Authentic Learning Exercise for Kubernetes Misconfigurations: An Experience Report of Student Perceptions

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***Abstract*—Kubernetes has become a popular tool for automated container orchestration. Despite reported benefits, practitioners report that the secure configuration of Kubernetes is one of the primary challenges among practitioners. Moreover, there is a significant skill shortage of Kubernetes security experts. Understanding misconfigurations in Kubernetes can help practitioners prevent security incidents. We systematically investigate whether authentic learning can help students learn about misconfigurations in Kubernetes. We conduct an authentic learning exercise and collected responses from 295 students. Based on responses from the students, we find (i) students who have little to no experience in cybersecurity, software quality assurance, or static analysis perceived the authentic learning exercise as useful to learn misconfigurations in Kubernetes, and (ii) students perceptions of authentic learning exercise activities vary based on and educational background. We conclude our paper with recommendations for instructors and researchers.**

***Index Terms*—devops, devsecops, authentic learning, cybersecurity, kubernetes, misconfiguration, security**

I. Introduction

Kubernetes is a popular tool among IT practitioners due to its benefits [1]. Organizations, such as the U.S. Department of Defense (DoD) adopted Kubernetes and reported improved release timelines from 3 months to 1 week [2]. As per the 2021 CNCF annual survey, 96% of the surveyed 19,000 practitioners use Kubernetes for their respective organizations [3]. Furthermore, the survey highlights that approximately 5.6 million developers globally are utilizing Kubernetes [3]. However, practitioners also acknowledge that Kubernetes has evolved into a complex software platform with a steep learning curve, emphasizing the need for a skilled workforce proficient in Kubernetes [4] [5].

According to the 2021 'State of Kubernetes Security Report,' 94% of 500 practitioners reported that they experienced at least one Kubernetes-related security incident, where most of security incidents are due to security misconfigurations [6]. The survey also states Kubernetes-related misconfigurations to "*pose the greatest security concern*" for Kubernetes-based container orchestration [6]. These concerns are further substantiated through evidence of well-known security attacks [7]. For example, a Kubernetes-related security misconfiguration resulted in a cryptomining attack in electric car manufacturer company Tesla's Amazon Web Services (AWS) resources due to Kubernetes security misconfiguration [7]. A recent survey conducted by Cloud Native suggests that 48% (595) of the survey respondents among 1,240 participants reported "lack of in-house skills/limited manpower" for running and maintaining their Kubernetes cluster [8]. According to the state of Kubernetes survey, among 247 participants 70% and 67% cited lack of experience and expertise as a top deployment and top management challenges [9] respectively. Moreover, practitioners often lack the knowledge to mitigate security misconfigurations [10]. According to the Red Hat 2024 survey, among 600 practitioners, 30% of them reported lacking internal security talents for their Kubernetes security solutions [11].

To create a skilled workforce with expertise in Kubernetes security, one possible approach could be developing authentic learning [12] exercises to educate students about misconfigurations in Kubernetes. Previous research has demonstrated that authentic learning exercises have proven effective in enhancing students' understanding of various subjects, such as mobile application security [13] [14], infrastructure as code (IaC) security [15], and white-box testing [16]. Prior research has reported that incorporating students' perceptions is useful in improving teaching frameworks [17]. Researchers also report that the student's perception of their assessment can help them understand student learning approaches [17]. By incorporating students' perceptions of authentic learning exercises to learn misconfigurations in Kubernetes, we can perform empirical analysis and recommend the instructors to adopt authentic learning pedagogy for teaching misconfigurations in Kubernetes.

The goal of the paper is to help the instructors teach misconfigurations in Kubernetes by providing an experience report of authentic learning exercise related to misconfiguration in Kubernetes.

In this paper, We answer the following research questions:

- **RQ1**: How do students perceive about an authentic

learning-based exercise to learn about misconfigurations in Kubernetes?
- **RQ2**: How do students perceive the components of an authentic learning-based exercise while learning about misconfigurations in Kubernetes?

We conduct a survey with 295 students from University of X to answer our research questions. We use the survey responses to analyze necessary data. The replication package of our paper is available online [18].

***Contributions*:** We list our contributions as follows:
- An evaluation of perceived usefulness of authentic learning to learn about Kubernetes misconfiguration.
- A publicly available replication package with authentic learning exercise activities and survey questionnaires.

We organize the rest of the paper as follows: Section II provides background for authentic learning, Kubernetes manifests, and related works. We describe our methodology in Section III. We report our findings in Section IV. We discuss our observations and limitations in Section V. Finally, we conclude in Section VI.

II. Background and Related Works

In this section, we provide background on authentic learning and its components, briefly describe Kubernetes manifests, and discuss related works.

A. Authentic Learning

Authentic learning is an instructional approach that prioritizes the engagement of students in problem-based activities that reflect real-world contexts [19]. Authentic learning exposes students to real-world problem-solving scenarios based on their in-class experiences. Authentic learning creates a learning environment where the exercise consist of activities that can reflect knowledge skill useful for performing authentic tasks in real world [20] [21].By engaging in authentic learning tasks, students can develop and refine soft and hard employable skills aligned with market demands [22]. The exercises also exhibit distinct characteristics that contribute to its effectiveness. These characteristics include [23]: (i) it focuses on hands-on exercises relevant to the real-world problems, (ii) it encourages students to have a diverse set of perspectives for the same exercise, and (iii) it utilizes available resources to solve exercises.

The implementation of an authentic learning-based exercise typically involves three distinct steps. In Figure 1, we have demonstrated three steps of authentic learning steps. Including these three steps in the authentic learning-based exercise ensures a holistic and practical learning experience for students, promoting deeper engagement and mastery of the subject matter.

B. Kubernetes Manifest

Kubernetes is a container orchestration tool that allows practitioners to create persistent objects using declarative configurations [24]. Kubernetes provides a command line tool called “kubectl” that allows the practitioners to communicate with the Kubernetes cluster to create, update, and delete Kubernetes objects with desired state using object configuration files called Kubernetes manifests [24]. Practitioners write Kubernetes manifests and use the “kubectl apply” command in the command line terminal using appropriate privilege to configure objects and update the live configuration of an object [24]. Kubernetes manifests are written as a YAML file that describes the desired state of a Kubernetes object in a Kubernetes cluster [25]. In Figure 2, we provide a sample example of a Kubernetes object `pod` defined by Kubernetes manifest [24].

