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Changing the Conversation: Impact of a Seminar-Based Classroom Innovation on Student Perceptions of Engineering*

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Examination of student perceptions of engineering has the potential to elucidate factors that affect enrollment and retention in engineering fields. The main goal of this study was to examine the effect of a classroom intervention—an engineering student ambassador program (Engineering Ambassadors)—on first-year engineering students' perceptions of engineering and engineering self-efficacy. Student changes in perceptions of engineering were examined in two studies. Results from Study 1 indicated evidence of the benefit of the engineering ambassador innovation on students' perceptions of engineering as well as positive ratings of the ambassador visits. Study 2 corroborated the findings of positive ratings and perceived benefits of the engineering ambassador visits, and demonstrated increases in engineering self-efficacy among students receiving the engineering ambassador intervention compared with students who did not receive the engineering ambassador intervention. Implications for increasing student interest in engineering based on the implementation of the classroom innovation are discussed.

Keywords: attrition; retention; women; underrepresented students; Engineering Ambassadors; engineering self-efficacy

1. Introduction

The scope of work examining factors that lead to enrollment and retention of students in engineering and STEM-related disciplines has increased significantly in recent years [1–4]. In this context, researchers have also examined factors that lead to students leaving majors, including within engineering [5–8]. These studies have identified mechanisms that facilitate persistence among students interested in engineering and STEM-related areas [9]. Salient findings from this area of research suggest that reasons for enrolling and persisting in engineering programs center on perceptions related to competence, confidence, interest, connections with engineering-related values, and a more complete understanding of the nature of the activities in which engineers engage [4, 9–11]. Despite several papers suggesting the importance of fostering an understanding among developing engineers of the impact of engineering on the health, happiness, and safety of the world, many courses within traditional engineering curricula maintain a heavy focus on the acquisition of technical skills and knowledge with little overview and emphasis on the impact of engineering on society [4].

Studies have reported significant concern over attrition among first-year college students, noting that half of the attrition occurs during students' first year of their undergraduate experience [12]. Such findings have been leveraged to highlight the critical importance of examining factors that buffer or mitigate the likelihood of attrition and instead contribute to the success and retention of engineering students [1, 2, 13]. Besterfield-Sacre, Atman, & Shuman, for example, found that attrition in engineering among undergraduate students was predicted by key factors such as differences in attitudes about engineering as well as overall appreciation for the engineering profession [8].

The link between gender disparities in engineering and inadequacies in enrollment of women in engineering fields at the university level is clearly established [2]. Efforts targeting outreach, encompassing outreach within universities, across universities, and at the high school and middle school level, are likely to be beneficial for the recruitment of students to engineering [2]. Thus, targeted programs anchored to students' curricular experiences that promote an appreciation for engineering as a discipline among early undergraduate students are warranted [14]. Recently, engineering ambassador programs have been implemented as a mechanism for increasing interest in STEM more broadly and engineering more specifically [15–19].

This work discusses the implementation and evaluation of a classroom intervention, executed by way of visits to first-year student engineering seminar courses by trained engineering ambassadors and aimed at increasing positive perceptions about engineering [4, 20, 21]. The work reflects a follow-up to a pilot program examining the impact

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of the visits on perceptions and understandings of engineering students [4]. The project also aimed to provide students with critical information to facilitate career and related decisions, such as major selection.

The engineering ambassador program at Penn State was initially created to attract young women to the mechanical engineering discipline via outreach visits to math and science classes in middle and high schools by outstanding female engineering undergraduate students to math and science classes in middle and high schools. The underlying strategy of the program was to communicate important themes conveyed by the *Changing the Conversation* effort that emphasized the benefit and importance of engineering to society [20]. The engineering ambassadors were trained in effective communication skills and strategies by taking course credits emphasizing specialized communication at the university in which the studies occurred [4].

One of the focal points of this coursework was to ensure the engineering ambassadors had the requisite skills and strategies for designing, implementing, and delivering effective scientific presentations to various audiences. Specialized training involved leadership development and advanced oral and visual communication techniques, including the assertion-evidence presentation approach, to allow the ambassadors to effectively communicate about their undergraduate engineering careers as well as applications of engineering principles that they were learning. The initial applications of these communication skills were utilized for informational sessions for prospective engineering and STEM students during on-campus tours and presentations and for outreach efforts directed toward middle school and high school students. The venues for this communication were then extended to include visits to first-year seminar classrooms [4].

