A Critical Review of Computer-Assisted Learning in Public Health via the Internet, 1999-2008

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Abstract

Computers and the internet have been utilized as viable avenues for public health education delivery. Yet the effectiveness, e.g., behavior change, from use of these tools has been limited. Previous reviews have focused on single health topics such as smoking cessation and weight loss. This review broadens the scope to consider computer-assisted learning across the field of health. Of the 99 publication, 58 were selected for analysis. First, the literature was qualitatively summarized. The studies could not be compared directly due to the specifics of each study. However, a commonality emerged to allow the meta-analysis of the quantitatively pooled results of randomized control trials (RCTs). The meta-analysis indicated that, in the literature analyzed, the use of computers provided a positive effect (general improvement) through changes in knowledge, attitudes, and/or behavior. This critical review will be constructive for the development of more comparable theory-driven, evidence-based educational programs via the internet in the future.

Key Words: Computer, Assisted Learning, Internet, Health Education.

Introduction

Despite the use of computers and the internet since the 1980s to deliver health messages to the public, there is limited empirical evidence that computer-assisted learning via the internet affects change in health behaviors.[1-3] This may not concern commercial website developers who reach out to individual internet users in order to generate mass sales.[4] Whereas, the aim of public health practitioners is to reach out to the mass of internet users to help individuals. In terms of this altruistic goal, the internet is an ideal educational tool because it is "free" and on demand for everyone. It can be continuously updated as scientific evidence evolves, adapted to different cultures, translated into all languages, and used to reduce the costs of face to face teaching and media production even as the number of users increases.[5, 6]

In theory, the internet enables individual users to overcome their psycho-social barriers to behavioral change by providing anonymity to users who are uncomfortable with their health issues while at the same time providing public health practitioners with the potential to access and monitor their target audiences. Specific to public health, the internet allows the scaling of a health message for populations down to individuals without losing its original effectiveness.[7] Previous reviews and countless effectiveness and feasibility studies have all come to the same conclusion regarding the perceived usefulness of computer-assisted learning via the internet. It is a viable strategy for health education.[8-19] However, the evidence tends to stop here.

The current trend in computer-assisted learning via the internet is to include interactive components that engage individuals and tailor information to their needs,[9,10, 19-25, 26, 27] but these programs have been slow to emerge in public health primarily because many practitioners, e.g., community health nurses, nutritionists, and educators, lack the funding, computer skills, time and/or advanced programming tools to develop contemporary internet products. Regardless if they have the creative talent, public health practitioners do not usually have the time to design nor the staff to manage effective websites. Compounding the challenges for newcomers to the computer programming arena is the existing literature on computer-assisted learning which has overused the term "interactive" to the point of deception. To label a product interactive does not prove it is effective. Therefore, the literature, which should be guiding public health practitioners to correctly estimate the costs and skilled man-hours needed to develop and maintain computer-assisted learning programs via the internet, does not.

Unfortunately, public health practitioners are left using unsophisticated tools to develop first generation programs simply to satisfy the requirement to provide resources to the public. The result is a persistent contribution to the internet as an information dump which inadvertently requires users to be highly self-motivated to wade through pages and pages of web text in order to find information that is personally relevant. The advent of powerful search engines has helped to direct users' attention, but good and valid health information websites are drowned out by commercial sites and advertisements.[4] Even relatively modern websites fall into the category of first generation programs if they contain no narration, no navigation instructions and no multi-media.[7] These programs have not been found to be significantly better than traditional media materials;[28-31] are written at a tenth grade reading level or higher;[32] and worse yet, have the added stigma of doing "more harm than good."[4, 33]

Second generation programs, on the other hand, may be more likely to be read and remembered[34] because they provide a more friendly user interface with graphics, audio, video, animation, guiding links and communication tools making them more competitive with commercial sites. However, these technological bells and whistles do little to increase readers' viewing beyond seven to thirteen minutes per website[1, 22, 35] Alternatively, registering readers and requiring them to log onto secure sites is the future, today.[36, 37] These websites employ survey tools to measure, for example, knowledge, attitudes and behavior, but they are still far from being interactive if no health message is tailored to individual users' needs.[19] Researchers are finding that if participants do not receive something substantive in return for their time, they will quickly drift away.[1, 17, 22, 38-41]

From the studies presented in this review, there are lessons to be learned, like the aforementioned, which can guide, *in toto,* modern practices in health education. To help program developers move beyond process analyses, we present a meta-analysis of the change in knowledge, psycho-social variables (attitudes), and behaviors from available randomized control trials (RCTs) of second generation programs developed across the field of public health. In so doing, we hope to encourage a more critical dialogue regarding computer-assisted learning via the internet.

