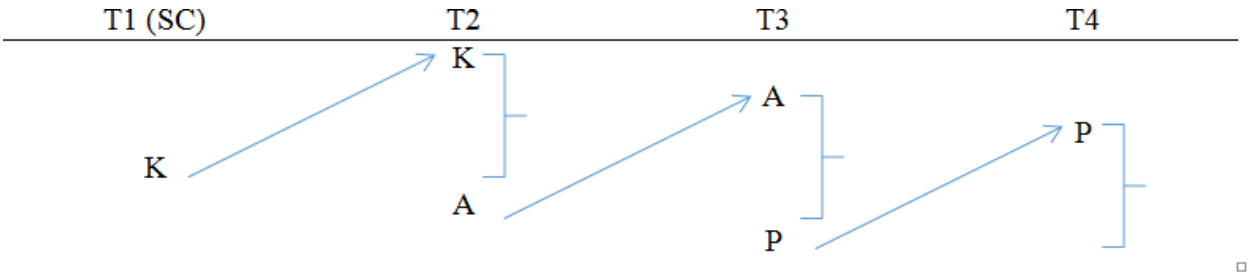

Figure 4. Deficit model presumed changes in K, A and P over time.

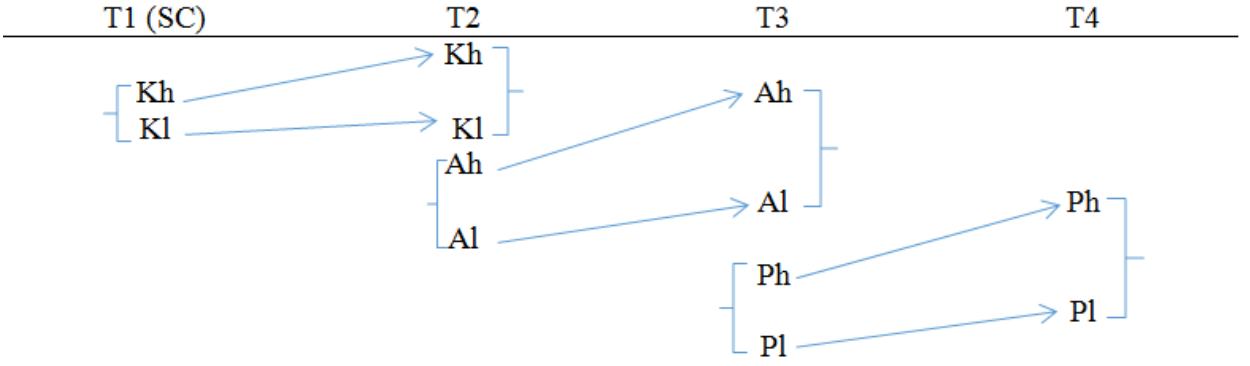

Figure 5. Cumulative advantage effects across the steps of K-A-P.

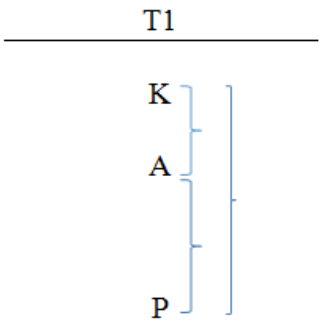

Figure 6. Pairwise and overall divergence in K, A, and P.

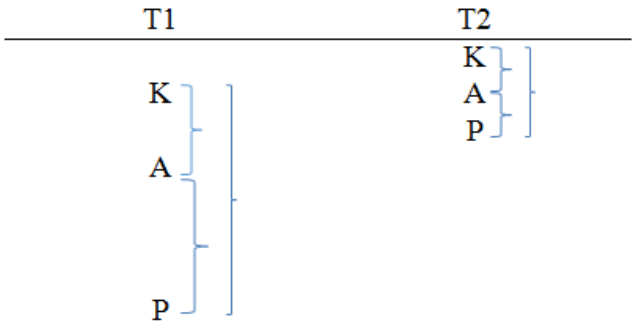

Figure 7. Increase in levels, and decrease in divergence, across K, A, and P, as presumed by the deficit model.

