GRADUATE FELLOWS IN THE CLASSROOM: MIDDLE SCHOOL STUDENTS' SCIENCE, TECHNOLOGY, ENGINEERING, OR MATHEMATICS BELIEFS AND INTERESTS

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Abstract

The purpose of this research was to determine if the interaction of a NSF Graduate Fellow in the classroom affected middle school students' science, technology, engineering, or mathematics (STEM) beliefs or interests. The study utilized a pre-test/post-test design and data were collected from a local voluntary population (N = 1145). The survey instrument consisted of Likert scaled questions and open-ended responses. STEM belief and interest scales were summated to determine an overall belief and/or interest for each subject. Descriptive statistics and multivariate analysis were performed on the summated scales. Overall, middle school students' STEM beliefs and interests were less positive on the post-test than on the pre-test, the notable exception being interests in technology which increased. Multivariate analysis indicated that NSF Fellow and grade level, not teacher, affected the rate at which students' STEM beliefs and interests changed. This study indicated that NSF Fellows affected the rate at which middle school students' STEM beliefs and interests changed, but did not indicate if that influence was positive or negative when accounting for grade level.

Introduction

Many are concerned about the public's decreasing science literacy and the decreasing number of students entering science careers, especially the agricultural sciences such as agronomy and crop science (McCallister, Lee, & Mason, 2005; Munn, Skinner, Conn, Horsma, & Gregory, 1999). Research indicates students' attitudes toward science become increasingly negative at higher grade levels and scientific content and its real-world applications also become increasingly disconnected (Morell & Ledermann, 1998; Weinburgh, 2003). Negative attitudes toward science are further reinforced by a stereotypical image (a lonely profession of white male scientists in lab coats with facial hair and glasses working in chemistry labs) held by the general public and many public school science teachers (Finson, 2002). Finson stated "that the extent to which an individual's perceptions are stereotypical has direct consequences on that individual's likelihood of selecting science coursework and entering a science-related field" (p. 343). This notion may be true especially for females and minorities educated in classrooms by teachers who subconsciously hold stereotypical images of scientists, and who transfer this image to their students either consciously or unconsciously (Finson).

The National Center for Education Statistics (NCES) reported that 39% of eighth graders in the United States scored below the basic level in science, while only 32% scored at or above the proficient level (NCES, 2002). State and national expectations of student achievement have risen to counter this disparity, increasing the burden on school districts. National Council of Teachers of Mathematics (NCTM) sought new, improved methods to reform education that create meaningful, context-rich learning environments for students, and effectively increase student achievement in a teacher-friendly manner (Harris, Marcus, McLaren, & Fey, 2001).

A reform effort, which research showed was successful in changing college and high school students' stereotypical images of scientists, centers on educator/scientist collaborations. Such collaborations between scientists and educators have demonstrated positive results, increasing students' positive attitudes toward science, teacher content knowledge, and use of inquiry learning (Caton, Brewer, & Brown, 2000; Davis et al., 2003; Evans, Abrams, Rock, & Spencer, 2001; Finson, 2002; Munn et al., 1999; Tanner, Chatman, & Allen, 2003; Weinburgh, 2003;). Scientists who collaborated with educators in the classroom had opportunities to share their excitement and enthusiasm for their field with students, potentially improving the scientific content in students' science education. Research also indicates that scientists' involvement in the classroom may have the added benefit of increasing inquiry learning and student scientific literacy levels (Caton et al., 2000; Munn et al., 1999).

Scientists, by demonstrating they do not have to fit the preconceived stereotype, have the potential to serve as positive role models for students, especially for female and minority students (Finson, 2002). Studies have indicated that as a result of students' interaction with scientists, students learned that scientists were "real" people who enjoyed their work and were not the solitary, lonely people so often portrayed as the stereotypical scientist. Other potential benefits of scientists actively participating in the classroom are increased opportunities for students to learn about the wide range of opportunities available in the sciences and increased opportunities for in-depth inquiry activities that connect science with real-world applications (Caton et al., 2000; Munn et al., 1999; Tanner et al., 2003; Weinburgh, 2003). Caton et al. found that "partnerships between teachers, scientists, and university science educators have the potential to improve significantly the content and effectiveness of science education" (p. 14). Wildman & Torres' (2001) also found that agricultural professionals and personal role-models positively influenced students' decisions to pursue agricultural careers. This finding indicates that collaboration between agricultural professionals and classroom educators has the potential to reverse current negative trends and increase student enrollment in the agricultural sciences.

