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# The Value of Adaptive Link Annotation in E-Learning: A Study of a Portal-Based Approach

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## ABSTRACT

Adaptive link annotation is one of the most popular adaptive educational hypermedia techniques. It has been widely studied and has demonstrated its ability to help students acquire knowledge faster, improve learning outcomes, reduce navigation overhead, increase motivation, and encourage the beneficial non-sequential navigation. However, almost all studies of adaptive link annotation have been performed in the context of dedicated adaptive educational hypermedia systems. The value of this technique in the context of widely popular learning portals has not yet been demonstrated. In this paper, we attempt to fill this gap by investigating the value of adaptive navigation support embedded into the learning portal. We compare the effect of portal-based adaptive navigation support on both the effect of the adaptive navigation support in adaptive educational hypermedia systems and to non-adaptive learning portals.

## Categories and Subject Descriptors

H.5.4 [Hypertext/Hypermedia]: Navigation

## General Terms

Design, Experimentation

## Keywords

adaptive hypermedia, navigation support, motivation, e-learning, portal self-assessment, open corpus adaptive hypermedia.

## 1. INTRODUCTION

Adaptive link annotation is one of the most popular adaptive educational hypermedia techniques [1]. It has demonstrated its ability to help students to acquire knowledge faster, improve learning outcomes, reduce navigation overhead, increase motivation, and encourage the beneficial non-sequential navigation. Among other projects, our recent work with self-assessment questions confirmed that adaptive link annotation could successfully guide students to the questions of appropriate difficulty, thereby increasing their chance to answer these questions correctly. It could also encourage students to work on the self-assessment questions more extensively, which in turn has a positive impact on their knowledge [2, 4, 12]. However, existing research on adaptive link annotation (including our past research) focused on the value of this technology in the context of dedicated adaptive systems specifically built to maximize the impact adaptive navigation support.

A recognized challenge nowadays is to apply adaptive link annotations techniques to the open corpus hypermedia systems and learning portals where learning content comes from outside of the host system [1]. While a range of architectures for open corpus adaptive hypermedia has been suggested (see Related Work section), the added value of adaptive link annotation for an e-learning portal has never been explored. This paper represents the first attempt to explore whether or not the power of adaptive link annotation exists only in the context of this special interface, or, if it also is apparent in the context of a traditional hierarchically organized learning portal, which differs from known dedicated interfaces in several aspects. To answer this question, we implemented a service-based personalization architecture PERSEUS [3]. It allowed us to apply adaptation to the context of a typical hierarchical learning portal and run the study presented below, which compared portal-based adaptive link annotation with both, an adaptive dedicated interface and a non-adaptive portal. In addition to simple class-level comparison the study attempted a deeper exploration of the problem assessing the value of the adaptive navigation support across different questions' complexity levels and individual student abilities, as well as various adaptive navigation support implementations.

The rest of the paper is organized as follows. In the next two sections, we describe the system implementation and present the evaluation. Then we provide a brief review of related work and conclude with the summary of results and ideas for future work.

## 2. TECHNOLOGIES & SYSTEMS

The goal of our study was to provide a three-way comparison of a non-adaptive portal, a dedicated adaptive interface, and a portal with integrated adaptive navigation support. This comparison extends our earlier research with contrasted just the first two of these settings. All these interfaces were explored in the context of user access to a specific kind of interactive content – parameterized question for assessing student knowledge of Java programming language. This section starts with introducing the type of learning content used in our studies (QuizJET questions) and then explains how we built two kinds of adaptive navigation support for accessing these questions.

### 2.1. QuizJET: Parameterized Questions of Java Evaluation Toolkit

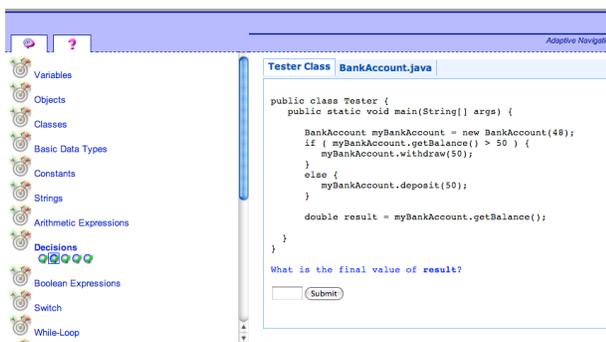
To explore the value of adaptive navigation support in providing access to interactive learning content, we developed QuizJET, a system for authoring and delivery of parameterized questions for