Methods

To generate an initial list of studies, we searched independently PubMed, Google and relative journals for adult health education interventions using technology. Studies with youth, defined as participants under the age of 18 years, were excluded as well as studies with families which included youth. The key words used were: computer; interactive; internet; multimedia; and web. These key words were then combined with health topics revealed through the search. As programming trends were identified in the literature, publications prior to 1999 were excluded from the search to eliminate as many knowledge-based, first generation programs as possible and to eliminate, for example, reports on flow-sheets; automated telephone calls; and database management systems, which have been sufficiently reviewed in the past.[9, 19, 42] This initial search yielded 99 English language publications (53 full-text articles and 46 abstracts) ranging in topics from asthma to verrucae. See Diagram 1.

Of the 99 publications found: 13 were review articles; 28 were narratives or qualitative studies of effectiveness, feasibility and process; and 58 were quasi-experimental RCTs. We performed a preliminary qualitative analysis of these 58 RCTs to identify common themes in research objectives, design, outcome measures, results and stated conclusions, which is an approach slightly different from other reviews of the literature[4, 11-14, 20, 25, 43-45] and websites.[33, 46, 47] Instead of generating a summary of publications on computer-assisted learning in one health discipline, we report who is doing what, when, where and how across public health to aid practitioners and researchers endeavoring to develop educational programming via the internet.

As expected, we found that every study was inherently different because of the specific nature of each health topic, which prevented any direct comparisons. However, we also found that all the RCTs sought, in general, to measure change in knowledge and/or psychosocial variables (attitudes) and/or behavior in a randomly assigned intervention group exposed to a new or improved computer-assisted learning program. The conclusions reported by the investigators of these studies could be categorized into either significant improvement or no improvement of the three measured outcomes and allowed for binomial testing of the null hypothesis that exposure to computer-assisted learning does not result in any improvement. We hypothesized that the combined data would show evidence of the effectiveness of computer-assisted learning to improve, in general, one or more of the following: knowledge of any health topic, attitudes towards any healthy behavior, or any targeted health behavior.

For the meta-analysis, the RCTs designed to test the use of cell phones or personal digital assistants,[48, 49] although something to be considered in the future,[23] were excluded as not fitting the traditional definition of computers. Computer-assisted learning programs provided at kiosks[11, 16, 17] and computers situated in physician offices, social services offices, or public spaces[10, 31, 39] were deemed unnatural settings for computer use and excluded. RCTs which only measured perceived effectiveness of a program and not change in knowledge, psycho-social variables (attitudes) or behavior were also excluded. Data from 29 RCTs remained and was separated into three binomial tables to record significant improvement (yes or no) in knowledge, attitudes and behavior to be used in a preliminary meta-analysis.

The frequency of observations of improvement and the probability of observing no improvement were determined using the Fisher Exact Test. Then each RCT resulting in significant improvement in any one of the three measured outcomes was identified through the transformation of data into one category of "General Improvement" (yes or no). This more robust category enabled us to test the dependency of achieving any Improvement (n=32) upon the use of training (yes or no) and/or incentives (yes or no) in the research design (n=6). Fischer Exact testing for categorical variables was again chosen for the statistical analyses of the data over Pearson's Chi-square test because it has more power to detect dependency between small samples.[50]

Next, because culturally diverse samples may not be appropriate for comparison,[19] the international studies were separated from the domestic studies. Again, Fischer Exact test was used to determine if General Improvement was dependent upon the sampling being from outside the United States (yes or no). In this case, Pearson's Chi-square test was also used to verify the results. Last, because the international studies were observed to have shorter follow-up times (0-90 days) and because the literature noted that reporting immediate improvements may not be enough evidence of effectiveness,[5] we used the Cochran-Mantel-Haenszel test to determine if Improvement was dependent upon the length of time of the studies.

Preliminary hypothesis testing of the initial data set (1999 - May 2008) was encouraging and led us to perform a secondary search for articles published through December 2008. From this secondary search, the pooled data from18 more RCTs of computer-assisted learning across public health were added to the meta-analysis. Data were managed using Excel 2000 (Microsoft Corp., Redmond, WA) and were analyzed using R 2008 (version 2.0, www.r-project.org). See Tables 1 and 2 for the results.

