Title
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ORIGINAL ARTICLE

Evaluating Effectiveness of Online Learning Modules in Pediatric Environmental Health Education

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Abstract

Objective Content and training about pediatric environmental health are lacking in healthcare professionals' education. In an initiative to improve pediatric environmental health education, the Pediatric Environmental Health Specialty Unit (PEHSU) program offers free, interactive, web-based ("eLearning") modules on environmental health topics. The aim of this study is to determine the effectiveness of PEHSU eLearning modules in increasing knowledge about pediatric and reproductive environmental health.

Methods This is a retrospective analysis of 994 users who had completed at least one of the 12 PEHSU eLearning modules and its associated pre-test and post-test scores between March 2016 and November 2018. Users who completed modules between March 2016 and April 2018 received a 6-month follow-up survey to assess the impact of the knowledge gained on their clinical practice.

Results A wide range of clinical professionals and nonclinical professionals utilized and completed the PEHSU eLearning modules. For all users, post-test scores were significantly higher than pre-test scores, with an increase of 30.55% ± 22.37 (paired t-test, $p < 0.0001$), after completion of eLearning modules.

Conclusion PEHSU eLearning modules are effective at increasing environmental health knowledge of clinical and nonclinical professionals. Further studies are needed to determine long-term knowledge retention and clinical impact.

Keywords Web-based instruction · Medical education research · Pediatric environmental health · eLearning · Reproductive health · Continuing medical education

Introduction

Health risks of environmental exposures are widely publicized by the media; however, misinformation can be detrimental to patients. Healthcare providers are instrumental in identifying and providing informed advice about potential environmental

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health exposures of their patients. Despite the negative health impact of environmental exposures, environmental medicine has been largely omitted in US medical education [1]. In the 2013 Association of American Medical Colleges graduate survey, more than one-third of medical school graduates reported inadequate exposure to environmental health education [2]. As reported in 8 surveys of over 1000 pediatricians, physicians are not taught the importance of an exposure history and conduct minimal counseling of patients about environmental exposures [3]. Pediatricians report they are ill-equipped to educate families about common exposures despite recognizing that children are suffering preventable illnesses of environmental origin [4, 5].

Significant efforts have been made to improve access to resources and expert advice about environmental health exposures. In 1998, the Agency for Toxic Substances and Disease Registry and its federal partner, the Environmental Protection Agency, began to fund a series of cooperative agreements to create and operate the Pediatric Environmental Health Specialty Unit (PEHSU) program, intended to enhance education, consultation, and referral in reproductive and pediatric

environmental health. In 2015, the PEHSU program launched its National Classroom to expand their educational outreach to all types of healthcare professionals and provide up-to-date information in emerging trends and current topics of interest [6].

The PEHSU National Classroom (https://www.pehsuclassroom.net/) provides free access to interactive, web-based ("eLearning") modules and monthly on-demand webinars. The offerings in the PEHSU National Classroom focus on environmental health topics including lead, marijuana, pesticides, endocrine disrupting chemicals, and school health. The eLearning modules were developed in cooperation with subject-matter experts on environmental health using proven instructional design and adult learning principles [7]; they contained interactive features including simulated clinical scenarios and knowledge checks to promote learning. The pre-test and post-test questions were written by subject-matter experts about information taught in the modules. In addition, most of the National Classroom offerings qualified as continuing education through the Centers for Disease Control and Prevention. As of December 2018, the Classroom had 5335 registered users from many countries, including the United States, Canada, Israel, Australia, India, and Spain.

eLearning has been shown to be an effective tool for increasing knowledge, confidence, and competency in graduate medical professionals [8–16]. eLearning modules can serve as a useful medium to educate healthcare providers about under-taught areas such as environmental health and provide current information on emerging topics of interest. Despite the accessibility and increasing popularity of eLearning, online eLearning resources for pediatric environmental health targeted towards healthcare professionals are limited [17]. Although a few studies have demonstrated success in educating healthcare providers about environmental health using web-based resources, few studies have evaluated the effectiveness of eLearning modules in environmental health in a large cohort [18, 19].

The purpose of this study was to evaluate the effectiveness of the PEHSU eLearning modules in increasing knowledge about pediatric and reproductive environmental health. Through an anonymous 6-month follow-up survey, the impact on clinical practice was evaluated. We hypothesized that eLearning modules can be effective in increasing healthcare provider knowledge and can lead to increase awareness about environmental health in clinical practice.

