International Journal on Recent and Innovation Trends in Computing and Communication
ISSN: 2321-8169 Volume: 11 Issue: 9
***Article Received:** 25 July 2023 **Revised:** 12 September 2023 **Accepted:** 30 September 2023*

A Study of Challenges and Recommendations for Teaching: DevOps Education

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Abstract— DevOps has gained significant popularity in the software industry due to its ability to enhance collaboration, improve software delivery, and drive organizational agility. However, providing effective education and training in DevOps poses several Issue. This research paper presents an interview study conducted with a seasoned DevOps professional to explore the challenges faced in DevOps education and provide recommendations for addressing these challenges. The study highlights the evolving nature of the DevOps landscape, the interdisciplinary nature of DevOps, and the need for hands-on learning experiences. Additionally, the study emphasizes the importance of continuous curriculum updates, practical exercises, cross-functional collaboration, industry partnerships, and fostering a continuous learning mindset. The findings from this study contribute to the understanding of the unique challenges and recommendations for improving DevOps education.

Keywords-DevOps,Education, Challenges,Recommendations, Theme based analysis.

I. INTRODUCTION

DevOps has emerged as a transformative approach in the software industry, blending development and operations practices to streamline software delivery and improve collaboration within organizations [1]. As the demand for DevOps professionals continues to rise, the need for effective education and training programs becomes crucial. However, DevOps education poses various challenges due to the rapidly evolving nature of the field and the interdisciplinary skills required [2].

This research paper presents an interview study conducted with a seasoned DevOps professional to explore the challenges faced in DevOps education and provide recommendations for addressing these challenges. The insights gained from this study can contribute to the development of more effective DevOps education programs.

Background of DevOps Education: DevOps is an amalgamation of development and operations practices aimed at bridging the gap between software development and IT operations [1]. It emphasizes collaboration, automation, continuous integration and delivery, and a culture of shared responsibility. By adopting DevOps principles and practices, organizations can achieve faster software delivery, improved quality, and increased business agility.

Significance of DevOps Education: As organizations increasingly adopt DevOps methodologies, there is a growing demand for skilled professionals who can effectively implement and manage DevOps practices. However, traditional educational programs often struggle to keep up with the evolving DevOps landscape, leading to a skills gap in the industry. Effective DevOps education programs can equip individuals with the necessary knowledge and skills to meet this demand and drive successful DevOps transformations within organizations [2].

Research Questions:

This interview study aims to address the following research questions:

1. What are the key challenges faced in DevOps education?
2. What recommendations can be provided to overcome these challenges and improve DevOps education?

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II. LITERATURE SURVEY

The challenges and approaches in DevOps education have been explored to some extent in existing literature. Several studies highlight the need for hands-on learning experiences to bridge the gap between theory and practice [3, 4]. Additionally, the evolving nature of the DevOps landscape poses challenges in curriculum design and relevance [5]. The interdisciplinary nature of DevOps, requiring a combination of technical and soft skills, has also been recognized as a challenge [6]. However, more research is needed to gain deeper insights into the specific challenges faced and potential approaches for effective DevOps education.

Overview of DevOps principles, practices, and benefits:

DevOps, a portmanteau of "development" and "operations," is an approach that emphasizes collaboration and integration between software development teams and IT operations teams..

Principles of DevOps: a. Collaboration: Encourages effective collaboration and communication between development, operations, and other stakeholders throughout the software development lifecycle. b. Automation: Advocates the use of automation tools and processes to streamline software delivery, deployment, and infrastructure management. c. Continuous Integration and Continuous Delivery (CI/CD): Promotes the frequent integration and testing of code changes, enabling rapid and reliable software releases. d. Infrastructure as Code (IaC): Treats infrastructure provisioning, configuration, and management as code, enabling reproducibility, scalability, and version control. e. Monitoring and Feedback: Emphasizes the collection and analysis of real-time data to monitor application performance, identify issues, and drive continuous improvement.