C. Related Work

Our research is related to prior research related to instructional approaches to educate students on software quality [26], AR/VR [27] and cybersecurity [28], [29]. Prior research has successfully integrated authentic learning-based exercises into various domains, such as secure software development in mobile computing [13], and mobile application security [14] resulting in improved self-efficacy and confidence among students. Researchers applied authentic learning in learning security threats in machine learning models [30], improving competency in real cybersecurity incidents [31], improving students competency geo-spatial information system(GIS) skills [32]. Authentic learning has also been applied to enhance learning for IaC security [15], information flow analysis [33], and white-box testing [16]. However, we observe a lack of research on teaching misconfigurations in Kubernetes. Our research attempts to address this gap by using authentic learning-based exercises to provide students with practical, hands-on experiences in addressing real-world challenges.

III. Methodology

We describe our methodology by discussing the steps of authentic learning exercise for teaching misconfigurations in Kubernetes. Next, we describe the construction of questionnaire and deployment process. After that, we describe the methodology for answering our research questions.

A. Authentic Learning Exercise Design

We designed our authentic learning-based exercise for misconfigurations in Kubernetes and deployed it in the ‘Software Quality Assurance’ course at University X. The ‘Software Quality Assurance’ course is a cross-listed course at University X, which means undergraduate students of the Bachelor of Science program or graduate students Master of Science or Doctor of Philosophy program can enroll in that course. The course is 16 weeks long and offered regularly in both Fall and Spring semesters. The course is intended for undergraduate senior students and graduate students. Any undergraduate student in junior year requires a minimum CGPA of 3.4 to enroll in the course. The learning outcome of the course is to help the students familiarize themselves with the processes, methods, and tools associated with producing robust, high-quality software.

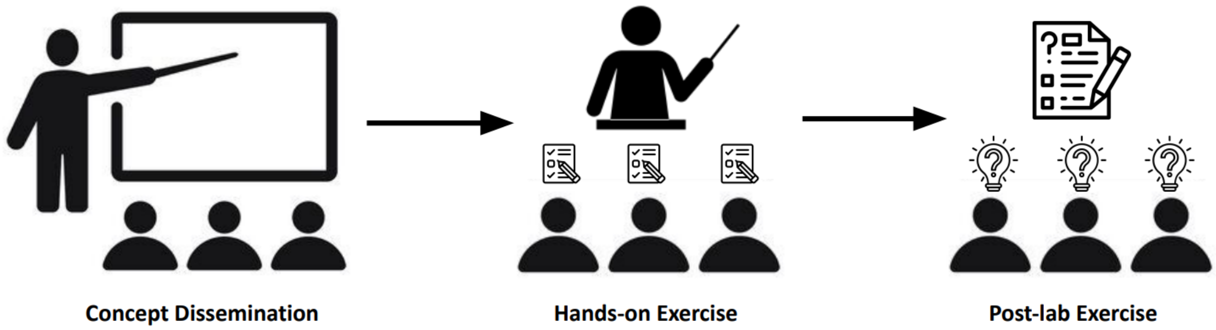

Fig. 1. An overview to illustrate the three steps of the authentic learning-based exercise: pre-lab content dissemination, hands-on and active learning, and post-lab exercises with real-world scenarios.

The instructor of the course is an assistant professor of University X. The instructor has six years of academic teaching experience and seven years of professional work experience in the software industry. Moreover, the instructor's primary research interest is software quality assurance. We apply authentic learning to construct exercises for the students to help them learn misconfigurations in Kubernetes. National Institute of Standards and Technology (NIST) defines a security misconfiguration as a setting within a computer program that violates a configuration policy, or that permits unintended behavior that impacts the security posture of a system [34]. The goal of the exercise is to help the students to understand how to use security analysis tools to identify security misconfigurations in Kubernetes manifests. The authentic learning exercise has three activities as follows:

*1) **Concept Dissemination**:* In the class, the instructor introduced the students with the container tools and the use of container as a part of the course curriculum. In this activity, the instructor introduced the students about tools to automate the configuration management of containers. The instructor specifically focus on one container management and orchestration tool, Kubernetes [24]. The instructor explained Kubernetes and discussed how practitioners specify configurations to manage container orchestration. Practitioners use configuration files known as manifests to automatically manage configurations of containers. Practitioners use the 'kubectl' tool in command line interface to execute the manifests to manage configuration of containers in the Kubernetes cluster. Practitioners develop the manifests using a language called Yet Another Markup Language (YAML) with .yaml or .yml extension. The instructor explained to the students how security misconfigurations appear in Kubernetes manifests while configuring containers and the use of static security analysis tools to identify Kubernetes security misconfigurations in Kubernetes manifests. The practitioner demonstrated an open-source static analysis tool 'SLIKUBE' that identifies security misconfigurations in Kubernetes manifests [35]. The instructor demonstrated a Kubernetes manifest for configuring container in Figure 2 that contains security misconfigurations. The instructor also mentioned their experience of using security analysis tool in software industry and academic research setting.

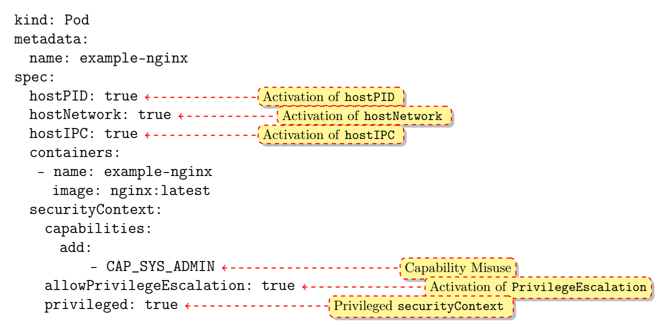

Fig. 2. An example of a Kubernetes manifest with misconfigurations. We use this manifest to demonstrate Kubernetes-related misconfigurations for the authentic learning-based exercise.