Results

The literature review of computer-assisted learning across the field of public health revealed a top 10 list of topics including: alcohol consumption awareness; cancer (breast, colorectal, and prostate), cardiovascular disease; diabetes (care and education); eating disorders; general health including lifestyle behaviors; general nutrition (dietary behavior, weight loss, and nutrition education); HIV/AIDS; physical activity; and smoking cessation. Four types of research designs were identified such that intervention groups were exposed to a specific computer program and compared to control groups that either received no exposure to a program at all, exposure to a placebo program typically providing generic information, or exposure to alternative media or standard care. The fourth type of design tested the effect of an improved program (intervention) compared to an existing program (control). For the meta-analysis, the results of exposure by an intervention group to a new or improved computer-assisted learning program were pooled as data.

Because of the number and quality of international RCTs found in the literature, they could not be ignored. In the final analysis, the majority of the international studies published in English came from the Netherlands; Australia and New Zealand; Canada; and the United Kingdom. Of the peer-reviewed journals cited in this review, the following offered the greatest variety of studies including RCTs: Addiction; Annals of Behavioral Medicine; Diabetes, Technology and Therapeutics; the International Journal of Eating Disorders; the Journal of Medical Internet Research; the Journal of Nutrition Education and Behavior; Patient Education and Counseling; and Obesity Research. Furthermore, the dominant authors in the field provided a considerable history of program development over the last decade as well as a peek into the future of computer-assisted learning via the internet. Those who were recognized included: R. J. Bensley; J. Brug J; M. K. Campbell; R. E. Glasgow; E. H. Jackvony; W. Kroeze W; K. Kypri K; E. Lehmann E; S. Linke; A. Oenema A; V. J. Strecher; D. F.Tate; M. W.Verheijden; R. A. Winett RA; and R. R. Wing.

These and other researchers reported a number of “firsts” in computer-assisted learning from 1999 through 2008. In 2001, Oenema, Brug, and Lechner reported being the first to empirically evaluate a second generation computer tailored intervention[51] which measured changes in determinants of behavior, i.e. awareness and intention. The intervention group received tailored nutrition education via the internet and the control group receiving a non-tailored information letter. A significant increase in awareness and intention to make dietary changes was found with the intervention group. Also in 2001, Tate, Wing and Winnett reported being the first to evaluate an internet behavior therapy program.[40] The intervention group received an educational website plus support through email, diaries and bulletin boards, and the control received only an educational website. The investigators measured change in weight and physical activity. They found a greater number of participants in the intervention group lost 5% of their weight and maintained their weight loss for up to 6 months, but found no significant difference in physical activity between the two groups.

In 2004, Womble and colleagues reported being the first to evaluate a commercially available weight loss program on the internet to alternative media, i.e. a weight loss manual.[29] The investigators measured change in cardiovascular disease risk factors and weight. After 52 weeks, they found no significant improvement in risk factors and reported greater weight loss by the control group using the manual. In 2005, Miller and colleagues reported being the first to study the effect of computer-assisted learning compared to standard care focusing on health screening.[18] Change in knowledge and behavior was measured, but the results were inconclusive. In 2006, Suminski and Petosa reported being the first to study the use of Social Cognitive Theory in computer-assisted learning compared to no exposure to a program.[52] After nine weeks, knowledge and self-regulation increased in the intervention group, but there was no change in the constructs of self-efficacy and social support.

In 2007, Polzien, Jakicic, Tate and Otto reported being the first to study the addition of computer-assisted learning with intermittent and continuous doses to standard care.[53] Differences in levels of exposure were not found to be statistically significant; however the investigators argued that the results may have been clinically significant, and deserved further investigation. Most recently, in 2008, Riper, Kramer, Smit and colleagues reported being the first to test a multi-component, interactive self-help program to alternative media, i.e. a brochure.[54] Behavior change, measured as decreased mean weekly alcohol consumption to normal was found to be significant for the intervention group at six months follow-up.