DevOps Practices: a. Continuous Integration (CI): Developers frequently integrate code changes into a shared repository, triggering automated builds and tests to identify issues early. b. Continuous Delivery (CD): Builds upon CI by automating the release process, ensuring that software is always in a deployable state, ready for production deployment. c. Infrastructure Automation: Automates the provisioning and management of infrastructure resources using tools like configuration management and infrastructure orchestration. d. Continuous Deployment: Takes CD a step further by automatically deploying software changes to production environments after passing all necessary tests. e. Monitoring and Logging: Implements tools and processes to capture real-time metrics, logs, and user feedback to monitor application performance and identify areas for improvement.

Benefits of DevOps: a. Faster Time to Market: DevOps enables faster software delivery cycles, reducing time between feature development and deployment, allowing organizations to respond quickly to market demands. b. Increased Collaboration and Communication: By breaking down silos between teams, DevOps fosters better collaboration, shared understanding, and effective communication, leading to improved efficiency and productivity. c. Continuous Improvement: DevOps practices facilitate a culture of continuous improvement, where organizations can gather feedback, measure performance metrics, and iteratively enhance their software delivery processes. d. Higher Quality and Reliability: The use of automation, CI/CD, and infrastructure as code practices minimizes manual errors, enhances software quality, and increases system reliability. e. Scalability and Resilience: With DevOps, organizations can scale their infrastructure resources dynamically, respond to increased demand, and ensure high availability and fault tolerance.

By embracing DevOps principles and practices, organizations can achieve faster software delivery, improved collaboration, increased efficiency, and enhanced customer satisfaction, thereby gaining a competitive advantage in today's fast-paced digital landscape.

Existing research on DevOps education and issues:

Existing research on DevOps education has identified various issues and challenges in preparing individuals with the necessary skills and knowledge. Here are some key studies that shed light on these issues:

This study explores the challenges and future directions of software engineering education, including the need to address emerging topics such as DevOps and agile practices [1].The authors conducted a literature review to identify the challenges in teaching DevOps. The study highlights the complexity of DevOps as an interdisciplinary subject and the difficulties in finding suitable educational materials [2].This systematic literature review examines the existing approaches to teaching DevOps in academic settings. The study discusses the lack of standardized curricula and the need for hands-on learning experiences to bridge the gap between theory and practice [3].The authors conducted a systematic mapping study to identify the inclusion of DevOps in software engineering curricula. The study reveals that DevOps is still relatively underrepresented in educational programs, highlighting the need for curriculum updates to address this gap [4].This empirical study investigates the challenges faced by instructors in teaching DevOps. The findings reveal difficulties in designing appropriate assessments, lack of industry collaboration, and the need for specialized training for instructors [5].These studies provide insights into the challenges of DevOps education, including the interdisciplinary nature of the subject, the need for updated curricula and educational materials, hands-on learning experiences, collaboration with industry, and instructor training. Addressing these issues can enhance the effectiveness

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of DevOps education programs and better equip individuals for success in the field.

III. METHODOLOGY

The interview study on DevOps Education was conducted to explore the challenges faced in DevOps education and gather recommendations for addressing these challenges. The study involved interviewing individuals with expertise in DevOps, such as experienced professionals, educators, and practitioners. The study used a qualitative research strategy to provide in-depth knowledge on the Participants' experiences and viewpoints. To allow for flexibility in questioning, interviews were done in a semi-structured approach while ensuring that critical DevOps education topics were covered.

The interview questions were designed to cover a broad range of topics, including curriculum design, assessment strategies, teaching methodologies, the interdisciplinary nature of DevOps, and industry collaboration. The questions aimed to understand the challenges faced in these areas and to explore potential approaches and recommendations for improving DevOps education.

The interviewees were chosen based on their experience and involvement in DevOps education. They were chosen from various backgrounds, including academia, industry, and training providers, to capture diverse viewpoints and experiences.

During the interviews, the interviewees were encouraged to share their experiences, insights, and opinions freely. The interviewer listened attentively, followed up with questions to clarify responses, and encouraged the interviewees to provide examples or elaborate on their perspectives.

To ensure that the information provided was adequately captured, the interviews were often audio-recorded. During the interviews, detailed notes were also gathered to augment the recordings and provide context. There are two primary phases in the design of this study. The First, semi-structured interviews with DevOps instructors were done. The obtained data is then analyzed to discover stated difficulties and recommendations. The two phases of our methodology are explained in the following subsections

Selection of Participants: we have selected Interviewees from DevOps courses on GitHub, Koggle, through our personal contacts, Bing, and Google. In Google, Koggle, and GitHub, We examine the search phrases "DevOps Education," "continuous delivery course," and "DevOps course."

