THE IMPACT OF SCENARIO-BASED TRAINING ON SECURE CODE EDUCATION PROGRAMS

by

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Abstract

Secure Code Education (SCE) is the compliance requirement for many organizations in the U.S. Consequently, many U.S. companies spend large sums on programs and tooling to meet this requirement and to upskill their developers. This tooling is largely underutilized. Classes beyond the bare required minimum are often not taken advantage of, leaving organizations an investment with a poor return. Gamification has been gaining ground as a way to increase these voluntary utilization rates. However, Scenario Based Training (SBT) could also attract developers to voluntarily utilize these programs and increase the SCE program's ROI. This paper explores the relationship between the SBT attributes of experience with SBT for secure code education and attitudes towards the fitness of SBT in secure code education. This research may provide insight into the overall effectiveness of SBT programming in secure coding environments.

Keywords: scenario-based training, secure code education, training preferences, training utilization

Introduction

The quality of the developer's code greatly impacts the risk businesses assume. According to new research (Application Security Market Size to Grow by 25.55%, Application Software Market to Be Parent Market -Technavio, 2022), application security is a 16.68 billion dollar market in the United States and will grow by over 25% in 2022. Secure Code Education has an outsized impact on this security domain with educational tooling being a considerable portion of the overall cost.

The business invests a great deal in Secure Code Education programs. The return on investment (ROI) on these investments is usually quite low (Fawcett, n.d.). Development staff often completes only the training required for compliance purposes, leaving most of the tooling underutilized (Warrior & Warrior, n.d.). Considering the impact developers with knowledge of secure coding can have on the risk profile of companies and a reported 88% improvement in fix rates (Ciccone, n.d.), improving the ROI, that is the utilization rate, of Secure Code Education (SCE) tooling, seems a worthwhile endeavor.

The purpose of this study is to establish if Scenario Based Training (SBT) is a desirable alternative to traditional SCE tooling and could potentially improve the voluntary use of SCE programs, and if so, what aspects of SBT are most impactful. The research seeks to answer the following question:

RQ1: Which of the predictor (independent) variables (i.e., scenario-based training experience and attitude) are influential in predicting the dependent variable of scenario-based training preferences?

The research is intended to improve understanding of how SBT can be used to improve SCE programs. Even a moderate improvement in utilization rates of these programs could provide improvements not only to a business's risk profile but also improve the speed at which new functions are deployed by decreasing rework related to vulnerability remediation.

Review of the Literature

Scenario-Based cybersecurity training

While there is not a great deal of research specifically on scenario-based secure code education, there is relevant research for scenario-based cybersecurity education in general. In research from Ghosh and Francia (2021), scenario-based training was demonstrated to be an effective tool for assessing skills. The assessment directly tested the activities the skills would support. Additionally, they argued that as skills-based recruiting increases, skills-based assessments are an increasingly important tool. Their argument was based on the contextual learning that happens within scenario-based training. That is, the activities that they would be performing as a part of their role could be directly assessed using real-world, but simulated, scenarios. The authors also referenced Bloom's taxonomy for use in evaluating the learning outcomes. We incorporated this idea of closely matching the skills through question 2 of the experience construct. That is, does the respondent have experience with SBTs that closely match their specific skillset?

According to research from (Pears et al., 2021), case-based learning, which is roughly analogous to scenario-based learning was also an effective learning tool. In their scenario, chatbots were created for the interactions the learner would participate in. While the chat-bots were deemed to not be complex enough, the learners showed a positive reaction to the training method. This engendering of a positive reaction from the learner's perspective is vital to creating training the learners want to participate in. If they do not enjoy it or find value in it, they will not pursue the training without some other motivator. While the study aims, in some respects, to measure attitude, we specifically asked several questions to measure this attitude toward using SBT in SCE. The attitude construct seeks to measure the ideas above; that is, does SBT in their experience engender a positive reaction through providing quality educational activities that are engaging, enjoyable, and efficient?

Giboney et al. (2021) explored the idea of using playable case studies to generate positive interest in cybersecurity. The researchers created this playable case study in a way that was intended to replicate real-world cybersecurity activities. The learners were given regular knowledge-based resources with which to support their scenarios. Participation in the playable case studies demonstrated a positive learner interest in a potential cybersecurity career.

A research project performed by Pettersson et al. (2017), examined a scenario-based approach to teaching hospital staff to search for online medical information. A series of workshops were set up where pediatricians were presented with medical situations and were first encouraged to use their methods of searching. The pediatricians then participated in a workshop with medical librarians and clinical educators to examine other search methods. At the end of the study, the participants completed questionnaires to assess their satisfaction with the experience. The approach results supported high scores for engagement and satisfaction with the training. This idea of the training being engaging is used in our study via the second question in the attitude construct.