Methods

Data Collection

PEHSU eLearning Modules

The PEHSU National Classroom was accessible at no cost and required users to register by creating an account to gain access

to the content. Users had unlimited access to the National Classroom and were able to complete modules at their own pace. Users were invited via PEHSU mailing lists or were recommended or required to complete the modules as part of a medical toxicology clerkship or fellowship program curriculum. Modules were publicized on the Centers for Disease Control and Prevention (CDC)'s online learning system, CDC TRAIN, and the websites of American Academy of Pediatrics, American Association of Colleges of Nursing, American College of Medical Toxicology, Agency for Toxic Substances and Disease Registry, and Environmental Protection Agency. The National Classroom was readily found via web search. Of the material available in the National Classroom, this study analyzed 12 modules – consisting of a pre-test, interactive module, and a post-test. The pre-tests and post-tests consisted of 5 to 15 multiple choice or true/false questions about information taught in the modules. Pre-test and post-test questions were unique to avoid recognition of answers. Launched throughout March 2016–October 2018, the modules ranged from 30 minutes to 1 hour to complete (Table 1).

De-identified data ranging from March 1, 2016 through November 30, 2018 were obtained from the PEHSU National Classroom learning management platform, provided by Docebo. The data set included course name, course creation date, first date accessed by user, completion date by user, last date accessed by user, pre-test score, post-test score, profession of user, whether the user participated in a medical toxicology fellowship program or medical toxicology clerkship program, and the state and country in which the user resided. 1604 users were identified as having started one of the eLearning modules. Data from all international users and all users without a completed pre-test and post-test were excluded, resulting in 994 users included in this study.

Follow-Up Survey

A 6-month follow-up survey was distributed to users who completed the modules prior to April 2018 (Table 1). Users who had completed a module that was launched after April 2018 were not included due to insufficient time for follow-up. 817 users were identified as having completed modules prior to April 2018. Surveys were sent to these users when at least 6 months had lapsed since the completion of a module during the survey period May 2017–November 2018. The user was emailed a link to a voluntary survey via survey platform SurveyMonkey. Reminder emails were sent weekly for 3 weeks to encourage completion. Survey questions can be viewed in Table 3. Data received for this analysis were de-identified.

Data Analysis

A biostatistician reviewed and approved the analytic plan used to evaluate the data. All analytical tests were conducted with

Table 1 Pediatric Environmental Health Specialty Unit (PEHSU) eLearning modules.

eLearning module	Number of completed modules (%)	Launch date	Follow-up survey administered
Pesticides and Child Health: Exposure Recognition and Prevention	87 (6.19)	March 1, 2016	Yes
School Environment, Health, Performance	73 (5.19)	March 7, 2016	Yes
Marijuana Exposure in Pediatric Populations	62 (4.41)	April 19, 2017	Yes
Marijuana Use in Perinatal Populations	7 (0.50)	June 30, 2017	Yes
Marijuana Use in Adolescent Populations	19 (1.35)	June 30, 2017	Yes
Endocrine Disrupting Chemicals in Consumer Products: Introduction	404 (28.73)	March 1, 2018	Yes
Endocrine Disrupting Chemicals in Consumer Products: Identification and Health Effects	305 (21.69)	March 1, 2018	Yes
Endocrine Disrupting Chemicals in Consumer Products: Prevention	218 (15.50)	March 1, 2018	Yes
Reproductive Health: Carbon Monoxide	25 (1.78)	September 17, 2018	No
Reproductive Health: Environmental Pesticide Residues	53 (3.77)	September 17, 2018	No
Firearm Marksmanship and Adolescent Lead Exposure: Adverse Health Effects, Surveillance, Control, and Prevention	26 (1.85)	October 1, 2018	No
Firearm Marksmanship and Adolescent Lead Exposure: Prevalence, Case Studies and Sources	120 (8.53)	October 1, 2018	No

Stata Special Edition version 15.0 (StataCorp). Tables and figures were created using Microsoft Excel. Descriptive statistics were used for reporting percentages within each profession and module category. Statistical analysis reported results as mean percent correct test scores with standard deviations.

Paired t-tests were used to compare the pre-test and post-test scores on all users. Significance level was set at 0.05 for all analyses. For users who completed more than 1 module, the average pre-test and post-test scores were calculated for that user and used in analysis. Users were then subdivided into five profession categories – nurses, physicians (i.e., residents, fellows, attending physicians), mid-level practitioners (i.e., nurse practitioner, physician assistant), students (i.e., medical and nursing), and other nonclinical professions. Paired t-tests were used to compare pre-tests and post-tests scores within each profession category. One-way analysis of variance (ANOVA) was used with F-tests to compare the score change between pre-test and post-tests among different professions categories.