Program Goals

Funded by a three year grant from the National Science Foundation, Texas A&M University developed the Partnership for Environmental Education and Rural Health (PEER) GK-12 project. This GK-12 project (currently completing its first year) utilizes an interdisciplinary partnership between differing colleges in the Texas A&M University system. Graduate and undergraduate fellows from various disciplines, public junior high school math and science teachers, and junior high school students within a 40 mile radius of College Station, Texas participate in the project. The goal of this collaboration is to enhance the quality of middle school student educational experiences using inquiry learning and improve middle school student's attitudes toward the STEM (Science, Technology, Engineering, and Mathematics) areas. The PEER GK-12 project has a long-term goal of developing a rural middle school model that will integrate current research and education, be transportable, relevant, engage students, provide under-represented, geographically isolated students enriching educational opportunities, and improve the interest, knowledge, and understanding of students in STEM areas (PEER, 2004).

Purpose and Objectives

The purpose of this research was to determine if NSF Graduate Fellows' (NSF Fellows) classroom interactions affected rural middle school students' beliefs or interests in STEM subjects. The objectives to fulfill this purpose were:

1. Determine rural middle school students' pre- and post-test beliefs about STEM.
2. Determine rural middle school students' pre- and post-test interests about STEM.
3. Examine the interaction effects of NSF Fellows' on students' STEM beliefs and interests.
4. Test multiple interaction effects (NSF Fellows, teacher status, and grade level) on students' STEM beliefs and interests.

Methodology

This paper was part of a larger study, the GK-12 PEER project at Texas A&M University. This study focused solely on middle school students' interests and beliefs about STEM subjects. The study utilized a pretest/posttest design and a voluntary sample. Middle school program and teacher drop-out resulted in pre-test data being collected from 12 lead teachers and 12 other teachers representing 10 schools in a 40-mile radius of the university; a total of 2,184 students responded to this study. Invalid surveys decreased the number of usable responses; only those students who completed both the pre- and post-tests were included in the data analyses (N = 1145).

Pre and post tests contained Likert-type scale questions and open-ended responses. Reverse coding of some statements was used to reduce biasing effect (Tuckman, 1999). The Likert scales measured students' agreement levels (1 = strongly disagree, 2 = disagree, 3 = neither agree nor disagree, 4 = agree, and 5 = strongly agree) with 12 statements pertaining to beliefs about STEM, and eight statements pertaining to interests in STEM. Statements were drawn from surveys originally developed for use in the National Science Foundation's *Mississippi Information Technology Workforce* project. Versions of these statements have been pilot tested with audiences similar to the population in this study (Lindner et al., 2004; Swortzel, Jackson, Taylor, & Deeds, 2003).

Sample statements for students' beliefs about science included: *I enjoy science class*; *Science is difficult for me; Scientists help make our lives better*; and *Being a scientist would be a lonely job*. Samples of the eight statements pertaining to interests in STEM included: *I like to use computers to learn about science*; *Science class activities are boring*; *The things we study in science are not useful to me in daily living*; *I don't usually try my best in science class*.

STEM belief and interest scales were summated to determine an overall belief and/or interest for each STEM area. Cronbach's alpha coefficient was used to determine summated scale reliabilities for both the pre- and post-surveys. Reliability coefficients for the pre-test were: Beliefs scale (.79) and Interests scale (.40). Reliability coefficients for the post-test were: Beliefs scale (.83) and Interests scale (.65).

The pre-test Interest scale reliability coefficient was below the acceptable range according to Tuckman (1999), who stated "Observational reliabilities should be at .75 or above…and .50 or above for attitude tests" (p. 445). However, it was included in the analysis because the post-test reliability coefficient met the acceptability criterion.