A key goal of the engineering ambassadors visits to engineering first-year seminar courses was to communicate the importance of engineering in making a difference in the world and in being essential to facilitating health, happiness, and safety [4, 20]. These themes are delineated in a National Academy of Engineering publication entitled *Changing the Conversation*, which found that K-12 students were more attracted to messages about engineering that centered on the role of engineering in improvements for society. Such themes were also suggested to be beneficial in fostering positive perceptions of engineering among women and underrepresented individuals [4, 20].

The intervention for the current study consisted of a series of four engineering ambassador visits to undergraduate engineering students' first-year seminar courses. Thus, interaction occurred between the ambassadors and undergraduate students over the course of a series of events scheduled throughout the semester. The overarching goal of the events was to provide students with a presentation and discussion of important themes about engineering, and to establish a viable model for conveying such ideas [4]. The first event was held early in the semester and focused on how engineering majors impact different industries including energy, transportation, healthcare, food, entertainment, and humanitarian efforts. The 20-minute presentation delivered by two engineering ambassadors highlighted projects within each industry as well as how different types of engineers contribute to successful design and implementation of projects.

The second event focused on different options within a specific engineering major and presented examples of types of careers and research opportunities. The third event was hosted by a senior-level engineering ambassadors student who shared their personal experiences from their college career with focus on how their extracurricular experiences including internships, research, study abroad, and other activities shaped their time in college and future opportunities. The fourth event consisted of an interactive panel that involved four engineering ambassadors discussing topics relevant to being a successful student including internships, study abroad, study skills, and extracurricular involvement. Each ambassador hosted a station and small groups of students rotated through the stations throughout the class period. Discussion was encouraged during and after all of the events providing an opportunity for students to ask questions.

The main goal of the current study was to examine the impact of the engineering ambassador visits on students' perceptions of engineering, including engineering self-efficacy, perceived understanding of engineering, conceptualizations of engineering, and reasons for being interested in the field of engineering. The following research questions guided the evaluation of the engineering ambassador visits:

1. Is there evidence of changes in perceptions of engineering among students who receive the engineering ambassador visits?
2. Is there evidence of gains in measures of engineering self-efficacy and perceptions of engineering among students who receive the engineering ambassador visits compared with students who do not?

To address the research questions, a two study design was utilized. In Study 1, all students received the engineering ambassador intervention to allow for an initial examination of changes in perceptions of engineering following the ambassador visits. It was expected that students would demonstrate increases in their perceptions related to engineering, including increases in their understanding of engineering, conceptualizations of engineering, and positive reasons for being an engineer. To evaluate for the effect of the innovation on student perceptions of engineering, Study 2 utilized a pre-post control group design. It was expected that students receiving the engineering ambassador visits would evidence gains in obtained scores measuring engineering self-efficacy and perceptions of engineering relative to students in the control group.

2. Study 1

2.1 Design

Students enrolled in an engineering first-year student seminar at Penn State received the ambassador innovation. This design was utilized to provide an initial examination of the effect of the innovation on student perceptions of engineering.

2.2 Participants

One hundred and thirty-two students completed Study 1. Of the participants, 77.3% were male (n = 102) and 22.7% were female (n = 30). The percentage of students participating in Study 1 who were female exceeded the typical representation of female students at the bachelor's degree level in engineering [22]. With respect to ethnicity information, 62.1% of the sample described themselves as White/Caucasian (n = 82), 31.3% (n = 41) as Asian, 3.8% (n = 5) as Hispanic, and 2.3% (n = 3) as two or more. One participant did not disclose ethnicity information. The participants were enrolled in six sections of the first-year engineering seminar across 3 years: 2011 (15.2%; n = 20), 2012 (68.2%; n = 90), and 2013 (16.7%; n = 22). The seminars were taught by six different instructors, with comparable enrollment across instructors of the seminar, χ^2 (5, 127) = 6.82, p = 0.23.