The interviewees were chosen using the following criteria: The instructor must have previous experience in educating DevOps courses. DevOps should be emphasized in the course, and the instructor should be actively involved in the course's execution. The instructor most recently taught the DevOps course (at least 2 years ago). Despite the fact that corona virus epidemic may have an impact on some existing courses, we chose this time frame since we were looking for recent DevOps teaching experiences.

We invited them by email after selecting a group of potential interviewees. We sent a follow-up email a week later to individuals who did not respond to the first. From the 40 candidates who were contacted through email, 25 expressed an interest in taking part in the study. Several of them, However, they were either too busy or unwilling to cooperate beyond the initial contact. We completed with a combined total of 20 participants. Table 4.1.2 highlights the profiles of educators who took part in our study.

The interview procedure is as follows: The interviews were done and recorded utilizing communication technology such as Zoom, Google Meet, or Microsoft Teams. The interview must be recorded with the permission of the participants. The 20 interviews lasted a median of the time limit is 42.5 minutes, with a minimum of 25 minutes and an overall duration of 55 minutes.

The interview begins with the research presentation, the interviewers, as well as the interviewees. The theme question is then posed to the interviewee: **What challenges did you face and what recommendations did you make when teaching DevOps courses?** Several variations on this core question are utilized to deepen the discussion (according to Table 4). All of these versions are based on the work of Fernandes et al. [7], which focuses the major question on the seven themes discovered in their research. At last, the educator is asked if they have any further challenges or suggestions to provide at the end of the interview.

Participants are listed in the following order: Throughout this research we conducted interviews with 15 male and 5 female educators who were identified as P1–P20. As shown in Table 4.1.2, we found 4 from Bing, 6 educators are on GitHub, 3 from Google, 4 on Koggle and 3 through our personal contact. 15 (75%) Participants have a combined teaching experience of more than eight years, while 12 (60%) have worked in the industry for greater than 10 years. In terms of teaching DevOps experience, 9 participants (45%) have been instructing DevOps for more than 2 years. Throughout the year, In addition, we have four educators, they are teaching in massive open online courses (MOOCs) and the National Programme on Technology Enhanced Learning (NPTEL).

Course Overview: as shown in Table 1. There are a total of 15 courses offered across 15 universities/companies located in Telangana, West Bengal, Tamilnadu, Karnataka, and Delhi. The majorities of courses are at the undergraduate and Post graduate levels, while two MOOC courses are also available. Due to the COVID-19 pandemic, remote teaching formats are

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currently being utilized. However, prior to the pandemic, 15 courses (84.6%) were typically offered in person. Of the courses available, 10 (76.9%) are paid, only 5 (15.3%) are mandatory, and 11 (84.6%) have been offered since 2020.

Table 1: Interview Questions Set

Category	Subject
General	Teaching DevOps courses: what are the difficulties and solutions?
Based on a theme	What are the difficulties and suggestions in the DevOps teaching environment?
Based on a theme	What are the issues and solutions for teaching DevOps concepts?
Based on a theme	What are the difficulties and solutions for DevOps class preparation?
Based on a theme	Teaching DevOps tools and technologies: what are the difficulties and suggestions?
Based on a theme	For assessing the learning outcomes and teaching strategies of DevOps, what are the challenges and recommendations?
Based on a theme	What are the difficulties and suggestions in the DevOps curriculum?
Based on a theme	What are the pedagogical issues and suggestions for teaching DevOps (not connected to curriculum or assessment)?
General	Are there any other difficulties or suggestions for teaching DevOps?