*2) **Hands-on Exercise**:* In this activity, the instructor conducted a live demonstration in the class on how to use static security analysis tool to detect security misconfigurations in Kubernetes manifests. As a part of this activity, the instructor guided the students to install 'Docker' in their computer. After the students installed 'Docker' on their computers, the instructor guided the students to download an open-source static security analysis tool called SLIKUBE [35] from 'DockerHub' [36] using `docker pull` command. The instructor used 'Docker' to expose the students in real-world experience. The instructor guided the students to execute the tool SLIKUBE using `docker run` command on the Kubernetes manifest 'example-nginx.yaml' showcased in Figure II-B. Upon execution of the security analysis tool SLIKUBE on the Kubernetes manifest 'example-nginx.yaml', SLIKUBE reported 6 security misconfigurations. The instructor explained the output of the SLIKUBE presented as a CSV file, such as the 'directory' column that represents the directory of the manifest, specific misconfiguration columns such as 'hostPID' that represents the number of occurrences of that misconfiguration, and the 'Total' column that reports the total

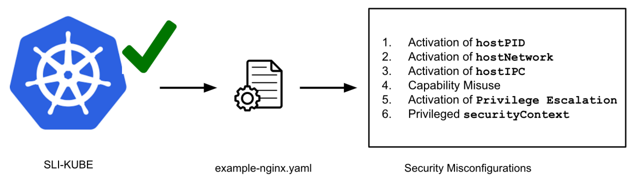

Fig. 3. Overview of in-class experience to detect Kubernetes security misconfigurations in Kubernetes manifests

occurrences of misconfiguration in Kubernetes manifest. In Figure 3, we provided the overview of the activity in-class experience. Throughout this activity, the students followed the instructions from the instructor and executed the tool SLIKUBE in their own computer. The instructor helped the students if any students face any technical difficulty.

*3) **Post-lab Exercise**:* In the post-lab exercise, the instructor provided students Kubernetes manifests from open-source repositories(OSS) such as GitHub and GitLab. As a part of this activity, the instructor asked the students to execute the security static analysis tool SLIKUBE on the provided Kubernetes manifests. The instructor also asked the students to analyze the output of SLIKUBE and report the top 3 most frequent Kubernetes security misconfigurations with the definition and consequences for each of the corresponding Kubernetes security misconfigurations. Upon completion of the tasks, the students were asked to submit a report and complete an online survey.

B. Questionnaire Design and Deployment

We conducted an online survey survey to collect feedback from the students who completed all three steps of the authentic learning exercise. Prior research has shown the effectiveness of authentic learning exercises to improve the understanding and learning the subjects, such as mobile application security [13], IaC [15]. We take motivation from the previous research and expanded their questionnaires to included in our questionnaire set.

*1) **Question-Related to Students' Background and Prior Experience**:* We provided a questionnaire to assess the student's background in the class. The participating students are from "Software Quality Assurance" course. As part of our questionnaire, we asked the students about their academic background. We asked this question as the course is a cross listed course at University X and undergraduate junior, undergraduate senior, graduate masters and graduate PhD students can enroll in the class. We provided the following four options for the question related to academic background: 'Undergraduate - JUNIOR', 'Undergraduate - SENIOR', 'Graduate - MSC' and 'Graduate - PHD'. We also asked the students whether they had any prior experience in cybersecurity, software quality assurance activities, and program analysis tools before participating in the exercise. We asked four questions related to students' academic background and prior experience. The specific questions in the questionnaire set related to student's academic background and prior experience are as follows:

1) Which program are you enrolled in?
2) How would you rate your experience in cybersecurity prior to the course?
3) How would you rate your experience in software quality assurance activities prior to the course?
4) How would you rate your experience with program analysis tools prior to the course?

The possible answer options are presented as a five-item Likert scale: 'Expert', 'Somewhat Expert', 'Knowledgable', 'Little knowledge' and 'No knowledge', following the recommendations of Kitchenham [37].

*2) **Question Related to Student's Perception of the Usefulness of Authentic-learning Exercise**:* To assess the authentic learning exercise's usefulness, we asked the students about their perception. We hypothesized that by analyzing the students' perceptions from the responses, we would be able to understand whether we achieved the learning objective of the authentic learning exercise and whether the students understood how to use security analysis tools to identify security misconfigurations in Kubernetes manifests.

As part of the questionnaire, we asked two questions regarding whether the exercise was helpful for students in learning about Kubernetes misconfigurations and automated configuration management tools. The questions were as follows:

- Overall, did the exercise help you to learn about Kubernetes misconfigurations?
- Which components of the exercise helped you to learn about Kubernetes misconfigurations?

To record the students' responses, we use a five-item Likert scale response: 'Extremely Helpful,' 'Helpful,' 'Somewhat Helpful,' 'Little Helpful,' and 'Not at all Helpful' for each question. Moreover, we ask students for additional comments to get their feedback about their overall experience with the authentic learning exercise.

*3) **Question Related to Students' Perception on the Activities of Authentic Learning Exercise**:* To assess the effectiveness of the authentic learning exercise, we asked the students about their perceptions of authentic learning exercise activities. We hypothesized that we could quantify the usefulness of each component of authentic learning exercise by analyzing the student's responses to authentic learning activities. We asked the students about the usefulness of each individual authentic learning exercise activity: 'Pre-lab concept dissemination,' 'In-class experience', and 'Post-lab activities.' We also asked the students about the combinations of activities in authentic learning exercises that were useful for them. In total, we administered a six-question questionnaire to the students to assess the perceived usefulness of our authentic learning-based exercise. In the question, we refer to 'Pre-lab concept dissemination' as 'Pre-stage' and 'Post-class activities' as 'Post-stage'. The questions were as follows:

1) Which part of the authentic learning experience was useful for you? - Pre-stage

2) Which part of the authentic learning experience was useful for you? - In-class experience
3) Which part of the authentic learning experience was useful for you? - Post-stage
4) Which part of the authentic learning experience was useful for you? - Pre-stage and in-class experience
5) Which part of the authentic learning experience was useful for you? - Pre-stage and post-stage
6) Which part of the authentic learning experience was useful for you? - All three steps

We asked the participating students to rate the usefulness of each of the individual authentic learning activities mentioned in questions (i), (ii), (iii) and the combination of authentic learning activities in questions (iv), (v), (vi) from their experience of performing authentic learning exercise activities. We gave the students five options to respond using a five-item Likert scale. We provided the response options ranging from 'Extremely useful', 'Useful', 'Moderately useful', 'Little useful', to 'Not at all useful'.