Statistical analysis was also completed based on each eLearning module. Paired t-tests were used to compare the pre-test and post scores of each eLearning module. Due to multiple eLearning modules which focused on the same topic, the following categories were created, and each module was sorted into the appropriate category: Endocrine Disrupting Chemicals in Consumer Products, Firearm Marksmanship and Adolescent Lead Exposure, Marijuana Use and Exposure, Pesticides, Reproductive Health, and School Environment. One-way analysis of variance (ANOVA) was used with F-tests to compare the score change between pre-tests and post-tests among module categories.

The University of Connecticut Health Institutional Review Board determined the project to not be human subject research and did not need Institutional Review Board involvement. The University of California, San Francisco Human Research Protection Program Institutional Review Board determined this research as exempt under the Revised Common Rule.

Results

Descriptive Characteristics

A total of 994 users of the PEHSU National Classroom completed at least one eLearning module and its associated pre-test and post-test. Twenty-seven percent of users completed 2 or more modules. Table 2 shows the professions of the users, which span a wide range of clinical and nonclinical professions.

Analysis by Profession

Majority of professions had direct patient contact and required continuing education – nurses (38%), physicians (19.6%), mid-level practitioners (i.e., nurse practitioner, physician assistant), and students (medical and nursing) (13%). The majority of emergency medicine residents, pediatrics residents,

Table 2 Mean pre-test scores, post-test scores, and mean difference in percent correct for PEHSU eLearning modules by profession.

Profession	n (%)	Associated with medical toxicology clerkship or fellowship (% of subgroup)	Mean percent correct pre-test score (SD)[a]	Mean percent correct post-test score (SD)[a]	Mean difference in percent correct (SD)	P value
Mid-level practitioner (i.e., nurse practitioner, physician assistant)	45 (5)		59.68 (21.87)	92.92 (7.93)	33.24 (23.22)	0.0001
Nurses	378 (38)		60.28 (17.82)	93.60 (6.94)	33.32 (18.78)	0.0001
Physicians	196 (19.6)		64.33 (18.50)	92.91 (7.32)	28.58 (20.46)	0.0001
Attending physicians (pediatrics, n = 51; internal medicine, n = 2; family medicine, n = 14; medical toxicology, n = 4; emergency medicine, n = 1; OB/Gyn, n = 2)	74 (7.4)	1 (25)	68.79 (17.77)	95.3 (6.70)	26.50 (19.21)	0.0001
Fellows (medical toxicology, n = 2; emergency medicine, n = 11)	13 (1.3)	8 (62)	63.06 (26.27)	91.15 (8.37)	28.09 (28.26)	0.0038
Residents (pediatrics, n = 15; family medicine, n = 2; emergency medicine, n = 92)	109 (10.9)	77 (71)	66.15 (16.90)	95.02 (6.45)	28.87 (18.66)	0.0001
Students	128 (13)		63.46 (16.84)	93.50 (6.73)	30.04 (18.96)	0.0001
Medical	70 (7)	57 (79.17)	62.56 (17.76)	93.48 (6.80)	30.92 (19.72)	0.0001
Nursing	58 (5.80)		64.58 (15.70)	93.53 (6.70)	28.95 (18.09)	0.0001
Other/not specified[b]	249 (24.9)	1 (1.75)	63.77 (19.89)	92.19 (7.64)	28.43 (20.74)	0.0001
All users	994 (100)	144 (14)	62.33 (18.61)	93.07 (7.22)	30.74 (19.94)	0.0001

[a] For users who took multiple modules, average pre-test and post-test scores were calculated for each user

[b] Includes administrators, child care providers, government employees, health educators, medical assistants, paramedics, pharmacists, pharmacy residents and students, public health professionals, students (other), and teachers

emergency medicine fellows, and medical students were associated with a medical toxicology clerkship or fellowship program that recommended or required the modules as part of their training (Table 2). Analysis completed on all 994 clinical and nonclinical professionals revealed that post-test scores were significantly higher than pre-test scores, with an increase of 30.74% ± 19.94 (paired t-test, $p < 0.0001$). All users started with low pre-test scores (62.21% ± 18.59), which were relatively comparable across the profession categories (nurses, mid-level practitioner, physicians, students, and other) ($F_{4,989} = 2.54$, $P = 0.0384$). Within the profession categories (nurses, mid-level practitioner, physicians, students, and other), post-test scores were significantly higher than pre-test scores (paired t-test, $p < 0.0001$). One-way ANOVA revealed statistically significant mean score change among the profession categories ($F_{4,989} = 3.17$, $P = 0.01$).