2.3 Measures

The following scales were administered at pre- and post-test: Engineering Self-Efficacy (4 items); Reasons for Being an Engineer (5 items); Conceptualization of Engineers (5 items); and Perceived Understanding of Engineering (3 items). The scales were developed by the authors and were measured using a 5-point Likert scale (1—Strongly disagree to 5—Strongly agree). Total scores on each of the scales were used for analyses. The Engineering Self-Efficacy scale assessed participants' confidence and belief in their skills relevant to becoming a successful engineer. An example item from the Engineering Self-Efficacy scale was "*I believe I have the skills to be a successful engineer*". The Reasons for Being an Engineer scale assessed participants' reasoning for interest in and plans to pursue engineering. An example item from the Reasons for Being an Engineer scale was "*I want to be an engineer so I can help people*" [4].

The Conceptualization of Engineers scale, as described by *Changing the Conversation,* assessed participants' views about the benefit of engineering to society [11]. An example item from the Conceptualizations of Engineering scale was "*Engineers have contributed greatly to fixing the problems in the world*". Finally, the Perceived Understanding of Engineering scale assessed understanding of what engineers do; an example item from the scale was "*I am familiar with what a practicing engineer does*". For the post-test, in addition to the measures administered during the pre-test, a series of items (8) were administered to assess the perceptions and ratings of the ambassador visits; the items are described in Table 2.

2.4 Procedure

All participants received the engineering ambassador innovation (N = 132). All items were consolidated into a single instrument to facilitate administration. Participants completed all measures of the pre-test during the first week of the semester; participants completed all post-test measures during the last week of the semester. Item order was the same across administrations of the measures to allow for direct comparison of gains. Participants completed all measures individually in their classes.

3. Results

To ensure that gains in obtained scores were not the result of differences based on gender, ethnicity, or instructor, a multivariate analysis of variance (MANOVA) was conducted for scores on the Engineering Self-Efficacy, Perceived Understanding of Engineering, Conceptualization of Engineers, and Reasons for Being an Engineer scales. Obtained scores on the scales did not differ by gender, Wilks's λ = 0.95, F (4, 101) = 1.32, p > 0.05, ethnicity, Wilks's λ = 0.92, F (12, 267.51) = 0.71, p > 0.05, or instructor, Wilks's λ = 0.74, F (20, 335.93) = 1.57, p > 0.05. The results supported the use of the measures in the sample and did not suggest the presence of differential gains based on gender, ethnicity, or instructor.

Table 1 presents descriptive and reliability statistics for each of the measures. In general, the measures demonstrated adequate distributional characteristics, including appropriate skewness and kurtosis. Cronbach's alpha was used as the estimate of reliability for each of the measures. The measures also demonstrated adequate reliability. The Reasons for Being an Engineer scale demonstrated lower reliability than expected. This finding was potentially the result of the nature of the items containing relatively disparate reasons for pursuing engineering; as a result, consistency among the obtained item responses may have been negatively affected.

To evaluate differences in students' perceptions of engineering from pre- to post-test, a series of repeated measures analyses of variance (repeated measures ANOVAs) were conducted with pre-test measures entered at time one and post-test measures entered at time two. Analysis revealed a statistically significant increase in Reasons for Being an Engineer scale scores, $F(1, 131) = 4.05$, $p < 0.05$, $\eta_p^2 = 0.03$, indicating a significant increase in the reasons measured for being an engineer among the students after the ambassador intervention. Similarly, a statistically significant increase in scores on the Conceptualizations of Engineers scale was also obtained, $F(1, 131) = 5.79$, $p < 0.05$, $\eta_p^2 = 0.04$. The effect sizes obtained indicated a small effect for the increases in Reasons for Being an Engineer and Conceptualizations of Engineers scores among the sample.

A statistically significant increase was also obtained in Perceived Understanding of Engineering scale scores by the participants, $F(1, 131) = 75.69$, $p < 0.05$, $\eta_p^2 = 0.37$. The results supported an increase in students' familiarity with what an engineer does (e.g., what a practicing engineer does, what engineers do in various engineering disciplines) after receiving the ambassador visits. Examination of increases in students' Engineering Self-Efficacy did not result in a statistically significant increase in self-efficacy scores, $F(1, 131) = 0.59$, $p > 0.05$.