The conflicting results, as seen above, have been reported throughout the literature and reinforced the conclusion of a 2004 review of the literature by Verheijden and colleagues that "as of yet computer-based interventions have not been the magic breakthrough they were hoped to be."[2, p.8] However, investigators of only four of the RCTs reported using power equations of which none reached 90% power ($\alpha = .05$)[10, 18, 31, 41] indicating a problem in how and what was being measured. When sample sizes were reported too small and when attrition was reported too great, the conclusions were that the true effect was too difficult to measure.[5, 10, 55] Therefore, results in the literature across the field of public health may be underestimated.

Also noted was that less than half of investigators in this review reported using theories or models to guide their research designs. However, the majority of the studies using theories and models have come about within the last few years, after 2006, which indicates a positive trend. The theoretical constructs reportedly used most often were from: Cognitive Behavior Theory;[54] Goal Setting;[1, 41] Motivational Theory;[41] the Transtheoretical Model;[2, 10, 35, 56] Health Belief Model;[19, 57] Theory of Self-control;[54] and most recently, the Social Cognitive Theory.[18, 58] The media uses and gratification paradigm was used for perception of use of media material,[30] and when no one theory of behavioral change would do, multiple constructs from multiple theories were utilized as needed.[51, 59-62]

In summary, because the qualitative analysis of the literature proved to be inconclusive, a meta-analysis to increase effect size was performed. From the observed values of the 47 RCTs in the final meta-analysis: knowledge was a measured outcome in ten of the studies and reported to significantly increase in nine of them (90%); attitudes was a measured outcome in 20 of the studies and reported to significantly improved in 15 of them (75%); and behavior was a measured outcome in 35 of the studies and reported to significantly increase in 20 of them (57%). Assuming the studies were independent of one another, the probabilities of not observing any improvement in knowledge, attitudes and behavior were all significant. See Table 1.
To determine if the use of training or incentives had an effect on the outcomes, a new variable, "General Improvement," was created. The result of the Fisher Exact test comparing the category of General Improvement to Training was p=0.6484 and for General Improvement to Incentives was p=1.0. These results indicated that the outcomes of the observed studies were not dependent upon the use of training or incentives.

Next, whether or not international sampling had an effect on General Improvement was investigated. The result of the Fisher Exact test was p=0.04854 (α = 0.05) which indicated dependency. The result of a Pearson's Chi-square test for dependency was p=0.05675 (α = 0.05), which approached significance. Together, the evidence for dependency is not strong.

When the differences between the international studies (n=17) and the domestic studies (n=30) were examined more closely, we found that besides cultural and socio-economic differences more of the domestic studies (57%, n=17) had a longer follow-up time than the international studies (35%, n=6). For convenience, we chose 90-days follow-up as a cut off to categorize the RCTs since 50% of the studies (n=23) fell into the category of less than 90-days in length and 50% of the studies fell into the category (n=24) of 90-days or more in length. The results of a Cochran-Mantel-Haenszel test for independence of Improvement on length of time, set conditionally at 90 days, was p=0.1012 (α = 0.05). This finding was not significant even though an analysis of the initial data (not reported) indicated some unknown differences between the international and domestic studies which could not be identified. The analysis was stopped here because pooled data was being utilized for this analysis. Thus the findings were not reliable.

Discussion

This meta-analysis of computer-assisted learning across the field of public health is the first of its size and design. Even though our data set is limited, using pooled output data is a simple yet valid method of analysis from which we found strong quantitative evidence. The probability of observing no effect on the measured outcomes was very small ($p \leq 0.0001$); therefore, we conclude that computer-assisted learning can improve knowledge, attitudes and behavior.

However, a comparison of dissimilar research designs limits our discussion,[4] and without more raw data, we must turn to our qualitative analysis to support the need for further development and testing. Unfortunately, we could find no starting point in the literature for researchers endeavoring to develop evidence-based computer-assisted learning programs. In education, this would be at least a list of best practices, but the lack of these practices may account for why the use of the internet currently in public health education is still being described as a "viable adjunct,"[1, p 1333] a "novel opportunity,"[34] or having "potential benefit."[5, p266] As stated before, this random evidence of effectiveness falls short of what researchers need to move forward. However, the literature supports the emerging use of theories and models to provide a way to consistently measure outcomes between studies in the future.