A mixed online and in-person study by Blickensderfer et al. (2012) focused on Emergency Whole-Plane Parachute use. Both lecture and scenario-based training were used to inform and allow the practice of using the lifesaving parachute measure by pilots in the experimental group. Two groups participated. One was a control group that participated only in traditional training. After training, virtual scenarios were used to test the participants in several emergency scenarios. A multivariate analysis was done on the results that demonstrated better performance for pilots who underwent scenario-based training in addition to the lecture training. It was suggested that additional research should be completed. Better performance for those pilots who underwent SBT speaks to the educational value of the training.

Koç et al. (2021) performed a study on gamified drone training simulation. The scenario-based simulations were completed in an online environment. Alpha and beta waves were monitored during the training, and it was found that repeated use of the training lowered stress and increased performance. In other words, repetition of the scenarios proved to increase attention, decrease stress, and enhance performance. As the number of sessions increased, performance increased. The idea of repetition increasing the value of SBTs appears to have merit based on this study. We did not directly address it in this study, but there appears to be value here that could make a case for including repetition in future studies of SBTs.

Macchiarella and Mirot (2018) found that experiential training, specifically computer-based simulation, was effective at improving training outcomes for unmanned drone pilots. Work that is done virtually or on a computer is relatively easy to simulate effectively, which created efficiencies in the development of new scenarios for the students to train with. Consequently, high levels of psychological-cognitive achievement through the platform provided high levels of student engagement. Programming scenarios are also natively performed on a computer, and consequently, they are even easier to create and attain high levels of psychological-cognitive fidelity, which would likely result in similarly high levels of student engagement. Again, the idea of engagement is coming up in existing research, reinforcing our use of it in this study.

In research by Adermann et al. (2014), surgeons were trained with a simulator for lumbar discectomy. Due to the realistic nature of the simulation, surgeons in the pilot rated the training highly for educational value. The training was rated higher than other simulations that used less realistic methods and didn't match the surgical experience as closely. The research concluded that the more accurately the simulation represented the real-world activity, the higher the educational value and acceptance of the training was by the target audience. This research, therefore, speaks to accurately matching the skills of the trainee. For secure code education, this matching of skills could mean not just programming examples, but also User Interface specific examples for UI developers, Java examples for Java developers, etc.

Research by Peeters et al. (2011) compared scenarios directed by automated controls to scenarios that were not directed. That is, one set of scenarios was adaptive based on the performance and choices of the students, while the control was a simple scenario script. The research demonstrated that the directed versions of the scenarios, which arguably become more specific to the users' needs based on their responses, provided a much more effective learning environment. Put another way, complex scenarios that can change the challenges presented to the user, based on the response of the users, were more effective training tools than linear scripts.

Jensen et al. (2022) looked at the gamification of training for reporting phishing. They performed three experiments in a simulated work setting, testing separate gamification elements: validation, attribution, incentives, and public presentation. Their research demonstrated that public attribution (recognition) and rewards were both valuable tools for increasing phishing reporting and were implemented through a leaderboard which fosters competition. We included these concepts in our experience construct. We looked at whether our respondents had experience with SBTs that had aspects of competition, rewards, and recognition via questions 1, 3, and 4 respectively.

Methodology

Instrument

The instrument for this study consisted of 14 questions. Questions 1-3 were used to retrieve demographic information. Questions 4-7 were used to measure experience with scenario-based training for secure code education tooling. Questions 8-11 were used to measure attitudes toward scenario-based training for SCE tooling. Questions 12-14 were used to measure user preferences for scenario-based training for secure code education tooling. Questions 4-14 used a 7-point Likert scale that ranged from (1) completely disagree to (7) completely agree (Appendix A).

Participants

A purposive sampling method was chosen due to the specific role and skillset of those who would be regularly required to use an SCE tool. According to Vaughn et al. (1996, p. 58), "Purposive sampling is a procedure by which researchers select a subject or subjects based on predetermined criteria about the extent to which the selected subjects could contribute to the research study." A purposive sampling method was chosen to include software developers and DevSecOps staff at several institutions, including Finance, Health, and Cybersecurity Consulting because they regularly use an SCE tool. Leaders in these organizations granted permission, and then the survey was disseminated to potential participants via internal email distribution lists for those roles. Reminders were sent to the same audiences via internal organization chat tools. Due to limited responses in the first group, the group was expanded to include 3 more organizations for a total of 6 organizations. The sample consisted of 100 participants. A total of 81 usable surveys were completed. Participant characteristics are shown in Table 1.