Twelve NSF Fellows were assigned to a "lead teacher" in middle school math and science classrooms in nine local schools. NSF Fellows in this project served as resource and content specialists. The Fellows provided content-rich, in-depth, and inquiry-based learning activities for students that lead teachers may not otherwise have had the knowledge, time, or resources to conduct. In the classroom, NSF Fellows were to serve as role models, correct student misconceptions about scientists and science, increase student awareness of the importance of science and scientific methods in everyday life, and help students develop positive attitudes toward math and science. NSF Fellows also were to help teachers develop an appreciation for teaching by inquiry methods, and increase teachers' abilities and comfort levels with inquiry teaching methods.

NSF Fellows were expected to spend approximately 10 hours/week interacting with middle school students in the classroom, four hours/week preparing materials and developing inquiry-based activities, and one hour/week attending weekly meetings to discuss program insights and problems. NSF Fellows were expected to serve as a resource to other teachers in the schools, and by the last 12 weeks of the school-year, spend approximately 60% of their time in their lead teachers' classrooms and 40% interacting with students in other teachers' classrooms.

Rural middle school students' beliefs about STEM subjects were collected at the beginning of the school-year. Participating middle school teachers administered the pre-tests prior to the NSF Fellows' classroom involvement.

Descriptive statistics were used to describe middle school students' STEM beliefs and interests before and after NSF Fellow classroom interactions. Multivariate analyses were performed on the data to determine the interaction effect (if any) of the NSF Fellows' and/or teachers' effects on students' STEM beliefs and interests. There were no engineering classes at the middle school level; therefore no results were reported for engineering.

Results

Data were analyzed from 1,145 matched pre- and post-tests. Of the respondents, 45.2% (n = 517) were male, 48.9% (n = 560) were female, and 5.7% (n = 65) did not declare their gender. Four hundred and seventy one students (41.1%) were in the 6th grade, 25.6% (n = 290) were in the 7th grade, and 32.8% (n = 371) were in the 8th grade. There were 844 students (73.7%) in science classes, 19.1% (n = 219) in mathematics classes, and 7.2% (n = 82) in technology classes. Sixty-two percent of the total population was Caucasian, 19% was Hispanic, 16% was African American, 2% was Native American, and 2% was Asian. Lead teachers' classrooms accounted for 727 students (63.5%) and 418 students were in other teachers' classrooms (Table 1).

Table 1

Demographics for (N = 1145)

Variables		*f*	Percent
Grade	6th	471	41.1
	7th	290	25.3
	8th	371	32.4
	Missing	13	1.1
Gender	Male	517	45.2
	Female	560	48.9
	Undeclared	65	5.7
	Missing	3	.3
Subject	Science	844	73.7
	Math	219	19.1
	Technology	82	7.2
Teacher	Lead	727	63.5
	Other	418	36.5

Objective 1

In order to determine specific areas where students indicated pre/post-test changes, descriptive statistics were applied to the individual pre and post-test results. The majority of middle school students' STEM beliefs were less positive on the post-test than were on the pre-test. Students' science post-test beliefs were more positive about scientists making their lives better (M = 4.26) and getting to do experiments in class (M = 4.32). Students' beliefs remained constant in wishing to take more science classes (M = 2.91), and technology classes (M = 3.16). All other beliefs were less positive on the post-test than were on the pre-test (Table 2).

Table 2

Descriptive Statistics for Middle School Students' STEM Beliefs (N = 1145)