For example, the Transtheoretical Model was found to be most prevalent in the literature and would seem to be most beneficial[60] because computer programs "can be used as a counseling tool when strategies are outlined for specific stages of change"[63] and designed as computer algorithms.[19, 23, 45, 56, 64] The Transtheoretical Model also lends itself well to the development of expert tailored systems that provide individualized feedback.[42] Since 2001, tailoring has been recognized as needed in computer-assisted learning[28, 35, 40, 41, 51, 65] to identify and provide greater assistance to those coming from the most severe baseline,[28, 60, 65, 66] i.e. lowest stage, highest risks, relevant family histories, or seriousness of a case.[5, 17, 31, 43, 60, 67-69] In clinical setting, use of stage of change theory is aiding practitioners with triaging clients.[19]

However, effective tailored programming requires extensive interactivity,[20, 57] which is dependent upon available technologies not only to public health practitioner but also to their target audiences. Interestingly in this meta-analysis, a disproportionately low number (< 10%) of the RCTs sampled domestic, underserved populations.[17, 37, 59, 70,] While anecdotal evidence suggested that those who have low socio-economic status have greater satisfaction with computer-assisted learning than high socio-economic status, possibly due to their greater need,[5, 66] portions of this population may still not have access to computers, use the internet, or computer literacy skills. This finding brings into question the assumptions that program developers in public health may have regarding the available resources of their target audiences, and requires further investigation.[55, 71]

What we did find currently being explored in the literature included user input for preference of bulletin boards, chat groups, blogs and on-line diaries to increase participant engagement.[2, 28, 40] In community settings, programs which adapt to multiple-literacy levels[17, 70, 72] were being considered, and in clinical settings, telephone or email contact with human counselors has been found to be most beneficial [36, 41, 73] This may seem surprising, but the belief that the development of computer-assisted learning is to replace people is now "outdated."[67] Programs today are being designed to compliment standard care,[19] i.e. to reduce the burden on staff,[16, 18, 67, 74, 75] and to save time and money.[1] For example, providing personal assistance to everyone with technology, instruction and orientation is becoming more common because it is thought to retain users[18, 30, 41, 57, 73, 76] Unfortunately, in this meta-analysis we were unable to stratify the data by demographics that relate to computer literacy, such as age and socio-economic status, but our finding that General Improvement was independent reflected the findings of Tate, Jackvony and Wing who reported that computer assistance did not bias the results of their study.[41] These findings, while limited, underscore the need to determine the correct "dose" of computer-assisted learning to social interaction.[17, 24, 35, 43, 68, 77, 78]

Conclusion

There appears to be ample room for dialogue among public health practitioners who are developing computer-assisted educational programs via the internet. We found that the literature from within individual health disciplines is not enough to substantially improve current practices, and, therefore, broaden our scope to look critically at the available research across the field of public health. Additionally, we found evidence that, in general, computer-assisted learning programs do improve knowledge; attitudes; and behavior, but that there is a need for more theory-driven, evidence-based research that can be replicated. It is hoped the contribution of this critical review of the literature regarding the use of computer-assisted learning in public health can inform those who endeavor to develop educational programming via the internet so that they may leap ahead of current practices.

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Figure 1. Inclusion/Exclusion Process for RCTs Included in the Final Meta-analysis