Procedures

The survey was administered electronically using SurveyMonkey. The survey was distributed to 100 developers. After two weeks, an email reminder was sent and reminders were sent to the same audiences via internal organization chat tools. The participants were guaranteed the anonymity of their responses and assured that the responses would not be shared. Eighty-one completed surveys were returned for a response rate of 81%. The data were imported into SPSS for data analysis.

Data analysis

To answer the research questions, multiple regression analysis was used to determine the predictor variables (experience and attitude) that are most influential in predicting user preferences for scenario-based training for secure code education tooling. Stevens (2012) stated that the coefficients table in multiple regression analysis determines the predictor variables that were influential in predicting the dependent variable. Before any interpretation of the results in the coefficients table, the following tests were performed.

1) The multicollinearity test – the results must indicate the non-existence of multicollinearity. The nonexistence of multicollinearity is indicated by the tolerance level where the values of all predictor variables must be above .1 and the variance inflation factor (VIF) where the values of all predictor variables should not be greater than 10.

2) The model summary/goodness of fit test points to how well the predictor variables predict the dependent variable. It includes multiple correlations (R), squared multiple correlations - coefficient of determination (R2), or "goodness of the fit" with a value between 0.0 (failing to accurately model the data) to 1.0 (highly reliable prediction model), and adjusted squared multiple correlations (R2adj).

3) The ANOVA test should indicate a linear relationship between the dependent variable and the predictor variables. To achieve this, the F test must be significant (the p-value should be equal to or less than .05).

Results

Demographics were collected and are presented in Table 1. Results indicate that the majority of users were male, between the ages of 35-54, and had a bachelor's degree or higher.

Table 1. Demographic Data for Respondents

Characteristic	N	%
Gender		
Male	60	74
Female	16	20
Other	1	1
Prefer Not to Say	4	5
Age		
18-24	1	1
25-34	19	24
35-44	23	28
45-54	32	40
55-64	5	6
65+	1	1
Education		
High School	3	4
Associate Degree	5	6
Bachelor Degree	53	65
Master Degree	19	24
Doctoral or higher	1	1

Regarding the research question, the results indicated the non-existence of multicollinearity. The tolerance level for both predictor variables was above .1 (experience = .75 and attitude = .75), and the VIF for both predictor variables indicated a value less than 10 (experience = 1.38 and attitude = 1.38).

The model summary results were R = .367, R^2 = .134, R^2adj = .112, and the standard error of the estimate = .835. The R^2 suggests that 13% of the dependent variable (user preferences) is predicted by the independent variables (experience and attitude), indicating a reliable prediction model. The ANOVA test (F = 6.05 and p = .004) indicated a linear relationship between the DV (user preference) and the predictor variables (experience and attitude).

Table 2 shows the coefficients. The predictor variable attitude contributed significantly to the prediction model (β = 0.338, p = .008). The β value for attitudes was positive, indicating that the dependent variable preferences increased in response to more positive attitudes toward the use of scenario-based training. The predictor variable experience did not contribute significantly to the model. Tables 3 and 4 show the descriptive statistics and Pearson correlations.

Table 2: Coefficient Results

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2.585	0.410		6.301	<.001
	Experience	0.024	0.059	0.050	0.404	0.688
	Attitude	0.245	0.090	0.338	2.730	**.008**

Dependent variable: Preferences

The descriptive statistics indicate that developer experience with SBT was neutral. Attitudes toward the use of SBT for secure code education training were somewhat positive, and preferences for the use of SBT were slightly below average.

Table 3: Descriptive Statistics

	Mean	Std. Deviation	N
Experience	4.25	1.87	81
Attitude	5.23	1.22	81
Preferences	3.97	0.89	81

The Pearson correlations indicate a moderate association between attitudes toward SBT and experience with SBT. Significant but weak correlations between Experience and Preferences and Attitude and Preference were noted.

Table 4: Pearson Correlations

	Experience	Attitude	Preferences
Experience	---		
Attitude	.525**	---	.
Preferences	.227*	.364**	---

*Note: * indicates p<.05; ** indicates p <.01*

Discussion and Conclusion

The reason businesses invest so much in SCE tooling is both to address compliance requirements and to reduce risk to the organization. With SCE tooling utilization rates so low, however, the ROI on such investments is low. Managers in DevSecOps organizations need to identify ways to increase utilization rates for SCE tooling from a voluntary perspective, and consequently, ROI. This research was intended to assist in finding ways to help understand the utilization of SCE tooling. Initially, gamification was considered as one possible method to improve utilization rates. However, there is a broad body of research already supporting the use of gamification to increase student engagement. Jensen et al. (2022) specifically addressed student engagement and found that recognition and rewards both improved the response rate (educational value) as well as the engagement of students.