Table 2 provides item descriptions and descriptive statistics for the ambassador visit rating items. Students experiencing the visits from the engineering ambassadors rated the benefit of the visits in accordance with the items listed. Seven of the 8 items were worded positively, where a high score on the item indicated a high appraisal of that element of the ambassador visit. One item asked participants to rate the extent to which they decided to consider another major; the mean for this item was low ($M = 2.45$), suggesting a lack of consideration of pursuing other majors after the ambassador visits. In general, all of the remaining items indicated positive appraisals of the ambassador visits. The most frequently occurring response for the items was a 4.00 (Agree), with most of the means at or above 4.00 as well. Taken together, the findings indicated positive ratings and benefit of the ambassador visits in helping

Table 1. Descriptive Statistics for Pre- and Post-Test Measures

Measure	*M*	*Mdn*	*SD*	Range	Number of Items	α
Pre-Test Measures						
Self-Efficacy	14.50	14.50	2.73	11.00	4	0.74
Reasons	16.50	16.00	2.46	14.00	5	0.58
Conceptualizations	20.98	21.00	2.36	17.00	5	0.74
Perceived Understanding	10.05	10.00	2.19	10.00	3	0.81
Post-Test Measures						
Self-Efficacy	14.64	15.00	2.86	11.00	4	0.71
Reasons	16.92	17.00	2.69	14.00	5	0.57
Conceptualizations	21.45	21.00	2.29	10.00	5	0.69
Perceived Understanding	11.49	12.00	1.78	9.00	3	0.74
Ambassador Items	31.28	31.00	3.72	25.00	8	0.71

Note: Self-Efficacy = Engineering Self-Efficacy Scale; Reasons = Reasons for Being an Engineer Scale; Conceptualizations = Conceptualizations of Engineers Scale; Perceived Understanding = Perceived Understanding of Engineering Scale; *M* = Mean; *Mdn* = Median; *SD* = Standard Deviation.

Table 2. Descriptive Statistics for Ambassador Visit Rating Items, Study 1

Item	*M*	*Mo*	*SD*
Better understand what engineers do	4.16	4.00	0.75
Better understand what other types of engineers do	4.15	4.00	0.73
More confident of my decision to be an engineer	3.71	4.00	0.91
Have decided to consider another major	2.45	2.00	1.12
Better informed about opportunities that can help me become a successful student	4.29	4.00	0.64
Better understanding of how engineers help people and society	4.08	4.00	0.71
Learning about experiences of other engineering students was helpful	4.39	4.00	0.64
Listening to other students talk about engineering and their experiences was effective	4.07	4.00	0.87

Note: M = Mean; *Mo* = Mode; *SD* = Standard Deviation.

students to develop an understanding of engineering disciplines.

4. Discussion

The results of Study 1 provided initial evidence of the benefit of the engineering ambassador classroom innovation on students' perceptions of engineering. Significant increases in scores were obtained, reflecting students' reasons for being an engineer and perceived understanding of engineering and what an engineer does. Increases were also obtained in students' conceptualizations of engineering that emphasize engineers as creative, contributing to problem solving, and dedicated to helping people and society. Students positively rated the effect and benefit of the ambassador visits, indicating perceived benefit of learning about experiences related to engineering, facilitating opportunities, and an improved understanding of what an engineer does.

Although the results suggest significant positive outcomes for students that participated in Study 1, we cannot fully separate the role of the course and instructor from the engineering ambassador innovation. It is therefore possible that the perceived benefits in understanding the role of engineers in society are partially or fully attributed to the overall course material. Study 2, where we compare an intervention group with a control group without varying the instructors and course material, was designed to isolate the contribution of the engineering ambassador innovation.

5. Study 2

5.1 Design

Students were assigned to either an intervention or a non-intervention group based on enrollment in a chemical engineering first-year student seminar. Students in the intervention group received the engineering ambassador visits and the students in the non-intervention group did not. All students, across the intervention and non-intervention conditions, were co-taught by the same two instructors to ensure that potential differences in obtained scores were not the result of differences attributable to instructor method, style, performance, or influence. The course materials, including lectures and assignments, were identical for both groups except for the engineering ambassador innovation in the intervention group; on days that the Ambassadors came to the classroom the control group did not hold class.