Java programming language. QuizJET is a self-contained non-adaptive system, which is able to generate parameterized questions for assessment and self-assessment of students' knowledge of a broad range of Java topics. Each QuizJET question asks the student to predict the results of execution of a specific Java program (i.e., mentally execute the program and enter the final value of some variable of the text to be printed by the program.) All questions are parameterized, i.e., include a random parameter, which QuizJET instantiates when the question is delivered to a student. As a result, student can attempt to answer the same question multiple times with different values of parameter, which helps to achieve the mastery level. The implementation and functionalities of QuizJET were described in detail in [13].

## 2.2. JavaGuide: Adaptive Navigation Support for QuizJET Questions

JavaGuide is an adaptive intermediary service, which generates a dedicated interface for adaptive navigation support in accessing QuizJET questions (Fig. 1). QuizJET groups JavaGuide questions into topics and annotates each topic with an icon representing the current state of a student's knowledge of learning material associated with the topic. The link annotations follow the "target-arrow" annotation approach, which was first explored in our earlier system QuizGuide [2] for the C programming domain. Each target icon presents two layers of meanings: knowledge adaptation (shown by arrows) and goal adaptation (shown by the color of the target). For knowledge adaptation, the number of arrows in the target represents the growth of student knowledge of a topic. For goal adaptation, the color of the target represents the relevance of the topic to the current course goal. The topic targets related to the most recent goal are bright blue, their direct prerequisites are light blue, and previous topics are gray. Finally, topics related to future goals are represented by crossed icons.

In addition to topic-level annotation, JavaGuide also provides simple history-based adaptive annotation for individual questions. Question icons in JavaGuide report on a student's question completion status using a checkmark. It shows whether the specific question has been solved correctly at least once and helps students to choose between similar questions characterized within a topic. Altogether, adaptive annotations make students constantly aware of their performance and help to focus attention on the most valuable topics and questions. More details on JavaGuide and its implementation can be found in reported in [4].



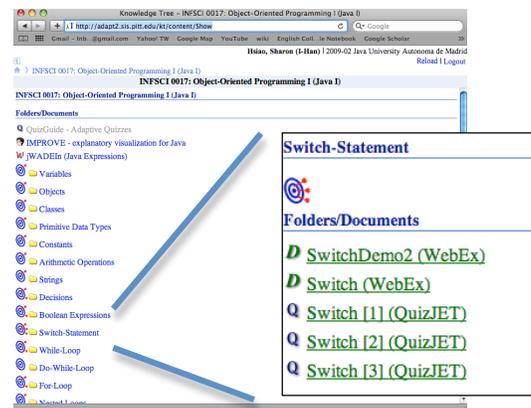
**Fig. 1. Adaptive link annotation in Java Guide:**  
(a) JavaGuide Interface with adaptively annotated topics on the left hand side and QuizJET questions on the right;

(b) goal adaptation shown by the color of the target and knowledge adaptation shown by the number of errors.

## 2.3. Portal: Adaptive Navigation Support on Portal for QuizJET Questions

Knowledge Tree portal represents our attempt to implement adaptive navigation support in the context of a typical hierarchical learning portal. When the students log on to the portal, they see a list of organized topic folders with adaptive navigation icon next to them (Figure 2). Just like a content folder on a regular learning portal, each Knowledge Tree folders includes a list resource links, which, among some other kinds of content, includes QuizJET questions. Knowledge Tree uses service-based personalization approach where all personalized is provided by an external service PERSEUS [3]. PERSEUS is an adaptation functionality server, which implements a number of adaptation services, including social, topic-based, and concept-based. To utilize PERSEUS, Knowledge Tree applies a data exchange protocol. To obtain personalization for a list of links, it sends a request to a specific service in the personalization engine. This navigation service has the option to consult a user modeling server, from which the information about user's progress is obtained. Then, a personalization service generates navigation cues and sends them back to the portal. A portal displays cues to links obtained from the personalization service next to these links.