4) Survey Deployment: Before deploying our questionnaire to students, we requested approval from the IRB authority at University X. According to IRB guidelines and FERPA policy, we did not collect any personal information, kept students' identities anonymous, and did not release grades. The instructor deployed the questionnaire using University X's online Qualtrics platform. The students participated in the questionnaire after completing the post-lab exercise. We asked for consent from students prior to participation.

C. Survey Analysis

We use the responses from the students participating in the online questionnaire to answer our research questions.

1) Methodology for RQ1: How do students perceive about an authentic learning-based exercise to learn about misconfigurations in Kubernetes?: We answer RQ1 by analyzing the responses from the questionnaire described in Sections III-B1 and III-B2. To understand the students perception about the authentic learning exercise, we hypothesize that the educational background of the students in the class, whether undergraduates or graduates. We also hypothesize that prior experiences in software engineering, namely (i) students' experience in software quality assurance, (iii) students' experience in cybersecurity, and (iv) students' experience in program analysis tools could affect the learning from authentic learning exercise. Regarding students' prior experience, we recorded their responses using a five-item Likert scale: 'Expert,' 'Somewhat Expert,' 'Knowledgeable,' 'Little Knowledge,' and 'No Knowledge.' We report the usefulness of our authentic learning-based exercise by getting the students' responses on whether the exercise helps the students in learning misconfigurations in Kubernetes. We record their responses using a five-item Likert scale: 'Extremely Useful', 'Useful', 'Somewhat Useful', 'Little Useful' and 'Not Useful'. We report the student's perception of the usefulness of the authentic learning exercise.

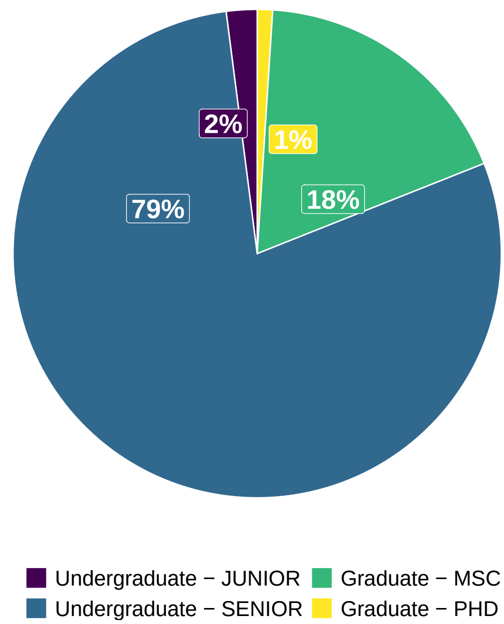

Fig. 4. Educational Background of Students Participating in the Authentic Learning-based Exercise

2) Methodology for RQ2:How do students perceive the components of an authentic learning-based exercise while learning about misconfigurations in Kubernetes?: We answer RQ2 by analyzing the responses from the questionnaire described in Section III-B3. We analyze the student's perception at each step of the authentic learning exercise, namely 'Pre-stage,' 'In-class experience,' and 'Post-stage.' We record their responses using a five-item Likert scale: 'Extremely Useful', 'Useful', 'Somewhat Useful', 'Little Useful' , and 'Not Useful'. Furthermore, we address the students' comments as part of their feedback. We demonstrate an analysis of students' perceptions of authentic learning activities for learning misconfigurations in Kubernetes based on their education, prior knowledge of cybersecurity, static analysis, and software quality assurance.

IV. Results

We collected 295 student responses from the Qualtrics platform at University X. Each student who submitted responses for the questionnaires also participated in all three authentic learning activities: prelab-content dissemination, hands-on exercise, and post-lab exercise activities.

Educational Background: In Figure 4 we demonstrate, the distribution of students based on their educational background during their participation in the survey. Notably, we observe that 79% of the students are undergraduate seniors, while 18% were graduate master's students. Furthermore, we notice that only 3% of the total students graduate PhD and junior undergraduates. All the undergraduate students are enrolled in the Bachelor of Computer Science program, and the graduate