Table 2: Profiles of Participants (N=20)

Id	Teaching experience (years)	DevOps teaching experience (years)	Work experience in the industry (years)	Source
P1	12-17	4-5	7-11	Kaggle
P2	3-7	4-5	—	Bing
P3	12-17	3-4	7-11	Personal Contact
P4	7-11	4-5	12-17	Kaggle
P5	3-6	3-4	3-7	GitHub
P6	7-11	3-4	---	Bing
P7	17-21	3-4	17-22	Google
P8	7-11	4-5	31+	Kaggle
P9	27-32	4-5	10-12	Personal Contact
P10	4-7	4-5	20-24	GitHub
P11	22-28	3-4	13-18	Kaggle
P12	12-17	3-4	18-22	Google
P13	8-12	2-3	5-9	Kaggle
P14	7-12	2-3	—	GitHub
P15	20-24	4-5	10-12	Personal Contact
P16	5-8	3-4	2-4	Google
P17	3-6	2-3	6-8	Kaggle
P18	8-10	3-4	2-3	Personal Contact
P19	8-10	4-5	-	Personal Contact
P20	10-12	4-5	4-5	GitHub

Collecting and analyzing data:

At first, we collected challenges and recommendations from the interviews, and then we completed the analysis stated below.

(a) Identifying and recommending DevOps-specific difficulties and recommendations

(b) Analyzing and Naming Themes

(c) analysis of the connections between challenges and recommendations.

Data* Collection*: We begin by collecting statements about challenges and suggestions from the transcriptions of the interviews. For example, the quote from Participant 2, "The Docker tool is difficult to use, especially in the beginning," is an example of a challenge. On the other hand, participant 9's quote, "Cloud computing technology enables us to easily create virtual machines for people and other purposes" is a recommendation for making virtual machine setup easier.

DevOps Specific: In our evaluation, we ensure that the challenges and recommendations put forth involve the DevOps mindset or concepts. For instance, a recommendation that pertains to DevOps is "A DevOps course should cover the fundamentals of building, testing, deploying, and monitoring" (P5, P13), which implies that DevOps concepts should be incorporated in the course material. On the other hand, a suggestion like "Continuously strive to enhance the course's quality" (P18) is not necessarily connected to DevOps.

Themes: We utilize Braun and Clarke's [9] thematic analysis framework to generate data summaries by creating themes.

Table 3: Course Details (N=15)

Course-Id	Interviewee	Level of Grade	State	The course's editions over the years
C1	P1	A^{++}	Telangana	2017–2021
C2	P2	A^{++}	Telangana	2019–2022
C3	P3	A^{++}	Tamilnadu	2019–2022

C4	P4	NPTEL	Delhi	2020–2022
C5	P5,P15	UG	Telangana	2019,2020,2022
C6	P6	NPTEL	Tamilnadu	2021,2022
C7	P7	UG	Tamilnadu	2018–2022
C8	P8	G	West Bengal	2020–2022
C9	P9,P17	G	West Bengal	2018–2022
C10	P10,P14	UG	Kanataka	2018–2022
C11	P11	UG	Canada	2021,2022
C12	P12	MOOC	West Bengal	2020,2021,2022
C13	P13	G	Delhi	2020–2022
C14	P16	MOOC	West Bengal	2020- 2022
C15	P18	G	Karnataka	2019–2022

Key: UG=Under Graduate Degree; A^{++}=Associate Degree; MOOC=Massive Open Online Courses; G=Graduate Degree; NPTEL=National Programme on Technology Enhanced Learning;

Intial Codes: We coded the data based on a brief summary of what was said during the interview.

Organize Codes into Themes: We began organizing the codes into different themes, taking into account that some topics may be sub-themes of other themes. Furthermore, certain codes might be relevant enough to become themes themselves. We opted to employ the same seven themes again that Fernandes et al. [7] had identified along with the theme what we have identified. Curriculum, DevOps concepts, pedagogy, Balancing theory and practice in DevOps courses, setting up environment, class preparation, assessment, and tools. It's worth noting that the class preparation and assessment themes are sub-themes of the pedagogy theme, Balancing Theory and Practice in DevOps courses is a sub-theme of the DevOps courses whereas the tools theme has a sub-theme called setting up environment.

Theme Analysis and Naming: We discovered that the thematic names needed to be more described and engaging after analyzing and improving the first themes. As a result, we made the following modifications: a) we changed the theme "pedagogy" to "course execution strategies" because they discovered along the course that the associated codes were linked to context execution; and b) We updated the theme's name from "tool" to "tools/technology" to emphasize the theme's scope.