While on the conceptual side, the result of this process is the same as in JavaGuide (each topic receives an adaptive annotation, which follows the target-error approach), Knowledge Tree and JavaGuide differ in both – their interfaces and their personalization mechanisms. From the interface side, JavaGuide makes all questions accessible through a single-view interface, while Knowledge Tree, in the spirit of traditional portals, requires constant navigation up and down the hierarchy of folders. From the technical side, the JavaGuide interface along with all its annotations is generated by a dedicated intermediary, while Knowledge Tree represents a traditional portal where each adaptive icon is generated by an external service PERSEUS.



**Fig. 2. Portal-based Interface & Inside the folder interface**

## 3. CLASSROOM STUDIES

To investigate the value of adaptive navigation support in a distributed architecture, we performed three classroom studies. All of them were done in an undergraduate introductory programming course. Two of them were offered by University of

Pittsburgh, the other one was offered at the Universidad Autonoma de Madrid. One class did not have adaptive navigation support (QuizJET) and will be referred as group 1 in the rest of the paper; another class used Portal-based adaptive navigation (Portal) and will be referred to as group 2; yet another class used an adaptive intermediary service (JavaGuide) which will be referred to as group 3. Three systems featured the same set of questions but different adaptation support (including the lack of it in group 1). In order for the comparison to be fair, all three classes took the same pre- and post-tests. Based on students' pre-test scores, we found no significant differences between groups before using the systems,  $F(2, 44) = 2.972, p = .062, \eta^2 = .119$ . The assumption of homogeneity of variance was met, Brown-Forsythe  $F(2, 44) = 2.839, p = .069$ .

We analyzed students' work with respect to two layers of measures: system usage and student performances. The system usage can be further analyzed on two levels: overall and within a session. On each level we looked at the following system usage parameters: total number of questions attempted by the student, success rate (the percentage of correctly answered questions) and course coverage (the number of distinct questions attempted by the student).

### 3.1. Basic Statistics

To compare three kinds of access to learning content, we compared most important performance parameters for three systems (Table 1). Note that the differences between QuizJET and JavaGuide were reported in [4]. The focus of this study was to collect data on student work in an adaptive portal and compare them with both non-adaptive portal and JavaGuide dedicated interface. Thus, the analysis below focuses mainly on student work in the adaptive portal.

Table 1. System Usage Summary

|                                 |                    | Group 1      | Group 2      | Group 3      |
|---------------------------------|--------------------|--------------|--------------|--------------|
|                                 |                    | QuizJET      | Portal       | JavaGuide    |
| adaptation support              |                    | not adaptive | adaptive     | adaptive     |
| parameters                      |                    | (n=16)       | (n=12)       | (n=19)       |
| Pre-test score                  | M±SE               | 9.56 ± 1.29  | 12.28 ± 1.22 | 7.11 ± 1.59  |
| Post-test score                 | M±SE               | 17.12 ± 0.86 | 15.89 ± 0.99 | 13.84 ± 0.79 |
| Overall User Statistics         | Attempts           | 80.81        | 112.16       | 144.0        |
|                                 | Success Rate       | 42.63%       | 87.07%       | 66.88%       |
|                                 | Distinct Questions | 33.37        | 40.50        | 58.42        |
| Average User Session Statistics | Session            | 3.75         | 2.16         | 4.63         |
|                                 | Attempts           | 21.55        | 51.92        | 31.10        |
| Average User Session Statistics | Distinct Questions | 8.9          | 18.75        | 16.32        |

The analysis of data confirms that two known effects of adaptive navigation support can be registered in the portal context. First, the provision of adaptive link annotation does motivate students to work more with the system. We can see that the overall amount of work with the system (measured in attempts made and number of distinct questions answered) increases, although to a lesser extent than in JavaGuide producing a median level of usage. Secondly, we can state that adaptive link annotation helped students to get to the most appropriate question more than doubling their success rate in comparison with a non-adaptive portal. With the adaption on the portal (Portal:  $M = .8707, SE = .0351$ ), students managed to

achieve a significant higher success rate than in both non-adaptive QuizJET ( $M = .4263, SE = .0669$ ) and JavaGuide ( $M = .6688, SE = .0207$ ),  $F_{12}(1,44) = 11.303, p < .01, \eta^2 = .204$ ;  $F_{23}(1,44) = 7.720, p < .01, \eta^2 = .149$ .