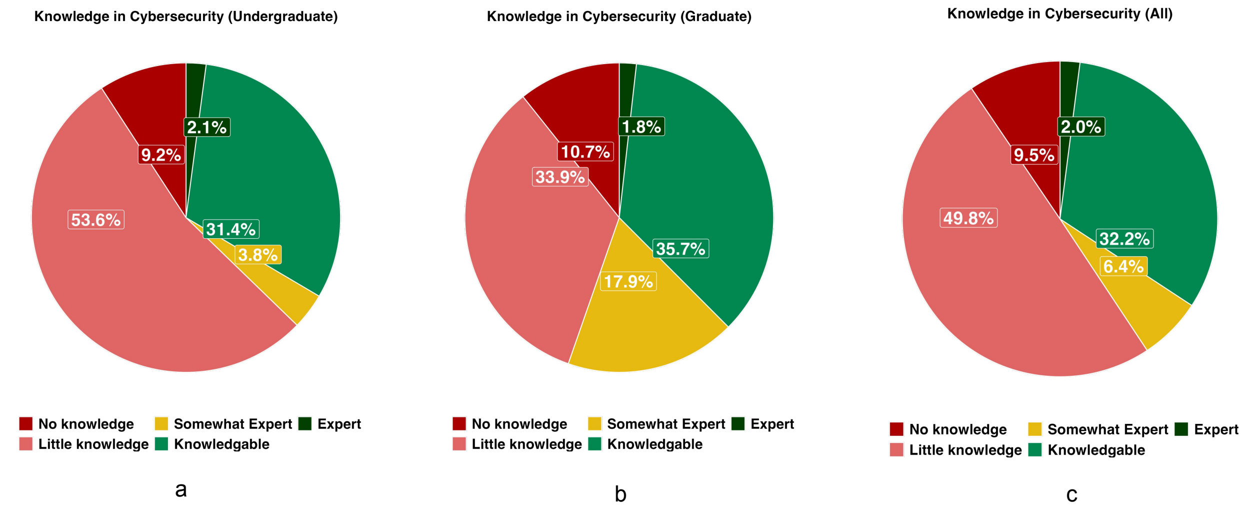

Fig. 5. Students' expertise in cybersecurity

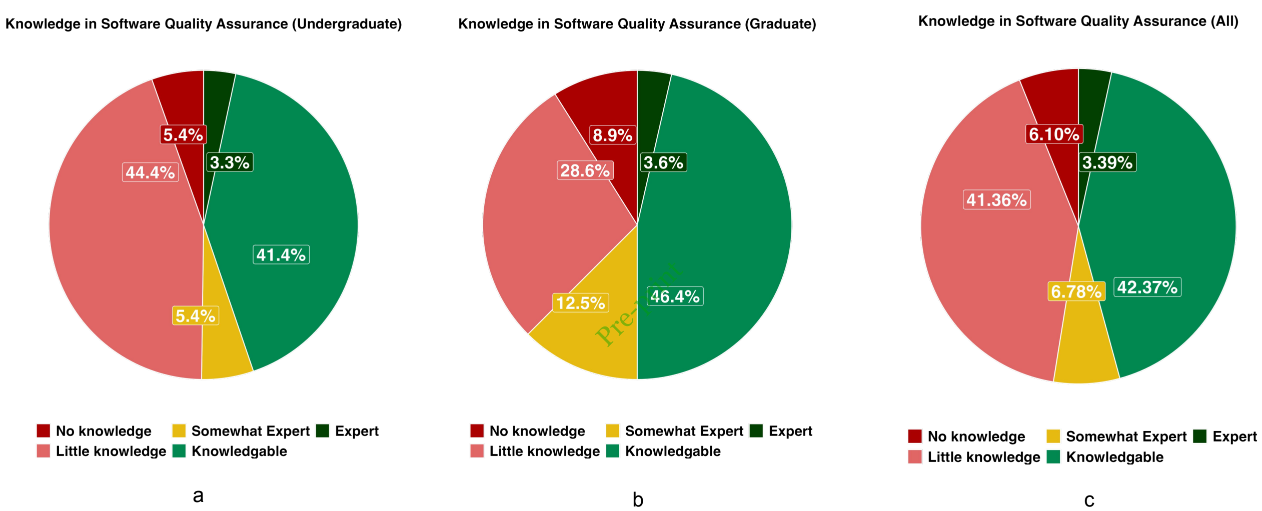

Fig. 6. Students' expertise in software quality assurance

students are enrolled in Masters in Computer Science or PhD in Computer Science program.

Demographics of Students' Prior Experience: To provide further insights about the students, we provide data related to the student's prior experience in cybersecurity, software quality assurance, and static program analysis in Figures 5, 6, and 7. To answer the questionnaire about their prior experience, the students provided responses based on their knowledge of the topic. We observe that 64.8% of the 239 undergraduate students have 'Little knowledge' or 'No knowledge' in cybersecurity. Also, we find 44.6% of the 56 graduate students and overall 59.3% of 295 students have 'Little knowledge' or 'No knowledge' in cybersecurity. Regarding software quality assurance, we find that 49.8% of the 239 undergraduate students and 37.5% of the 56 graduate students do not have any background. Furthermore, we observe that 64.8% of 239 undergraduate students and 42.8% of 56 graduate students have 'Little knowledge' or 'No knowledge' in static program analysis, and overall, 60.7% of students have little to no background in static program analysis. We observe that students' reported lack of expertise, 'Little Knowledge' or 'No knowledge' in static program analysis(60.7%) is higher than cybersecurity(59.3%). From Figure 5, 6, and 7, we also observe that the graduate students have more familiarity and background knowledge compared to the undergraduate students in all three areas of expertise we have considered in our questionnaire.

A. Answer to RQ1

We answer RQ1 by presenting the student's perception of learning misconfiguration in Kubernetes based on their diverse backgrounds, including their educational level, expertise in software quality assurance, expertise in cybersecurity, and expertise in static analysis tools. We report our findings related to

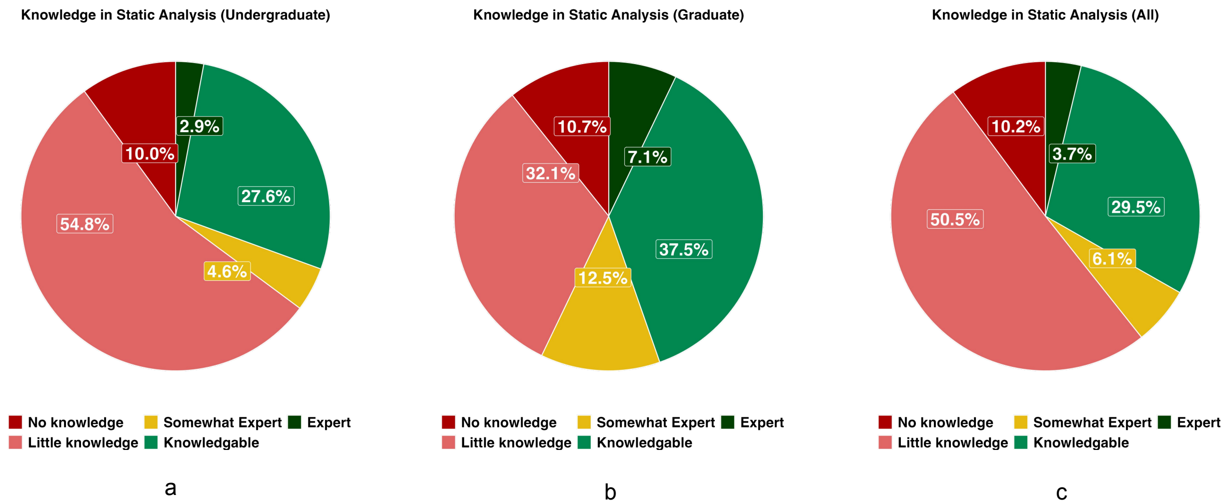

Fig. 7. Students' expertise in static analysis

students' perception of learning Kubernetes misconfigurations in Figure 8a, Figure 8b, Figure 8c, and Figure 8d respectively.