Less research could be found on the use of SBT to drive the utilization of SCE. However, there is a good body of research supporting SBT for other fields such as police training and pilot training. The research by Koç et al. (2021) was particularly applicable to SCE as the drone simulations were computer-based and demonstrated improved responses based on increasing numbers of repetitions. Given that the drone simulations used the same medium that developers use to perform their function, computers, their study is a particularly noteworthy example for this research. With SBT proving effective in other fields that can utilize computer-based training, it follows that it may also prove effective with SCE. To that end, would developers prefer SBT for SCE?

This research showed that both experience and attitude had significant but weak correlations with preference. This demonstrates that both independent constructs have at least some impact on the preference construct but that likely, something else is going on with a greater impact. While the average respondent had relatively little experience with SBT, an association was shown between experience and attitude. As users had more experience with these methods, in other words, there was a correlation to a higher (better) attitude towards SBT use in SCE.

This study found that more experience with SBT correlates to a better attitude toward SBT. While experience didn't show a direct prediction of preference, attitude did. So, as a respondent's attitude towards SBT improved, so did user preference towards using it.

If respondents' preference for using SBTs is predictable by their attitude towards them, then this can help managers to find methods to improve their attitudes towards SBTs. Looking at experience in relation to attitude, it appears to indicate that more experience with SBTs improves attitude towards SBTs. Consequently, using SBTs in required training could potentially improve respondents' attitudes, and consequently preference, for using SBTs. If managers then incorporated SBTs into existing SCE-required training, it may be possible to improve the preference for SBTs and provide the respondents with an SBT-based SCE program that they would prefer to use.

While increasing their exposure to and experience with SBTs might improve their attitude towards SBTs, we have individual components within our predictor construct of Experience. Future studies should examine the individual components of competition, skill set specific, rewards or recognition might have a stronger correlation to the attitude construct. Additionally, the repetition of the exercises was mentioned as a predictor of educational value in several other studies. If the intent is to find ways to improve the voluntary utilization of training tools, looking at whether or not repetition impacts student preferences also might have value.

This study has demonstrated that the attitude construct is a predictor of preference. The attitude construct is made up of individual components, including educational, engaging, efficient, and enjoyable. There may be value in examing their relationship with the preference construct to see if some of those items were more impactful to preference than others.

This research has shown that SBT attitude is a predictor of SBT preference, but the experience was not shown to be a predictor. The experience was also shown to correlate with attitude. Consequently, additional work should be done to determine if any of the individual experience methods can be shown to be a predictor for attitude and to what degree. These methods could then be incorporated into SBT-based based SCE curricula to improve developers' attitudes towards SCE tooling via SBT methods.

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Appendix A

Instrument

Part 1:

Demographics

What gender do you identify as?

A. Male
B. Female
C. Short Answer
D. Prefer not to say

What is your age?

A. 18-24
B. 25-34
C. 35-44
D. 45-54
E. 55-64
F. 65+

What is the highest level of education you have completed?

A. Some High School
B. High School
C. Associate degree
D. Bachelor's degree
E. Master's degree
F. Ph.D. or higher
G. Prefer not to say

Part 2:

The instrument's constructs are 1) Experience with scenario-based training, 2) attitude towards scenario-based training, and 3) preferences for scenario-based training. The instrument will be empirically examined for reliability and validity.

The Likert-type scale was used for the instrument with the following scoring strategy: 7 = completely agree, 6 = mostly agree, 5 = somewhat agree, 4 = neither agree nor disagree, 3 = somewhat disagree, 2 = mostly disagree, 1 = completely disagree.

SCE Tooling Experience Construct

I have experience with Scenario-Based SCE tooling that includes

1. I have experience with Scenario-Based SCE tooling that includes competition (e.g., hack-a-thon)
2. I have experience with Scenario-Based SCE tooling that includes technology examples specific to my skillset (e.g. Java scenario for Java developer)
3. I have experience with Scenario-Based SCE tooling that includes rewards (e.g., vendor swag)
4. I have experience with Scenario-Based SCE tooling that includes public Recognition (e.g., publishing leader lists)

SCE Tooling Attitude Construct

I've found Scenario-Based SCE tooling, on average, to be

1. I've found Scenario-Based SCE tooling, on average, to be educational (learn from)
2. I've found Scenario-Based SCE tooling, on average, to be engaging (to get involved with the content or just skim through it)
3. Efficient (to invest less time)
4. Enjoyable

SCE Preferences Construct

Scenario-Based SCE tooling should be used

1. Scenario-Based SCE tooling should be used in addition to traditional knowledge-based training
2. Scenario-Based SCE tooling should be used in place of traditional knowledge-based training
3. Scenario-Based SCE tooling should not be used at all