5.2 Participants

Forty-four students across two sections of the chemical engineering seminar course completed Study 2. Nineteen students participated in the intervention group, while 25 students participated in the non-intervention group. Frequency of student participation was found to be comparable across the two conditions, χ^2 (1, 42) = 0.82, p = 0.37. Of the participants, 79.5% were male (n = 35) and 20.5% were female (n = 9). With respect to ethnicity, 65.9% of the sample described themselves as White/Caucasian (n = 29), 31.8% (n = 14) as Asian, and 2.3% (n = 1) as Black/African American. The participants were enrolled in two sections of the engineering seminar taught in 2014; the seminar was co-taught by the same two instructors. In general, the percentage of students participating in Study 2 who were female and from underrepresented groups was comparable with or exceeded the typical representation of students at the bachelor's degree level in engineering [22].

5.3 Measures

The same measures used in Study 1 were used and administered in Study 2. Descriptive and reliability statistics for all measures are provided in Table 3. Participants were administered scales measuring Engineering Self-Efficacy (4 items); Reasons for Being an Engineer (5 items); Conceptualization of Engineers (5 items); and Perceived Understanding of Engineering (3 items). Example items for each of the measures are included in the descriptions of the measures in Study 1. The ambassador visit rating items (8) were administered to students in the intervention condition to assess the perceptions and ratings of the ambassador visits; the ambassador rating items are described in Table 4 [4].

5.4 Procedures

Participants completed all measures of the pre-test during the first week of the semester; participants completed all post-test measures during the last week of the semester. The items were again consolidated into a single instrument to facilitate administration. Item and administration order were the same across administrations of the measures to allow for direct comparison of gains. As in Study 1, participants completed all measures individually in their classes.

6. Results

Table 3 lists descriptive statistics for each of the measures. The measures demonstrated acceptable distributional characteristics. Cronbach's alpha was again used as the estimate of reliability. To evaluate for the presence of gains among the students in the intervention group on measures of engineering self-efficacy and perceptions of engi-

Table 3. Descriptive Statistics for Pre- and Post-Test Measures

Measure	*M*	*Mdn*	*SD*	Range	Number of Items	α
Pre-Test Measures						
Self-Efficacy	14.25	14.50	2.92	15.00	4	0.64
Reasons	16.23	16.00	2.36	12.00	5	0.40
Conceptualizations	20.84	21.00	1.82	7.00	5	0.50
Perceived Understanding	9.21	9.00	1.83	7.00	3	0.55
Post-Test Measures						
Self-Efficacy	14.95	15.00	2.65	9.00	4	0.72
Reasons	15.98	16.00	2.21	11.00	5	0.25
Conceptualizations	21.21	21.00	2.17	10.00	5	0.58
Perceived Understanding	11.28	11.00	1.78	8.00	3	0.60
Ambassador Items	30.17	30.00	2.28	8.00	8	0.44

Note: Self-Efficacy = Engineering Self-Efficacy Scale; Reasons = Reasons for Being an Engineer Scale; Conceptualizations = Conceptualizations of Engineers Scale; Perceived Understanding = Perceived Understanding of Engineering Scale; *M* = Mean; *Mdn* = Median; *SD* = Standard Deviation.

Table 4. Descriptive Statistics for Ambassador Visit Rating Items, Study 2

Item	*M*	*Mo*	*SD*
Better understand what chemical engineers do	4.17	4.00	0.38
Better understand what other types of engineers do	3.63	4.00	0.83
More confident of my decision to be a chemical engineer	3.53	3.00	0.77
Have decided to consider another major	2.32	2.00	1.20
Better informed about opportunities that can help me become a successful student	4.26	4.00	0.56
Better understanding of how chemical engineers help people and society	4.21	4.00	0.56
Learning about experiences of other engineering students was helpful	4.11	4.00	0.74
Listening to other students talk about engineering and their experiences was effective	3.95	4.00	0.78

Note: *M* = Mean; *Mo* = Mode; *SD* = Standard Deviation.

neering, gain scores were computed that resulted in the obtained difference in scale scores from post- to pre-test. A series of ANOVAs were conducted with the gain scores calculated for the Engineering Self-Efficacy, Reasons for Being an Engineer, Conceptualizations of Engineering, and Perceived Understanding of Engineering scales as the dependent variables, and the intervention/non-intervention condition as the fixed factor variable.