From Figure 8a, we observe that a significant majority of graduate master's students (79.3%), undergraduate senior students (72.9%), and graduate PhD students (100%) find our authentic learning exercise to be 'Very helpful' and 'helpful' in learning about misconfigurations in Kubernetes. However, we also observe that 33.4% of undergraduate junior students find the authentic learning exercises 'Little helpful' and 'Not at all helpful'.

From Figure 8b, we find that the students who perceive their knowledge level as 'Expert', and 'Somewhat Expert' have found the authentic learning exercise 'Very helpful', 'Helpful' and 'Somewhat Helpful'. Moreover, those students who perceive their expertise level as 'Knowledgable,' 'Little knowledge', and 'No knowledge', among them 93.6%, 91.2%, and 75% respectively have found the exercises to be 'Very helpful,' 'Helpful,' and 'Somewhat helpful.' However, we observe that 25% of the students with little knowledge to no knowledge of cybersecurity found his exercise to be 'Little helpful' or 'Not helpful at all.'

From Figure 8c, and Figure 8d, we notice that the students who perceive their knowledge level as 'Expert', and 'Somewhat Expert' in static program analysis and 95% of students who perceive themselves as as 'Expert', and 'Somewhat Expert' in software quality assurance have reported that they perceive the authentic learning exercise to be 'Very helpful', 'Helpful' and 'Somewhat Helpful' to learn misconfiguration in Kubernetes. Moreover, of students who perceive their expertise level as 'Knowledgeable' and 'Little knowledge' in static program analysis and software quality assurance, at least 90% of them reported that the exercise helped them learn misconfigurations in Kubernetes. We find that more students who evaluate themselves as having 'No knowledge' in cybersecurity, static program analysis, and software quality assurance perceived the exercises 'Little helpful' and 'Not helpful at all' for learning Kubernetes misconfigurations compared to other students in the class. One potential reason is the lack of adequate technical background to follow through with the hands-on exercise and perform post-lab exercises. These findings demonstrate the importance of considering students' prior software engineering background and educational levels when designing and implementing authentic learning-based exercises. The results highlight the positive impact of our authentic learning-based exercise on students with higher educational levels and expertise in software quality assurance, cybersecurity, and static analysis tools.

B. Answer to RQ2

In Figure 10 and Figure 11, we have reported the students' perceptions regarding the components of authentic learning exercise.

Students' perception based on education: In Figure 10a, 10b, we demonstrate undergraduate and graduate student's perspective of the usefulness of the authentic learning activities for learning Kubernetes misconfigurations. In Figure 10a, we observe that 66.9%, 75.3% , and 77.8% of undergraduate students perceive the 'Pre-Stage' step, 'In-Class Experience' step and 'Post-Stage' step of our authentic learning exercises as 'Extremely useful' and 'Useful'. Also, In Figure 10b, we observe that 75%, 84% , and 80.4% of graduate students perceive the 'Pre-Stage' step, 'In-Class Experience' step and 'Post-Stage' step of our authentic learning exercises as 'Extremely useful' and 'Useful'. We observe that as many as 5.4% of the graduate students find the pre-stage experience 'Not at all useful'. In contrast, only 2.1% of undergraduate students find the pre-stage and in-class experience report as 'Not at all useful'. We observe that 29.3%, and 48.8% of the students find all the three steps 'Extremely useful' and 'Useful' respectively. We notice that only 2.4% of the students report that all three steps of our designed authentic learning-based exercise are 'Not useful at all'.

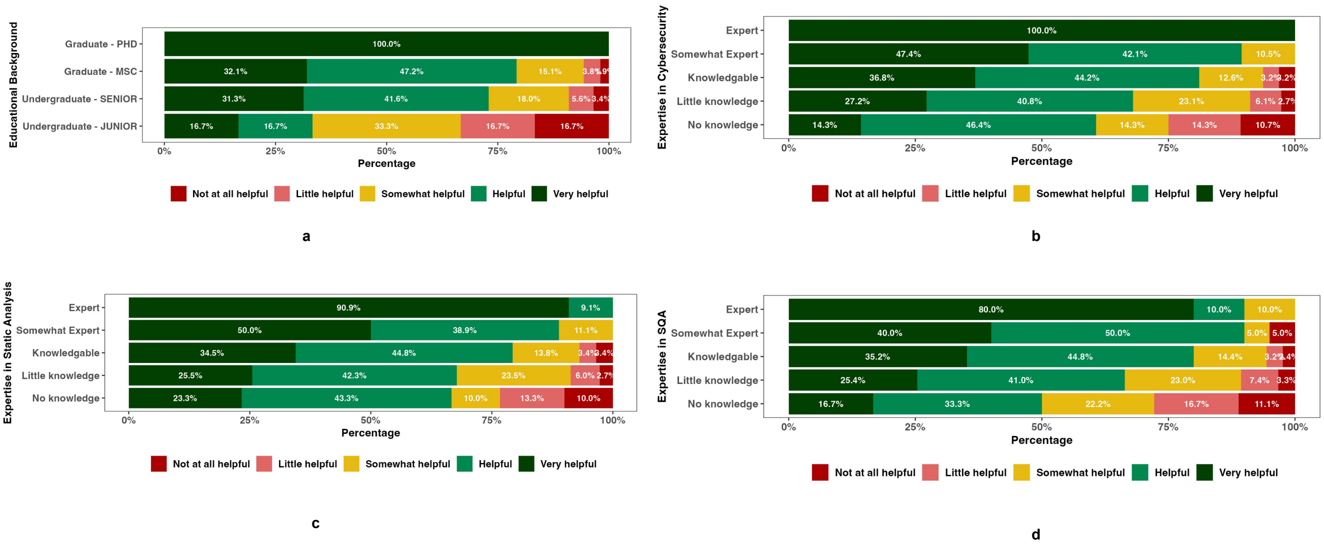

Fig. 8. Students' perception on the usefulness of the authentic learning exercise.