Analysis by Modules

Paired t-tests were conducted on a sample of 12 modules to determine whether there was a statistically significant mean difference in pre-test and post-test scores after completing each PEHSU eLearning module. In all eLearning modules, users in each module had statistically significant increase in pre-test to post-test scores (paired t-test, p < 0.05) as represented in Fig. 1. Modules that had lower pre-test scores demonstrated a greater score improvement compared to modules with higher pre-test scores. In our analysis, the eLearning modules were divided into Endocrine Disrupting Chemicals in Consumer Products, Firearm Marksmanship and Adolescent Lead Exposure,

Marijuana Use and Exposure, Pesticides, Reproductive Health, and School Environment. One-way ANOVA revealed that there was a statistically significant difference in the pre-test scores among the module categories ($F_{5,988} = 9.09$, $P < 0.0001$). One-way ANOVA also revealed statistically significant differences in mean improvement among the various module categories ($F_{5,988} = 9.28$, $P < 0.0001$).

Follow-Up Survey Evaluating Impact on Clinical Practice

Of the 817 eLearning module users who were emailed a 6-month follow-up survey, 169 responses (21%) were received. Only 8% (62 of 817 surveyed) fully completed the survey. Responses to survey questions are reported in Table 3. 110 of 130 respondents agreed that they would return to the PEHSU National Classroom to complete additional eLearning modules.

Discussion

This study found that the PEHSU eLearning modules significantly increased environmental health knowledge among physicians, nurses, mid-level practitioners, and other nonclinical professions. The overall low pre-test scores suggested a low baseline knowledge in the environmental health topics covered by the eLearning modules, irrespective of profession. This further highlights the lack of emphasis in environmental health in medical education. When compared across module categories, pre-test scores were statistically significantly different, suggesting that baseline knowledge differed based on

Fig. 1 Mean percent correct pre-test and post-test scores according to PEHSU eLearning modules. Error bars represent standard deviation in each group. Asterisks represent statistical significance ($p < 0.05$) when post-test scores were compared to pre-test scores in paired t-tests.
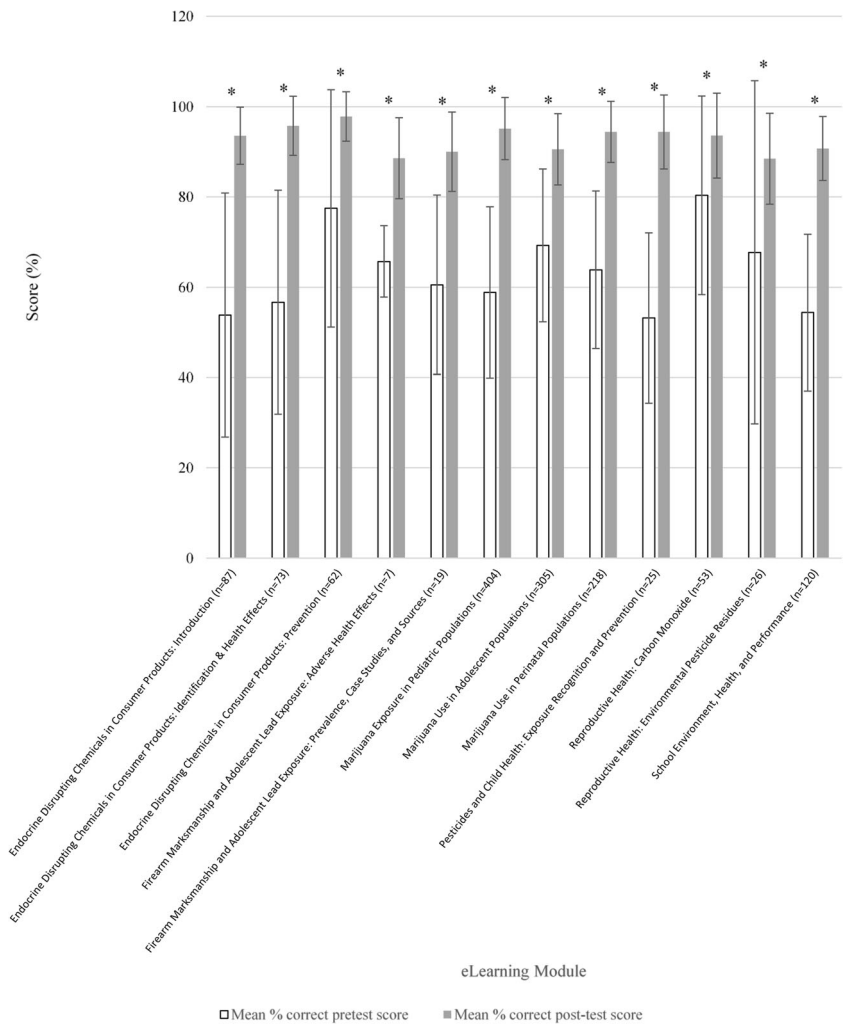

Table 3 Six-month follow-up survey responses from 169 users who had completed a select group of PEHSU eLearning modules during September 2016–April 2018. Of the 817 users who were sent the survey, 62 fully completed survey responses were received.