	Science[a] (n = 838)		Technology[a] (n = 82)		Math[a] (n = 219)	
STEM Beliefs Statements	Pre	Post	Pre	Post	Pre	Post
I enjoy ______ class.	3.84	3.74	4.06	4.01	3.73	3.51
I think I could be a good ______.	2.67	2.63	3.16	2.95	2.93	2.57
I like to find answers to questions by doing experiments.	3.77	3.69	4.10	4.06	3.58	3.54
I get to do experiments in my ______ class.	4.19	4.32	4.05	4.01	3.00	3.73
Being a ______ would be exciting.	3.27	3.17	3.50	3.28	2.94	2.69
______ is difficult for me.*	3.43	3.43	3.50	3.51	3.21	3.20
I like to use the ______ book to learn ______.	2.63	2.32	3.04	2.61	2.53	2.87
______ is useful in everyday life.	3.96	3.89	3.98	4.36	4.33	4.20
Studying hard in ______ is not cool.*	3.48	3.43	3.86	3.95	3.55	3.49
______s help make our lives better.	4.20	4.26	4.16	4.35	3.89	3.76
Being a ______ would be a lonely job.*	3.43	3.41	3.68	3.77	3.36	3.41
I want to take more ______ classes.	2.91	2.91	3.16	3.16	2.86	2.68

Note. [a]Means for pre- and post-Fellow experiences. Likert-type scale: 1 = strongly disagree, 2 = disagree, 3 = neither, 4 = agree, 5 = strongly agree.
* Indicates items that have been reverse coded.

Students' STEM beliefs improved most in Technology. Post-test results improved, in that students held more positive beliefs about the usefulness of technology in everyday life (M = 4.36), and technology making their lives better (M = 4.35) (Table 2). For all other statements, students' beliefs were less positive at the end of the school-year. Students were more positive in their beliefs about using the math book to study math (M = 2.87) and getting to do experiments in math class (M = 3.73) on the post-test. Students post-test beliefs were less negative in that mathematicians have lonely jobs (M = 3.41), and were more negative in their beliefs for all other statements. There were no engineering classes at the middle school level; therefore there are no results to report for engineering (Table 2).

Objective 2

In order to determine changes in students' STEM interests, descriptive statistics were applied to the individual pre and post-test results. Students' science interests were more positive toward working in small groups on the post-test (M = 3.89), and were less positive for all other statements on the post-test (Table 3).

Table 3

Descriptive Statistics for Middle School Students' STEM Interests (N = 1145)

	Science[a] (n = 838)		Technology[a] (n = 82)		Math[a] (n = 219)	
STEM Interest Statements	Pre	Post	Pre	Post	Pre	Post
I think ______ is important only at school.*	3.89	3.85	3.84	4.24	3.98	4.08
I like to use computers to learn about ______.	3.94	3.75	3.67	4.18	3.78	3.87
______ tests make me nervous.*	2.82	2.77	3.02	3.21	2.86	2.76
I like to use ______ equipment to study ______.	4.31	4.04	3.94	4.19	3.79	3.60
I don't usually try my best in ______ class.*	4.03	3.89	4.38	4.13	4.08	3.79
The things we study in ______ are not useful to me in daily living.*	3.79	3.71	4.06	4.26	4.04	4.04
I like to work in a small group in ______ class.	3.66	3.89	3.61	3.61	3.82	3.80
______ class activities are boring.*	4.19	3.83	4.38	3.93	3.86	3.75

Note. [a]Means for pre- and post-Fellow experiences. Likert-type scale: 1 = strongly disagree, 2 = disagree, 3 = neither, 4 = agree, 5 = strongly agree.
* Indicates items that have been reverse coded.

Students' technology interests improved the most overall. Students held more positive interests in using technology equipment (M = 4.19) and computers (M = 4.18) to study technology on the post-test. Students held more positive interests about technology not being useful in their daily living (M = 4.26). Students' interests for working in small groups (M = 3.61) in technology remained constant. For all other statements, student interests were less positive at the end of the school-year (Table 3).

Post-test responses showed increased positive interests for using computers to learn about mathematics (M = 3.87) and mathematics only being important at school (M = 4.08). Students' post-test responses were less positive for all other interest statements. There were no engineering classes at the middle school level; no results were reported for engineering (Table 3).

The individual belief and interest scales were summated to determine students' overall STEM beliefs and interests. The summated beliefs scale ranged from zero to 60, with scores below 30 indicating negative attitudes. The summated interests scale ranged from zero to 40, with scores below 20 indicating negative attitudes.