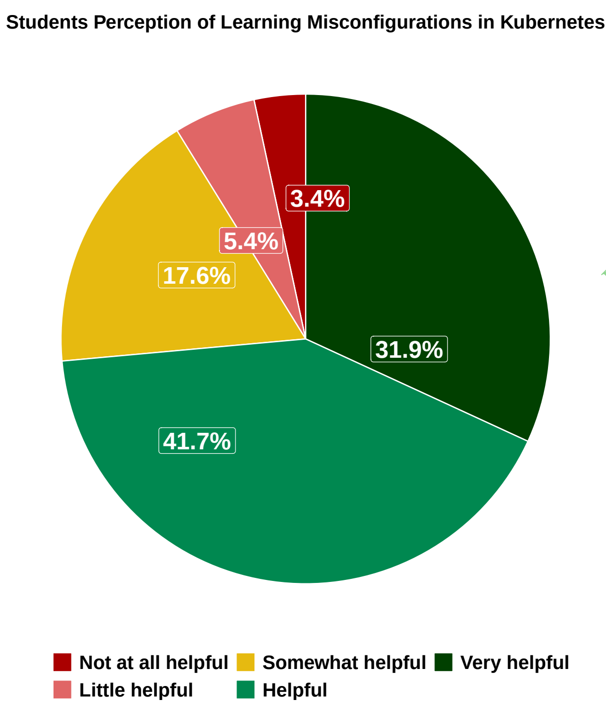

Fig. 9. Overall students' perception

Students' perception based on background knowledge: We demonstrate the overall students' perception of the usefulness of all three steps of authentic learning-based exercise based on background knowledge in Figure 11. In Figure 11a, we observe that 100% of the graduate PhD students, 84.9% of graduate masters, 78.1% undergraduate seniors, and 33.3% of undergraduate junior students found all three steps as 'Extremely useful' and 'Useful.' No undergraduate junior students reported the authentic learning exercise steps as 'Extremely helpful' or 'Not useful at all'. In contrast, only 3.8% of the graduate masters students and 2.1% of the undergraduate senior students reported the authentic learning exercise steps as 'Not at all useful'.

In Figure 11b, we observe that the students report themselves as 'Expert', and 'Somewhat Expert' in cybersecurity perceived the steps of authentic learning to be 'Extremely Useful' and 'Useful' and 'Moderately useful'. Those report themselves as 'Knowledgable,' 'Little knowledge,' or 'No knowledge' in cybersecurity, 96.9%, 94.6% and 75% of them perceived the exercise to be 'Extremely Useful' and 'Useful' and 'Moderately useful.' Of those students who reported having 'No knowledge' in cybersecurity, only 17.9% and 7.1% of them perceived that the exercise activities were 'Little useful' and 'Not at all useful'.

In Figure 11c, we observe that the students report themselves as 'Expert,' and 'Somewhat Expert' in the static analysis, 100% of them perceived the steps of authentic learning to be 'Extremely Useful' and 'Useful' and 'Moderately useful.' Those report themselves as 'Knowledgable,' 'Little knowledge,' or 'No knowledge' in cybersecurity, 95.6%, 93.9% and 80.1% of them perceived the exercise to be 'Extremely Useful' and 'Useful' and 'Moderately useful.' In Figure 11d, we observe that of those who report themselves as experts in software quality assurance, 90% of them reported 'Extremely useful.' In contrast, the remaining 10% reported 'Moderately useful.' Also, those who report themselves as 'Somewhat expert,' 45%, 45%, 5%, and 5% of them found themselves as 'Extremely useful,' 'Useful,' 'Moderately Useful,' and 'Not at all useful.' Of those who reported having 'Little knowledge' and 'No knowledge,' 92.6% and 77.8% of them found the exercise steps helpful, and only 2.5% and 11.1% of them reported that exercises were 'Not at all useful'.

In summary, the graduate and undergraduate students found

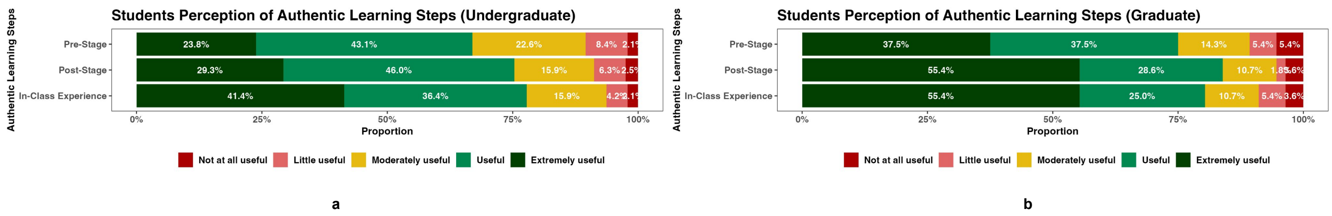

Fig. 10. Reported Perception of Students on the usefulness of Authentic Learning-based Exercise