In order to better understand the motivation effects of the systems, students' amount of work was analyzed on both overall level and session level. The session level analysis revealed that, despite the overall lower motivation impact, the adaptive portal does significantly impact student motivation to work with the system on the session level. Portal ( $M = 43.089, SE = 5.924$ ) and JavaGuide ( $M = 34.151, SE = 4.708$ ) registered significantly higher number of attempts per session on average than QuizJET ( $M = 19.446, SE = 5.130$ ),  $F_{12}(1,44) = 9.103, p < .01, \eta^2 = .171$ ;  $F_{13}(1,44) = 4.461, p < .05, \eta^2 = .092$ . In addition, the numbers of distinct attempted questions per session for Portal ( $M = 19.193, SE = 2.637$ ) and JavaGuide ( $M = 16.327, SE = 2.095$ ) are significantly higher than QuizJET ( $M = 7.865, SE = 2.832$ ),  $F_{12}(1,44) = 10.550, p < .01, \eta^2 = .193$ ;  $F_{13}(1,44) = 7.457, p < .01, \eta^2 = .145$ . It shows that in both contexts, adaptive navigation support encourages students to explore more questions from the course.

We should also note that in all three conditions, the students achieved a significant knowledge growth as measured by post-test scores,  $t_1(15) = 6.108, p < .01$ ;  $t_2(11) = 3.821, p < .01$ ;  $t_3(18) = 7.853, p < .01$ . However, we do not think that three systems can be compared by the achieved knowledge gain. We remind that in all three contexts, the systems were used as just supplementary course tools. The students were able to learn the subject by many ways with the self-assessment QuizJET/JavaGuide/Portal system being just one of many factors that contributes to the learning.

### 3.2. The Impact of Guidance on Student's Work with Questions of Different Complexities

To explore the impact of adaptive navigation support on students' work with questions of different complexity, we have divided all questions into three categories, *Easy*, *Moderate* and *Complex* based on the number of involved concepts (that ranged from 4 to 287). A question with 15 or less concepts is considered to be Easy, 16 to 90 as Moderate, and 90 or higher as Complex. Overall, the set of questions available in each of the three systems includes 41 easy, 41 moderate, and 19 hard questions. In order to compare how these three systems helped students to learn with questions of different complexity, we conducted two separate 2 by 3 ANOVA. To evaluate their performance we used the familiar parameters *Attempts* and *Success Rate* within adaptive and non-adaptive versions of the systems and complexity levels. The values for means and standard errors of each system are reported in Table 2.

The first 2 by 3 between-subjects ANOVA assessed *Attempts* as a function of *Systems* (QuizJET, Portal and JavaGuide) and *Complexity Level* (Easy, Moderate and Complex). We found that students had significantly higher attempts on the easy and moderate level of questions in JavaGuide than in QuizJET or Portal,  $F_{13easy}(1,132) = 9.636, p < .01, \eta^2 = .068$ ;  $F_{13moderate}(1,132) = 9.502, p < .01, \eta^2 = .067$ ;  $F_{23easy}(1,132) = 4.504, p < .05, \eta^2 = .033$ ;  $F_{23moderate}(1,132) = 5.649, p < .05, \eta^2 = .041$ . There were no significant differences between system QuizJET and Portal average across three complexity levels,  $F(1,132) = .449, p = .504, \eta^2 = .003$ . It indicates that given the adaptive navigation support on

the portal can promote marginal boost on overall attempts (Fig 3 left). However, the overall effect is not as obvious as it is by session (see section 4.1).

The second set of 2 by 3 between-subjects ANOVA was performed on *Success Rate*. We found that both systems with adaptive navigation support outperformed the portal version with no support,  $F_{12}(1,132)= 58.962, p < .01, \eta^2 = .309$ ;  $F_{13}(1,132)= 53.932, p < .01, \eta^2 = .290$ . Such effect was significant on all three complexity levels. It means that students were much more likely to answer a question correctly with adaptive navigation support than without regardless the complexity levels. In addition, there were no significant differences between the adaptive systems (Portal & JavaGuide),  $F(1,132)= 1.427, p = .234, \eta^2 = .011$ . As shown on figure 3 right, the success rate lines for both adaptive systems collided while being far above the non-adaptive one. It says that students were able to achieve higher success rate with both kinds of adaptive annotations. This is encouraging news for teachers who use learning portals in their courses. Adaptive navigation support, which can now be provided in a regular portal by using service-based adaptation approach, does make a remarkable difference in this context.