Connection Links: When we say a challenge is linked to a recommendation, we mean that the recommendation can solve or mitigate the impact of the challenge. We may, for example, relate the recommendation to "Create scenarios for students to run on their computers." (P2) with the challenge "Professional use of cloud services requires commercial payment."(P16). The purpose here is for students to be able run course programs on their PCs rather than paying for cloud services. To identify such connection links, we conduct a theme-based search. This method raises the possibility of discovering recommendations that can solve difficulties relating to the same theme.

Conflicts or inconsistencies: Inconsistency may develop when a challenge and a recommendation differ, or when two recommendations contradict. Inconsistency may develop when a challenge and a recommendation differ, or when two recommendations are in conflict. To identify such inconsistencies, we first look for themes.

IV. RESULTS

In this research, we have analyzed the data collected during interviews that lasted for an average duration of 32.9 minutes, with a standard deviation of 14.6. All the data we collected has been included in the set of artifacts we provide [8]. The level of saturation is the proportion of challenges and recommendations uncovered in earlier interviews. When fresh interviews only resulted in modest adjustments to themes, the interview phase was finished.

Specific DevOps Challenges and Recommendations

Interviewees Discussed Challenges And Recommendations For Teaching Devops Concepts And Culture, As Well As Education.

Figure 1 depicts how specific DevOps challenges and recommendations are distributed. (57.7%) are associated with DevOps principles, whereas 47.6% are specific to DevOps. For example, consider the challenge of “Difficulty in evaluating students' performance: comprehension of Continuous Delivery" (P11) is Specific to DevOps because DevOps concept is continuous delivery. On the other hand, "Students rely heavily on their professor's Presentation slides, which are frequently limited" (P15) is not seen specific to DevOps since it refers to general behavior of students.

Similarly, the recommendation of "Continuous Integration is taught using “GitHub Action, Circle CI, Travis CI, and Jenkins" (P15) is identified as specific to DevOps since One of the DevOps strategies is continuous integration. He added,

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"Because the course time is restricted, it is crucial to prioritize which tools and topics are necessary. (P7) is not specific to DevOps because course topic selection is a universal educational concern.

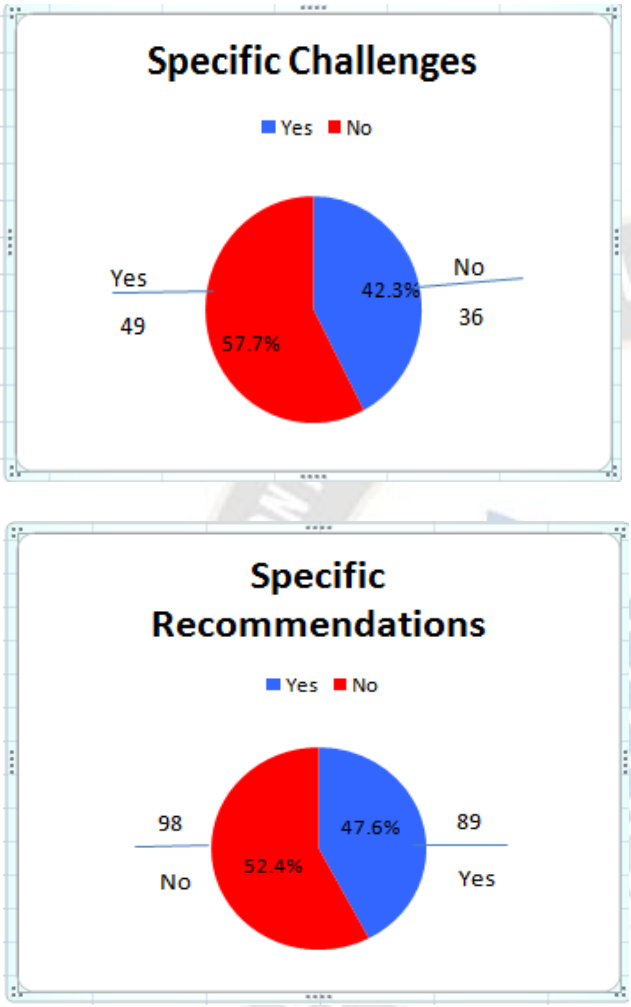

Figure 1: Specific DevOps Challenges and Recommendations Distribution

Theme Development of Challenges and Recommendations

Our research involves identifying themes connected to instructors' challenges and recommendations. We were able to identify eight themes that encompassed these areas: Course Execution Strategies, Tool/Technology, Assessment, DevOps concepts, Class Preparation, Balancing Theory and Practice in DevOps Courses, Curriculum, and Setting up Environment. Figures 2 and 3 show how these themes are distributed among difficulties and recommendations.