Survey questions	Answered "strongly agree" or "agree"/total who answered question
Do you work in a clinical setting (including students and trainees)?	103/150
As a result of completing the module: (strongly disagree to strongly agree)	
I have added environmental health questions to care conversations	44/65
I have incorporated environmental factor questions in assessment of sick child	53/68
I have added environmental health risk reduction in counseling	47/65
I have used PEHSU and other resources to provide environmental health risk reduction at individual level	42/68
I have used PEHSU and other resources to provide environmental health at community level	30/65
I have enhanced my knowledge and awareness of children's environmental health	62/62
I know where to find more resources about children's environmental health	58/62
I plan to return to the PEHSU National Classroom to complete additional eLearning modules	110/130

the topic. All modules were effective in increasing knowledge, which suggests that PEHSU eLearning modules were effective educational tools for a range of environmental health topics and professions. There was a statistically significant difference in mean score change among module categories, which suggests that some modules may be more effective than others. However, this could vary based on topic, content, and difficulty of the pre-test and post-test questions. Among the 12 modules, 66% of the 1399 completed modules were one of the three modules about marijuana exposure and use in pediatric populations, suggesting strong interest in this area and potential lack of prior training among providers.

A wide variety of clinical and nonclinical professionals accessed and completed the modules, suggesting that this platform is useful and appealing to a variety of learners. Moreover, 27% of users took 2 or more modules, suggesting that the format of the modules and information provided were helpful. In the 6-month follow-up survey, many users who completed the survey reported they would return to the PEHSU National Classroom to complete additional eLearning modules. A large portion of the users were nurses, suggesting a strong interest among nurses in environmental health education [20–22].

Limitations

Although our findings suggested PEHSU eLearning modules were effective in significantly increasing knowledge regarding environmental health, this conclusion is limited by several factors. Since the eLearning modules were taken in an uncontrolled environment, we were unable to account for any use of external resources which may falsely elevate the post-test scores. Learners who chose to take these learning modules may be more intrinsically motivated by interest in environmental health topics, which may lead them to be more engaged with the content and, as a result, score higher on the post-test assessments. Furthermore, follow-up testing at later intervals is needed to determine retention of information learned from modules.

Investigation into how best to engage physicians in environmental health education is necessary. Although there are a small number of residency and fellowship programs with emphasis in toxicology and environmental health, these topics continue to be underrepresented in most residency training programs. Further surveys are needed to determine the motivation for learners taking the modules and reasons for attrition. Additional studies are needed to determine if content presentation should vary depending on learner profession (i.e., physician, nurse practitioner, nurse, physician assistant, or student).

Lastly, we are unable to determine the clinical impact of the PEHSU eLearning modules based on this analysis. The 6-month follow-up survey conducted was limited in scope and may be subject to bias due to a low response rate of 8% who fully completed the survey. Nonrespondents may have less interest in environmental health concerns or did not find the eLearning modules to be helpful; respondents may have overstated their level of interest and the efficacy of the modules. The low response rate may be due in part to the fact that some participants who were required to complete the modules for a rotation requirement were presumably less likely to be motivated to complete a follow-up survey after they had completed their rotations. The completion rate was likely lower since a portion of respondents did not work in a clinical setting and questions about clinical questions were not applicable. Moreover, the survey did not evaluate all modules offered in the National Classroom. Further surveys with more robust participation and investigation of all modules will be needed to determine if healthcare professionals altered their clinical practice after completing the eLearning modules. Knowledge retention could be analyzed through incorporation of module-specific competency questions in the follow-up survey. Analyzing more objective measures such as diagnoses from a chart review after completing eLearning modules may provide better insight into clinical impact.

Conclusion

In summary, PEHSU eLearning modules are effective in significantly increasing knowledge about environmental health across a range of clinical and nonclinical professions. Further studies are necessary to determine long-term retention of information at later intervals and the potential clinical impact of healthcare providers. Additional investigation will be needed to determine best methods to engage physicians and other clinicians in environmental health education.

The findings and conclusions in this publication have not been formally disseminated by the Agency for Toxic Substances and Disease Registry and should not be construed to represent an agency determination or policy.

Compliance with Ethical Standards

Conflicts of Interest　None

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