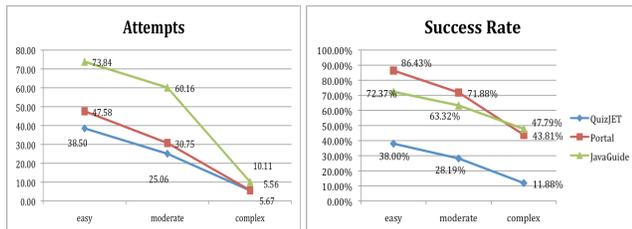


Fig. 3. The total Attempts (left) & Success Rate (right) of three systems on different complexity levels

Table 2 Means and standard error of Attempts and Success Rate, by system and complexity level

| DV            | System   | n             |               |               |
|---------------|----------|---------------|---------------|---------------|
|               |          | QuizJET       | Portal        | JavaGuide     |
| Total Attempt | Easy     | 38.50 ± 8.39  | 47.58 ± 9.69  | 73.84 ± 7.70  |
|               | Moderate | 25.06 ± 8.39  | 30.75 ± 9.69  | 60.16 ± 7.70  |
|               | Complex  | 5.56 ± 8.39   | 5.67 ± 9.69   | 10.11 ± 7.70  |
| Success Rate  | Easy     | 38.00% ± 6.1% | 86.40% ± 7.1% | 72.40% ± 5.6% |
|               | Moderate | 28.20% ± 6.1% | 71.90% ± 7.1% | 63.30% ± 5.6% |
|               | Complex  | 11.90% ± 6.1% | 43.80% ± 7.1% | 47.80% ± 5.6% |

### 3.3. The Impact of Guidance on Weak and Strong Students

To obtain a deeper understanding on the effects of adaptive navigational support on different kinds of students, we analyzed the impact of guidance separately on students with weak and strong knowledge of the subject. The students were split into two groups based on their pre-test scores (ranging from a minimum of 0 to a maximum of 20). *Strong* students scored 10 or higher points in the pre-test and *weak* students scored less than 10 points.

The impact of adaptive link annotation in a dedicated JavaGuide interface is reported in [4]. In this study, we focused on the effects of portal-based adaptive navigation support. Figure 4 analyzes the impact of adaptation separately for strong and weak students on three question complexity levels for all three systems. The analysis shows some interesting patterns. We found that weaker students took the advantage of adaptive navigation support and

attempted more questions on average than stronger students did,  $F(1, 30)= 5.102, p < .05, \eta^2 = .145$ . However, the impact of navigation support provided by the portal was remarkably different from the effect of JavaGuide navigation support. Without adaptation, both weaker and stronger students attempted a relatively low number of questions. With JavaGuide adaptation, both weaker and stronger students attempted a relatively high number of questions (with weaker students naturally leading in easy question). However, portal-based navigation support affected weaker and stronger students in different ways. Weaker students of the Portal system users followed the same high-motivation pattern as JavaGuide system users. On the contrary, the stronger students were not additionally affected by the portal-based navigation support and behaved just like users in a non-adaptive portal.

Another interesting pattern was found by analyzing the *success rate* parameter. While success rate was increased for both stronger and weaker users in the presence of either kind of adaptive link annotation, we registered an interesting reverse pattern in its impact in portal-based adaptation context. While in our earlier studies we observed that stronger students have higher success rate than weaker students in both adaptive and non-adaptive conditions, portal-based adaptation allowed weaker students to achieve higher success rate than stronger students. This is another evidence of the earlier observation that weaker students are much more affected by portal-based adaptation than stronger students. Overall, weaker students were able to achieve significantly higher success rate than non-adaptive users,  $F(1, 41)= 18.149, p < .01, \eta^2 = .307$ . The result is consistent with our earlier findings in [4]. In other words, portal-based approach of adaptive navigation support can attain the same impact in terms of high success rate.