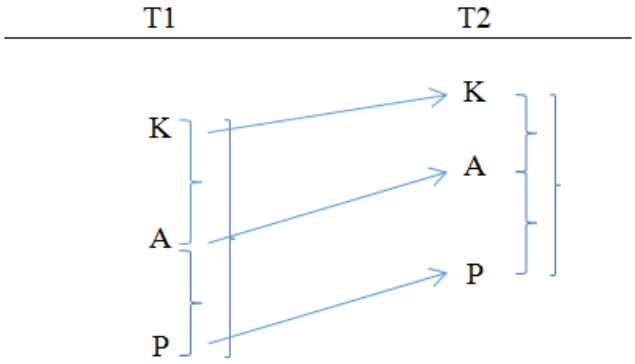

Figure 8. Example of slightly reduced KAP divergence over time.

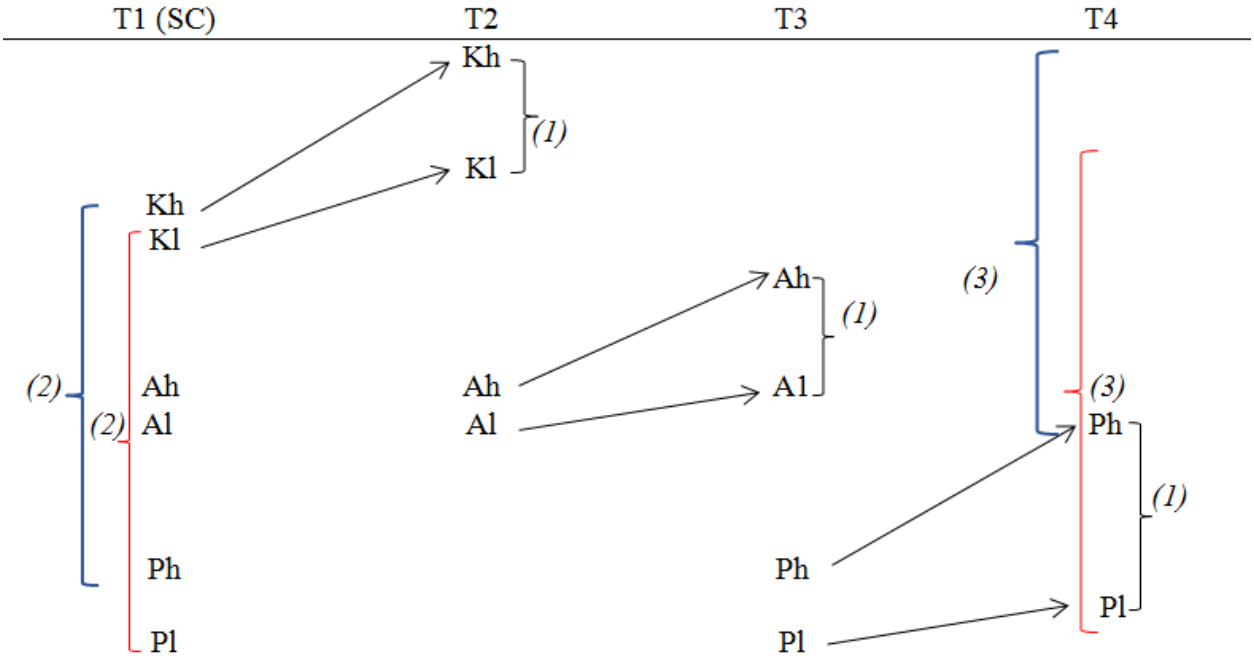

Figure 9. Gaps (1), divergence (2), and divergence gaps (3) in the K-A-P process.