As seen in Figure 2, the overall number of challenges for the Setting up Environment, DevOps concepts, and Tool/Technology is balanced, accounting for approximately 50% of the total challenges. Additionally, we found that Tool/Technology was the most recurrent theme, while Curriculum was the least recurrent theme.

Figure 3, demonstrates that the amount of recommendations under each category is uneven. The theme of Course Execution Strategies accounts for approximately 26% of all recommendations. Tool/Technology and Course Execution Strategies together represent around 51% of the total number of recommendations. The findings in Figures 2 and 3 show that for educators, tool/technology is a reoccurring theme. During our conversations with instructors, we discovered that creating an environment is a reoccurring challenge. However, to address it, just a few recommendations were provided.

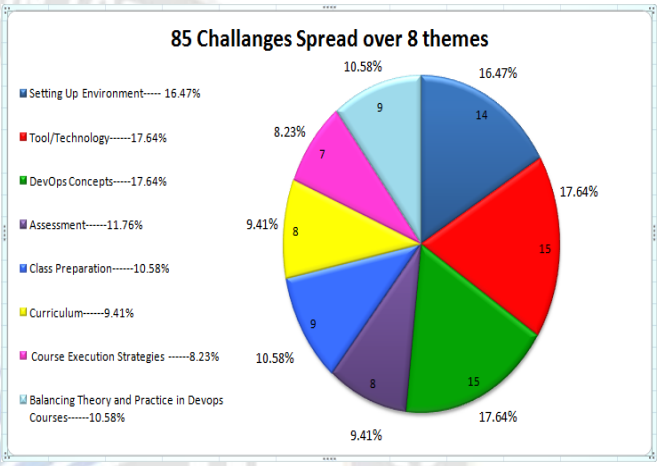

Figure 2: Challenges by themes

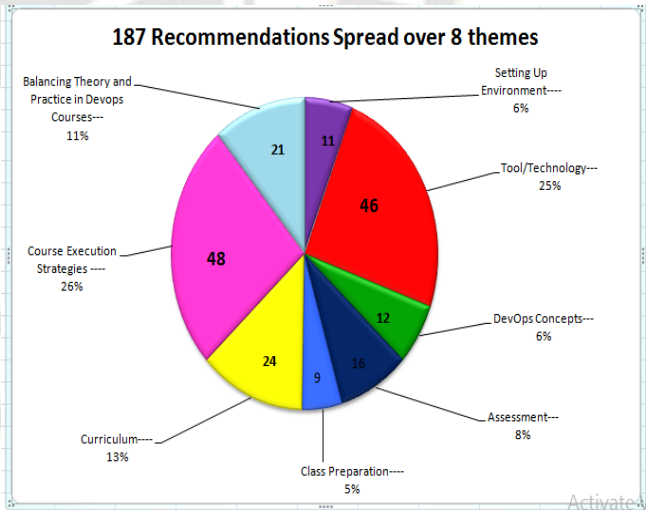

Figure 3: Recommendations by themes

V. CONCLUSION

We summarize our findings by comparing them to previous systematic review findings, as well as the implications for educators and academics.

Systematic Evaluation

In comparison to Fernandes et al.'s [7] systematic assessment of 18 source papers, our analysis identified significantly more material based on 20 interviews. Here is a statistical comparison (this work vs. Fernandes et al.'s work [7]): 85 challenges vs. 73, 187 recommendations vs. 85. There are 448 associations versus 149 between challenges and recommendations. Furthermore, there are more (50 vs. 26) specific to DevOps challenges and (90 vs. 23) specific to DevOps recommendations in this study. Our work incorporates 60% (44 of 73) of the difficulties and 54% (46 of 85) of the suggestions from Fernandes et al.'s systematic review. As a result of our interview-based research, we discovered 12 new challenges and 102 new recommendations.

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