Awareness for Air Pollution Impacts on Lung Cancer in Southern California: A Pilot Study for Designed Smartphone Application

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Abstract—This study follows the design science research methodology to design and implement a smartphone application artifact. The developed artifact was evaluated through three phases. The System Usability Scale (SUS) metric was used for the evaluation. The designed artifact aims to spread awareness about reducing air pollution, decreasing lung cancer development, and checking the air quality status in Southern California Counties. Participants have been drawn for a pilot study to facilitate awareness of air pollution. The study found that smartphone applications have a beneficial effect on the study's aims.

Keywords—Air pollution, design science research, indoor air pollution, lung cancer, outdoor air pollution, smartphone application.

I. INTRODUCTION

 $E_{\rm those}$ with underlying respiratory issues are at a higher risk of developing certain diseases, such as lung cancer. Inhaling polluted air causes damage to the respiratory system, leading to a range of respiratory problems, including asthma, bronchitis, and emphysema. The particles in polluted air can also cause inflammation, forming scar tissue and other changes in the lung tissue [1]. Over time, this damage can increase an individual's risk of developing lung cancer. Air pollution is defined by the World Health Organization (WHO) as "contamination of the indoor or outdoor environment by any chemical, physical, or biological agent that modifies the natural characteristics of the atmosphere" [2]. Air pollution has been proven to contribute to millions of deaths worldwide each year, making it a major public health concern [3]. WHO has shown that 24% of global deaths are linked to the environment, about 3.2 million deaths yearly from indoor smoke exposure, and 4.2 million annual deaths attributed to ambient air pollution [4]. Since outdoor air pollution is recognized by the International Agency for Research on Cancer as a known human lung carcinogen, indoor air pollution is considered a significant risk factor for lung cancer [3]. Outdoor air pollution is a preventable risk factor that places a heavy weight on society by increasing disabilities, health disorders, and deaths [5].

Overall, respiratory health issues are affected by indoor and outdoor air pollution, meaning that exposure to a variety of environmental air pollutants may worsen the conditions who are at high risk of developing lung cancer [6].

The study focuses on the southern California region since it

has a long history of air pollution due to its geographical location and large population. Air pollution in Southern California has been a risk factor for causing COVID-19 death [7]. In addition, California has several industrial areas, including the Los Angeles area, where air pollution is a major concern [8]. There are several ways to reduce air pollution, such as reducing vehicle emissions, limiting industrial pollution, and promoting the use of clean, renewable energy sources. The State of California is already working on raising awareness amongst the population; they carry out early Computerized Tomography (CT) scans. The CT scan helps people who have a high risk of acquiring lung cancer [9]. The entire country and the state of California are working on increasing awareness of lung cancer and how to take preventative measures. There are other smartphone applications for monitoring air quality and pollution, and some are designed for lung cancer patients and their families. However, no smartphone applications combine the big picture of air pollution impacts on lung cancer, for example, explaining the causes of air pollution, how to reduce it, what to do if the air quality is bad, and many other features and risk factors details.

In this research, we designed, developed, and implemented an air pollution awareness smartphone application called "Fresh Lungs" in the Google Play App Store. The smartphone provides awareness educational materials and the air quality status for the residents, including lung cancer patients in Southern California Counties.

II. BACKGROUND

This section briefly outlines related studies about how air pollution is linked to lung cancer. Namely, from 1975 to 2022: Chen et al. found that improving indoor air quality may help lower lung cancer risk [10].

Yang et al. found a link between persistent exposure to high ambient air pollution levels and a higher risk of lung cancer [11]. Turner et al. conducted an overview of the current evidence on the relationship between outdoor air pollution and cancer; they concluded that reducing air pollution is an important public health priority [1].

Wang et al. revealed that a significant increase in the probability of lung cancer mortality was associated with short-term exposure to ambient air pollution [12]. Caiazzo et al. investigated the impact of air pollution on early deaths in the

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United States; they found that the transportation and electricity sectors had the largest impact on air pollution and premature; deaths [13].

Künzli et al. studied the impact of air pollution on respiratory health in Los Angeles, and they found that prolonged exposure to air pollution was significantly connected with respiratory problems, including asthma and lung cancer [14].

Beeson et al. studied the link between adult lung cancer incidence in California and long-term exposure to ambient air pollution; they found that persistent exposure to air pollution was associated with a higher chance of developing lung cancer [15]. Cohen and Pope reviewed previous research on the relationship between air pollution and lung cancer, and they identified several potential mechanisms by which air pollution may contribute to the development of lung cancer [16]. Henderson et al. investigated the relationship levels between lung cancer and air pollution in south-central Los Angeles County. They analyzed data on air pollution levels and lung cancer incidence rates and found that lung cancer incidence rates were significantly higher in areas with higher levels of air pollution [8].

In general, these studies provide valuable insights into the impact of air pollution on cancer. They highlight the need for continued research and public health efforts to address this important issue. This study adds to the existing body of research on the risk factors for lung cancer, it designed, developed, and implemented an awareness solution, and a smartphone application software artifact represents the solution. The objective of this study is to decrease exposure to air pollution from various aspects. Eventually, it will reduce the factors development of lung cancer disease.