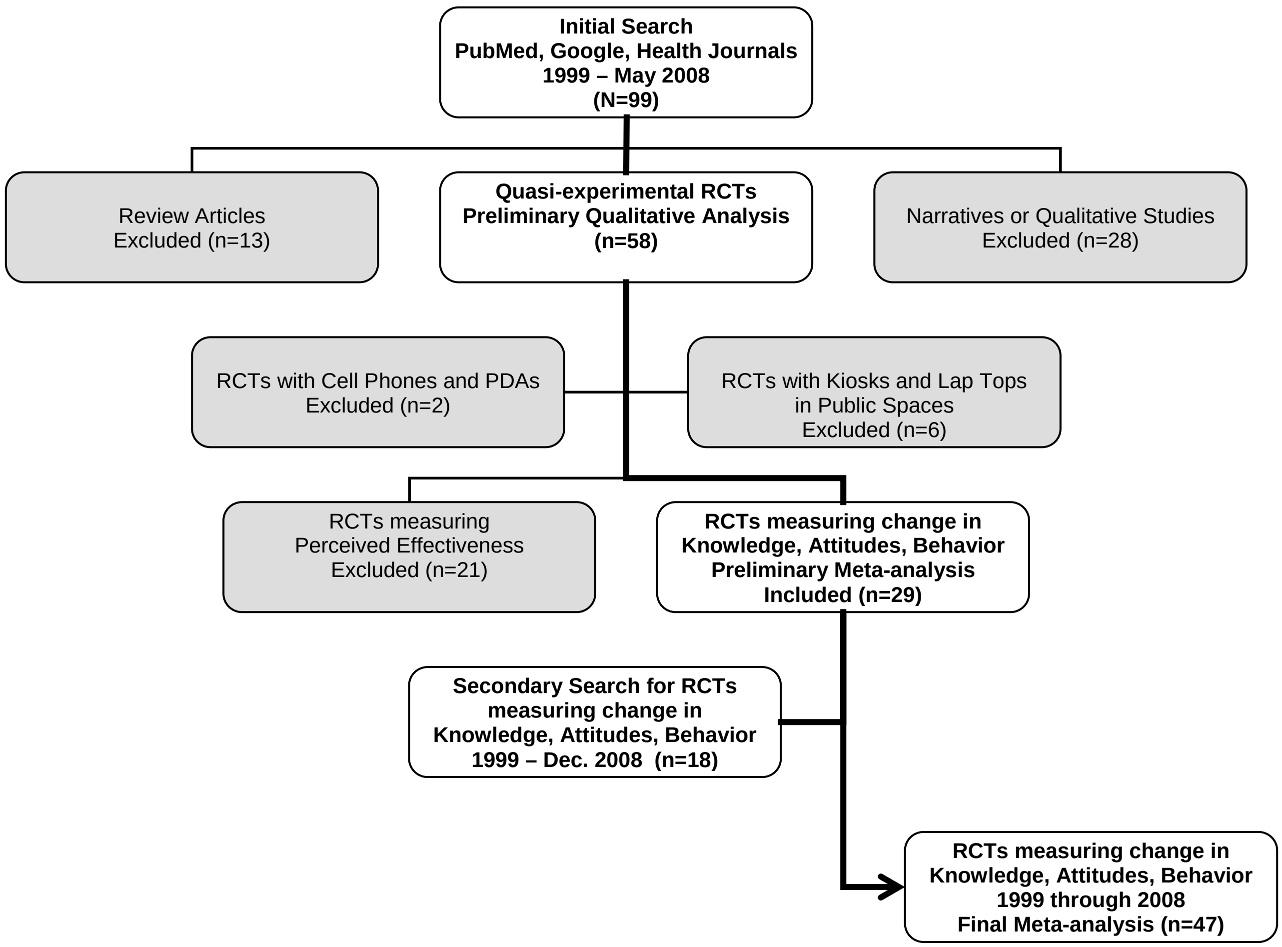

Table 1. Hypothesis Testing of Knowledge, Attitudes, and Behaviors

Pooled Output Data	Frequency of Observations (n = 47)	Per Cent Improvement Observed	Fisher Exact Test Probability (p), 95% Confidence Interval (CI)
Knowledge	-	90%	p = 9.1e-9 [a] CI = 55.5%, 0.99.8%
No Improvement	1		
Significant Improvement	9		
Attitudes	-	75%	p = 9.5e-12 [a] CI = 50.9%, 91.3%
No Improvement	5		
Significant Improvement	15		
Behavior	-	57%	p = 7.3e-12[a] CI = 39.4%, 73.7%
No Improvement	15		
Significant Improvement	20		

Note:
[a]The results are significant ($\alpha = 0.05$); therefore, we reject the null hypothesis that exposure to computer-assisted learning does not result in improvement.

Table 2. Test for Dependency Testing of General Improvement on the use of Training, the use of Incentives and the Sample Population

Combined Data	General Improvement	Dependency Testing (Probability = p)
No Training (n = 42)	-	$p = 0.6484$ ($\alpha = 0.05$)
No Improvement	13	
Significant Improvement	29	
Training (n = 5)	-	
No Improvement	2	
Significant Improvement	3	
No Incentive (n = 42)	-	$p = 1.0000$ ($\alpha = 0.05$)
No Improvement	14	
Significant Improvement	28	
Incentive (n = 5)	-	
No Improvement	1	
Significant Improvement	4	
Domestic (U.S.) Studies	-	$p = 0.04854$[a] ($\alpha = 0.05$)
No Improvement	13	
Significant Improvement	17	
International Studies	-	$\chi^2 = 0.05675$[b] ($\alpha = 0.05$)
No Improvement	2	
Significant Improvement	15	

Notes:
[a]The results of the Fisher Exact test are significant.
[b]The results of the Pearson’s Chi-square test approach significance.