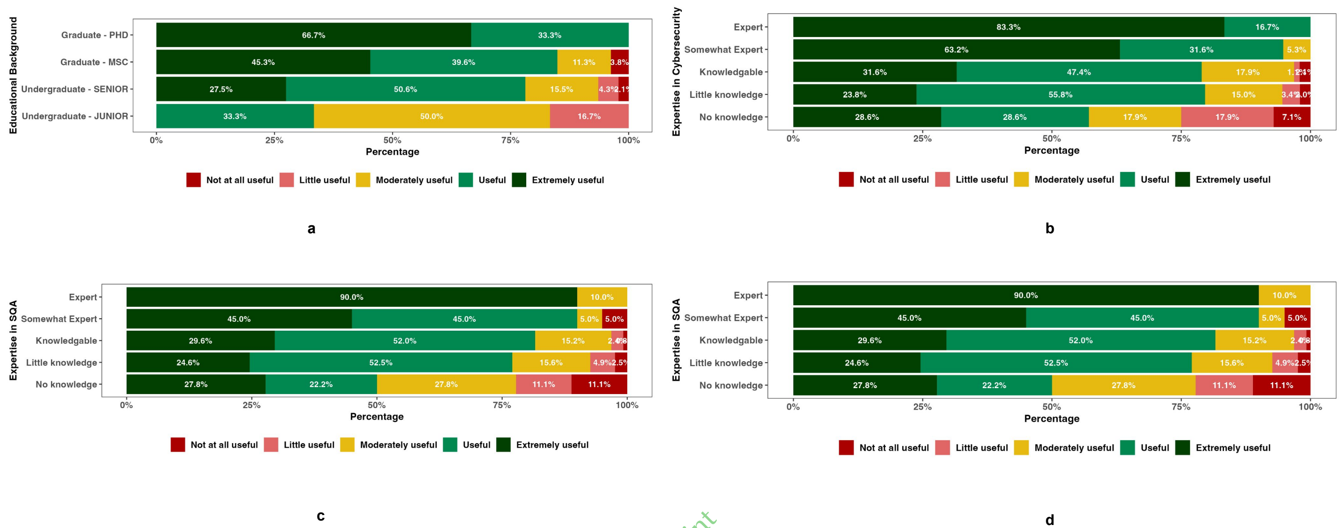

Fig. 11. Reported Perception of Students on the usefulness of Authentic Learning-based Exercise

hands-on and post-lab exercises more useful rather than pre-lab content dissemination. Moreover, students with prior knowledge in cybersecurity, static analysis, and software quality assurance and those with little or no knowledge in those areas perceive the exercise as beneficial for learning Kubernetes misconfigurations.

Observation#1: Authentic learning exercises are helpful for students in learning misconfigurations in Kubernetes. We find only 91.2% of the 295 students to perceive the exercise as helpful.

V. Discussion

We discuss our observations as follows:

A. *Effectiveness of Authentic Learning*

From Figure 5,6,and 7, we observe that 62.8%, 44.6%, and 60.7% of the total 295 students have little to no familiarity in cybersecurity, software quality assurance and static program analysis. However, from Figure 9, we find that 91.2% students perceive the authentic exercise to be helpful for learning Kubernetes security misconfigurations whereas only 3.4% students reported the exercise are not helpful at all. All of the results show that the authentic learning exercises are helpful for students even with no prior software engineering background to learn misconfigurations in Kubernetes.

B. *Implications for Instructors*

Our reported results in Section IV-B show that authentic learning exercise activities are useful for students irrespective of their background. However, we observe that graduate students found the individual authentic learning activities more useful than undergraduate students as per the report in Figure 10a, and Figure 10b. We also noticed that undergraduate students find the in-class experience more useful, while graduate students perceive post-class activity as more useful.

Based on our observations in Figure 10a and 10b, we advocate that the instructor should prioritize in-class activity for the class if the class only contains undergraduate students. Also, the instructor should prioritize in post-lab activities if the class contains only graduate students.

Observation#2: Instructors should prioritize specific authentic learning exercise activities according to the student's educational level in the class.

C. Implications for Researchers

Our results in Section IV-B demonstrate that authentic learning exercises are useful for students irrespective of their software engineering background. In our case, the instructor's prior background in teaching and industry experience might make the prelab content dissemination, hands-on exercise, and post-lab activities useful for software engineering experts and those without prior knowledge of software engineering. In Figure 10a and 10b, we observe that undergraduate and graduate students have varied perceptions of authentic learning-based exercise activities.

We advocate that researchers conduct empirical studies to investigate our results and provide further explanations. We urge the researchers to investigate whether the usefulness of authentic learning exercise activities correlates with students' educational level and prior background and whether the instructors' background correlates with the perception of the usefulness of authentic learning exercises.

Observation#3: Researchers can conduct empirical studies to provide instructors with strategies for designing authentic learning activities. They can also investigate whether an instructor's background is correlated with the usefulness of authentic learning.

D. Threats to Validity

We discuss the limitations of our study as follows:

1) Conclusion Validity: Our results are limited to the survey responses from the 295 students participating in the authentic learning-based exercise in class. Also, our results and observations rely on students' perceptions of the usefulness of authentic learning exercise activities in learning Kubernetes' misconfiguration. We used a five-item Likert scale with Kitchenham's guideline to mitigate that limitation [38]. We also acknowledge that the students' prior background might affect our results.

2) Internal Validity: Our survey data might have been impacted by students' expectations as we conducted the survey as part of the course. To mitigate this limitation, we follow IRB guidelines and FERPA policy, and we do not reveal students' grades and personal information. Also, we asked for the student's consent before participating in the survey.

3) External Validity: Our observation is limited to the 56 graduate and 239 undergraduate students of the University of X. Our results and recommendations described in Section IV and V, respectively, may not be generalizable in other classes at other universities where the instructor taught misconfigurations in Kubernetes.

VI. Conclusion

Kubernetes is a container orchestration tool that provides benefits, such as automated deployment and improved deployment time. However, practitioners report that the secure configuration of Kubernetes is a significant challenge. In this study, we investigate whether authentic learning can be useful for students in learning misconfigurations in Kubernetes. We deployed our authentic learning-based exercise and received 295 students from students. We observe that students with prior backgrounds in software quality assurance, cybersecurity, and static analysis find the exercise useful. Furthermore, we observe that only 3.4% students report that they learned about Kubernetes security misconfigurations. Hence, we recommend that instructors develop authentic learning exercises suitable to students' educational backgrounds. We also recommend that researchers conduct further empirical studies to investigate (i) the correlation between the usefulness of authentic learning exercises and students' perception and (ii) the correlation between the instructor's background and the usefulness of authentic learning exercise activities.

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