III. SMARTPHONE APPLICATION DESIGN AND PROGRAMMING

An instantiation represents the artifact as a smartphone software application. The application was coded using Java programming language by one of the researchers. The application works on Android smartphones. The application's name is Fresh Lungs; the name combines two words: "Fresh" comes from fresh air, and "Lungs" comes from lung cancer. The developed artifact detects the air quality status levels in the Counties of Southern California. The smartphone application also provides some educational resources to the participants that can be accessed inside the application, which is the novelty part of the topic.

The air quality status levels provide real-time data from Airnow.gov's official website, which belongs to U.S. Environmental Protection Agency. Airnow.gov provides data represented as a score, indicating whether the current air quality is healthy or unhealthy, and color-coded categories represent the score.

The educational materials educate the participants about the risk factors and prevention tips for lung cancer disease; the materials also include some articles to educate the participant about how to keep the air healthier. These materials are published by the following trusted professional resources: AirNow.gov, American Lung Association, Centers for Disease Control and Prevention CDC, National Cancer Institute, U.S. Environmental Protection Agency, and WebMD. We have selected these educational resources based on important reasons: the information's accuracy and the users' privacy protection. These websites provide accurate information and protect the privacy of their website visitors. Some of the important design elements we have been working on are to make the smartphone application a user-friendly interface, encourage users to use it, make it easier to use in terms of feasibility, and protect the users' privacy. A brief detail of some important design elements is:

User-friendly interface: To understand the empathy of the desired user interface colors for users, we have decided to implement the natural colors of blue and green. A recent study referenced the green color, and the blue color has great significance for people's mental and emotional health [17].

Privacy: The smartphone application was developed without collecting any personal information of the users. For example, the application does not collect users' locations or phone numbers. We wrote a privacy policy statement for the users, and this policy declared what types of personal information the researchers were collecting. Moreover, the application does not detect the user's location, participants see the air quality service areas as buttons, and these buttons display the following countries in Southern California: Los Angeles, Monterey, Orange County, Riverside, Santa Barbara, San Bernardino, San Diego, San Luis Obispo, Tulare, Tulare, and Ventura.

The smartphone application was published on the Google play store and distributed to the participants.

A. The Evaluation of the Smartphone Application

Before recruiting participants for the evaluation, we evaluated the smartphone application artifact through the following phases:

- *Phase 1.* We had an internal evaluation among team members to evaluate the prototype leading to the final product.
- *Phase 2.* The team re-evaluated the final product, and new materials were added to the educational sections; also, further improvements were made to the interface.
- *Phase 3.* The SUS was used to measure the score of the developed smartphone application. SUS includes a pre-and post-survey.

IV. METHODOLOGY

We applied the design science research methodology to bring awareness of air pollution and educate individuals. In this research, we address the following research question:

• *Research Questions*: "How to raise awareness and educate people about air pollution for residents and lung cancer patients in Southern California?"

To answer this question, we are not only trying to understand the causes of air pollution and how it is linked to lung cancer but rather to solve them by designing and evaluating an appropriate software artifact, the smartphone application called "Fresh Lungs." A pilot study was designed to get preliminary information on how the designed smartphone application can benefit the reduction of the air pollution impact on lung cancer. The sample size was 10 participants, four were males, and six were females. Most of them had graduate degrees, and a couple had undergraduate degrees. All participants were physically living in Southern California. A survey was distributed to the participants in two phases. The first phase was a pre-survey before using the smartphone application. The second phase was after they had downloaded and used the smartphone application.

V.CONCEPTUAL FRAMEWORK

To conduct this research, we rely on the design science framework in conducting the study [18]. The framework includes eight checklist questions mapped within it [18, p.20]. Fig. 1 shows the framework [18].



Fig. 1 Design Science Framework with Checklist Questions [18]

The framework has three phases: the environment phase, the design science phase, and the knowledge base phase. There is a checklist of eight questions mapped within the design science framework as follow:

- 1. First checklist question is about directing the research question: "How to raise awareness and educate people about air pollution for residents and lung cancer patients in Southern California?"
- 2. Second checklist question is about providing details about the designed artifact: The artifact is represented by software instantiation, its smartphone application, which we called "Fresh Lungs." A low-fidelity prototype was implemented at the beginning while developing the smartphone application. The developer sketches the graphic user interface of the smartphone application on a small piece of paper, "post-it," and shares it with the researchers' team to gather feedback for further improvement.
- 3. Third checklist question is about outlining the designed process that is associated with building the artifact: We worked on understanding users' empathy in adopting the graphic user interface, the feasibility of use, the motivation to use the application, and protecting the users' privacy.
- 4. Fourth checklist question is about understanding the knowledge role in the designed process and the artifact: We have referenced the study on different theories from the literature about the air pollution impact on lung cancer. We also rely on some theories in designing and developing the artifact.
- 5. Fifth checklist question is about describing the evaluations and improvements stages for the design cycles internally: Several evaluations have been completed throughout the internal design cycle of the artifact. The graphic user

interface and choosing sufficient educational resources were the major design improvement. The smartphone application software was tested on virtual and physical devices, then continued developing to improve the graphic user interface after each time of testing cycle. There are some limitations during the internal testing; the smartphone application software was tested on a smartphone with a 6-inch screen size.