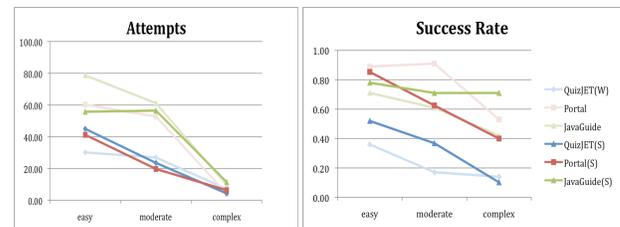


Fig. 4. The pattern differences for weak and strong students of the Attempts (left) & Success Rate (right) on three systems by different complexity levels

### 4. SIMILAR WORK

Several approaches were explored so far to provide adaptive navigation support for open corpus adaptive hypermedia. KBS-Hyperbook [5] and SIGUE [6] implemented a hyperspace extension approach, by providing the ability to add external resources into the context of regular closed corpus AH system by integrating internal content with external references. Such an approach, however, required individual work with every learning recourse included in the system. Some other systems [7, 8] explored dedicated adaptive interfaces, which allowed integrating multiple resources into a relatively light portal. These systems introduced adaptive intermediary services, which reside between the portal and the interactive content, generating an interface for personalized access to this content. The negative side of this approach is the need to develop an intermediary service for each kind of learning resources. Other projects [9, 10] suggested a personalization service approach, which passes references to both

the user and the resource under consideration and receive the adaptation decision in the form an icon, shown next to the resource link [3]. A similar service-based approach has been explored in the APeLS system [11] and the Personal-Reader framework [9]. This service-based personalization could be considered as the most advanced of the known approaches since it allows implementing adaptive navigation support in any context – from dedicated systems to traditional learning portals. In brief, wherever a link to an educational resource can be placed, it can be adapted using a personalization service approach.

## 5. SUMMARY AND FUTURE WORK

This paper investigated the value of adaptive navigation support in the context of a traditional hierarchical learning portal. Expanding our earlier work, we compared two approaches for implementation of adaptive navigation support in e-learning systems (a dedicated interface and an adaptive portal) with a non-adaptive portal. We have found that the impact of adaptive link annotation is not restricted to dedicated adaptive hypermedia interfaces, but can be also obtained within a regular learning portal. As shown in the study, adaptive link annotation in the portal context provided generally the same effect as a dedicated interface with adaptive link annotation. It guided students to the right question at the right time, significantly increasing their chances to answer the question correctly. It also motivated students to explore more questions. At the same time, the motivational effect of adaptive link annotation was less pronounced on the portal.

A deeper analysis uncovered that the portal-based approach most significantly affected weaker student, causing them to attempt more questions. They behaved similarly to their peer cohort of weaker students who were using a dedicated adaptive interface. At the same time, the motivation of stronger students was not affected by the navigation support on the portal: they acted similarly to their peer cohort of stronger students in a non-adaptive system context. Apparently, this is the aspect in which the effect of adaptation is different between a portal and a dedicated interface. We can hypothesize that this difference was caused by the difference in navigation structure between these two options. The dedicated interface allowed students to see the state of all topics and all questions at once. Thus, stronger students who can relatively quickly master the content of one specific topic relatively quickly, still see challenging questions far beyond this topic and thus be sufficiently motivated to visit the system more frequently and to do more work per session. In contrast, the hierarchical portal-based interface “locks” students in to one topic making it harder to see the big picture and the “big challenge”. While it was not critical for weaker students, who require more attempts to master even a single topic, it did affected stronger students’ motivation. At the same time, being “locked” into one topic had another positive effect on weaker students: it reduced distraction and increased their success rate in answering moderate to complex questions.

Although further studies are required to identify whether our hypotheses are correct, our data hints that while adaptive link annotation has its merit in both contexts – a hierarchical portal and a dedicated interface – the effect of these interfaces may depend on the student’s level of knowledge of the domain. Weaker students may benefit more from a hierarchical portal interface working on one topic at a time, while stronger students

may be better served by a dedicated interface, which provides access to all topics at the same time

The results are encouraging and initiate new challenges for the future. Our next step is to incorporate more sophisticated adaptive navigation icons on the portal, including topic-level and goal-level adaptations and perform more exhaustive evaluation. In addition, we are motivated to scale up the personalization services to more computationally-intensive ones on the portal. A similar study to evaluate students’ performances will be followed up.

## 6. ACKNOWLEDGEMENT

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