Analysis revealed a significant difference in Engineering Self-Efficacy scale scores by intervention vs. non-intervention condition, F (1, 42) = 4.77, $p <$ 0.05, $\eta_p^2 = 0.10$. Follow-up examination of means revealed a significantly higher engineering self-efficacy gain score for students receiving the classroom innovation (1.21) than for students that did not receive the classroom innovation (0.04; mean difference = 1.17). The findings supported an increase in students' engineering self-efficacy after experiencing the ambassador visits. Significant increases in reasons for being an engineer, conceptualizations of engineering, and perceived understanding of engineering were not obtained (*p*s > 0.05).

In general, students rated the visits from the ambassadors positively, with the most frequently occurring response again a 4.00 (Agree). In particular, students indicated benefit in terms of the ambassador visits in facilitating their understanding of what a chemical engineer does, opportunities to help them become successful, how chemical engineers help people and society, and experiences of other engineering students. There was little indication of students considering a major other than chemical engineering after experiencing the ambassador visits.

7. Discussion

The results from Study 2 replicated and further supported the benefit of the engineering ambassador visits on students' perceptions of engineering. Students again positively rated the effect and benefit of the ambassador visits, indicating perceived benefit of the visits in developing their conceptions of the positive aspects of engineering. The findings extend those obtained in Study 1 by demonstrating a significant increase in engineering self-efficacy scores among students who participated in the classroom innovation and experienced the ambassador visits compared with those students who did not experience the visits.

8. General discussion and implications

The current study provided evidence for the impact of an engineering ambassador classroom innovation that emphasized the real-world or practical importance of engineering in solving problems faced by society. Rather than focusing on more traditional conceptions of engineering as the application of science to the real world, a conceptualization of engineering presented as making a significant difference in the world and as contributing to the health, happiness, and safety of society resulted in increases in positive perceptions of engineering as well as increases in students' engineering self-efficacy [4, 20]. The current findings suggest the importance of incorporating these themes that draw on a positive, global, and pragmatic conceptualization of engineering in facilitating the development of students' positive perceptions of engineering as well as academic- and career-related decisions [20, 21].

Taken together, the findings suggest important ways to address inadequate enrollment and retention in engineering as well as potential ways to appeal to underrepresented individuals in engineering fields by emphasizing the themes contained in the engineering ambassador intervention [2, 21, 23, 24]. Prior research has found the themes embedded within the intervention to be appealing for K-12 students, and also to be particularly appealing for women interested in engineering [20]. Building on research conducted by de Cohen and Deterding suggesting that disparities in engineering are driven by issues with enrollment, as opposed to prior suggestions of disparities resulting from issues with attrition, the embedding of the themes incorporated in the intervention, when implemented early and proactively into undergraduate engineering curricula, may provide a mechanism for addressing the underrepresentation of women in engineering fields [1, 2, 20, 21, 24, 25]. Furthermore, deploying engineering ambassadors to deliver themes from *Changing the Conversation* provides a complementary approach to material delivered by the course instructor.

9. Limitations and future research

Despite the finding that the obtained sample matched or exceeded the typical enrollment of women and underrepresented individuals at the undergraduate level, a relatively limited number of women were enrolled in the first-year seminars. This limited the number of statistical analyses that could be employed to more closely examine relative gains in perceptions of engineering and engineering self-efficacy for women in engineering. Nevertheless, the finding of no differences in obtained scores based on gender or ethnicity reflects a strength of the study and suggests the potential for equitable increases in perceptions of engineering across individuals. Future research would likely benefit from a more focused examination of gains among women and underrepresented students, drawing on larger subsamples of both groups, to evaluate the impact of such themes on developing positive perceptions about and self-efficacy with engineering.

10. Conclusions

This research presented findings from an examination of the effectiveness of embedding positive, pragmatic themes about the importance of engineering in messages conveyed to undergraduate engineering students by engineering ambassadors. Across Studies 1 and 2, the benefits of the engineering ambassador program to students' perceptions of engineering were supported. In addition, students demonstrated conceptualizations of engineering that emphasized engineers as creative, contributing to problem solving, and dedicated to helping people and society. Our findings align with and extend previous work [15–19] demonstrating the benefit of utilizing engineering ambassadors to facilitate development in students' perceptions of engineering.

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