The idea of selecting their educational resources material was based on the following:

- What medically necessary steps are needed to avoid the detrimental effects of air pollution? Especially for people diagnosed with lung cancer.
- How do the users understand what causes lung cancer?
- How do the users understand how to prevent lung cancer disease?
- How do the users understand the risk of lung cancer?
- How do the users learn what to do when the air is unhealthy?
- How do the users work to improve air quality in their neighborhoods?

More than six articles have been selected as an educational resource. We have reviewed the selected educational materials several times, and they decided to choose the following six articles are matching the addresses questions:

- 10 Tips to Protect Yourself from Unhealthy Air by the American Lung Association.
- How Communities Can Help People Lower Their Lung Cancer Risk by the Centers for Disease Control and Prevention CDC.
- How You Can Help Keep the Air Cleaner by the AirNow Official Website.
- Health Risk of Radon by the U.S. Environmental

Protection Agency.

- Lung Cancer Prevention by the National Cancer Institute NIH.
- What Causes Lung Cancer? By WebMD Website.

Another reason for selecting the addressed educational resource materials is privacy and security. Professional, trusted websites published the chosen materials. These websites carefully maintain visitors' privacy and security, protecting the users' smart devices and data.

- 6. Sixth checklist question is about introducing the artifact to the application environment and choosing the suitable metrics: The artifact, the smartphone application "Fresh Lungs," has been published on the Google play store. The participants received an invitation via email and text messages to download the application from the Google Play Store to join the study. We have used the SUS as a metric to evaluate the developed artifact. We chose this metric to perform in the evaluation process because it is a software instantiation that will be installed on an actual smartphone device. The developer initially tested the smartphone application several times internally on different virtual and physical smartphone devices before publishing it on the Google play store.
- 7. Seventh checklist question is about checking the newly added knowledge towards existing knowledge: An IT artifact represents the added knowledge as a software instantiation, the smartphone application. The smartphone application checks the quality of the air. Also, it educates

the users who are diagnosed with lung cancer disease as well as other users who are not diagnosed with lung cancer disease. There are many air quality monitoring applications such as AirVisual, Air Quality App, AirNow, etc. These applications show the current air quality and pollution depending on the user's location; however, they do not show what steps to take and how the users should protect themselves when they are out. With the developed artifact of this study, the smartphone application focuses on the Southern California Counties only and provides tips on how they can protect themselves.

8. Eighth checklist question is about confirming whether the research question was satisfactorily addressed or not: With the current number of participants and by analyzing their responses, this study was on a good track to addressing the research question. There was a significant difference between the pre-survey and post-survey responses. The majority of the participants' awareness increased after using the smartphone application.

VI. FINDING

The pre-survey results in Fig. 2 show that many are unaware of how air pollution can cause lung cancer. About half the respondents were unaware of radon risks, and half of them were unaware of how to prevent possible chances of getting lung cancer.



Fig. 2 Fresh Lungs Pre-Survey Feedback

After using the Fresh Lungs app, the participants took part in the SUS survey, and once they had finished the survey, we used the SUS formula to find the score. Fig. 3 shows the scores. The smartphone application scored about 69.17 on the SUS score, equivalent to a "B," meaning "Good."

The post-survey results in Fig. 4 showed a significant change. Since using the application, the participants responded that they are now more aware of air pollution and how to prevent it.

VII. CONCLUSION

Generally, the link between air pollution and lung cancer is well established throughout recent research studies [1], [10], [11]. However, there needs to be more awareness throughout the country and globally. Therefore, in this paper, we have addressed the importance of bringing awareness about air pollution and developed a smartphone application called "Fresh Lungs" to bring awareness. We evaluated the application through each phase and made changes based on feedback. With the final artifact, we recruited ten participants to evaluate the smartphone application through a pre-survey, SUS, and post-

survey. With this study, we have seen a change in participar	ts'
responses before and after using the smartphone application.	

	SUS	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
1.	I think that I would like to use the Fresh Lungs App frequently.	1	2	3	4	5
2.	I found the Fresh Lungs App unnecessarily complex.	1	2	3	4	5
3.	I thought the Fresh Lungs App was easy to use.	1	2	3	4	5
4.	I think that I would need the support of a technical person to be able to use this Fresh Lungs App.	1	2	3	4	5
5.	I found the various functions in this Fresh Lungs App were well integrated.	1	2	3	4	5
6.	I thought there was too much inconsistency in this Fresh Lungs App.	1	2	3	4	5
7.	I imagine that most people would learn to use this Fresh Lungs App very quickly.	1	2	3	4	5
8.	I found the Fresh Lungs App very cumbersome to use.	1	2	3	4	5
9.	I felt very confident using the Fresh Lungs App.	1	2	3	4	5
10.	I needed to learn a lot of things before I could get going with this Fresh Lungs App.	1	2	3	4	5

Fig. 3 Fresh Lungs Application's SUS



Fig. 4 Fresh Lungs Post-Survey Feedback

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