Students' overall post-test beliefs and interests in science were less positive (M = 40.92 and 29.52 respectively) than were their pre-test beliefs and interests (M = 41.61 and 29.55 respectively). Overall, students held less positive post-test beliefs about technology (M = 43.78), but students' post-test interests were more positive (*M* = 31.56). Students' overall post-test math beliefs (*M* = 39.30) were less positive, but their post-test math interests (*M* = 29.47) were more positive. There were no engineering classes at the middle school level; therefore there are no results to report for engineering (Table 4).

Table 4

Descriptive Statistics for Middle School Students' STEM Beliefs and Interests (N = 1145)

	Science (*n* = 838)		Technology (*n* = 82)		Math (*n* = 219)	
STEM Summated Scales	*M*	*SD*	*M*	*SD*	*M*	*SD*
Pre-test STEM Beliefs	41.61	7.56	44.11	6.91	39.87	7.89
Post-test STEM Beliefs	40.92	7.84	43.78	7.06	39.30	9.01
Pre-test STEM Interests	29.55	4.73	30.33	4.20	29.30	4.33
Post-test STEM Interests	29.52	4.86	31.56	4.51	29.47	5.20

Note. STEM Beliefs ranged from: Science = 14-60; Technology = 26-60; and Math = 12-60. STEM Interests ranged from: Science = 3-40; Technology = 20-40; and Math = 12-40.

Objective 3

Changes in students' STEM beliefs and interests were analyzed using the repeated measures function of SPSS for NSF Fellow to determine if there was an interaction effect between NSF Fellow and students' STEM beliefs and/or interests. A four-way repeated measures analysis was performed to determine interaction effects when all three factors (grade, teacher, and NSF Fellow) were present in the classroom.

Within subjects analysis by NSF Fellows indicated no statistically significant ($\alpha = 0.05$) difference between pre and post-test student mean STEM beliefs. Within subjects analysis indicated a statistically significant ($\alpha = 0.05$) interaction effect between NSF Fellow and students' STEM beliefs. Between subjects analysis indicated a statistically significant ($\alpha = 0.05$) pre- and post-test difference in STEM beliefs between NSF Fellows (Table 5).

Table 5

Analysis of Variance for NSF Fellow and Student STEM Beliefs (N = 1145)

Source	df	F	η^2	P
	Between Subjects			
Intercept	1	32819.381	.967	.000
NSF Fellow	8	22.316	.136	.000
Error	1135	(84.694)		
	Within Subjects			
beliefs	1	.021	.000	.885
beliefs * NSF Fellow	8	4.752	.032	.000
Error(beliefs)	1135	(25.727)		

Note. Values enclosed in parenthesis represent mean square errors.

Within subjects analysis of students' STEM interests by NSF Fellow indicated a statistically significant (α = 0.05) difference between pre- and post-test means. Within subjects analysis indicated a statistically significant (α = 0.05) interaction effect between NSF Fellow and students' STEM interests. Between subjects analysis indicated a statistically significant (α = 0.05) pre- and post-test difference in means between NSF Fellows (Table 6).

Table 6

Analysis of Variance for NSF Fellow and Student STEM Interests (N = 1145)

Source	df	F	η^2	P
	Between Subjects			
Intercept	1	51085.911	.978	.000
NSF Fellow	8	24.915	.150	.000
Error	1130	(28.362)		
	Within Subjects			
interest	1	4.836	.004	.028
interest * NSF Fellow	8	2.348	.016	.017
Error(interest)	1130	(12.385)		

Note. Values enclosed in parenthesis represent mean square errors.

Objective 4

To answer objective four, tests on the multiple interaction effects (NSF Fellows, teacher status, and grade level) were performed on students' STEM beliefs and interests. Within subjects analysis indicated there were statistically significant (α = 0.05) differences between pre- and post-test means for students' STEM beliefs. Within subjects analysis indicated statistically significant interaction effects (α = 0.05) between grade level and STEM beliefs, and between NSF Fellow and STEM beliefs. No statistically significant interaction effect (α = 0.05) was indicated between teacher effect and students' STEM beliefs (Table 7).

Table 7

Analysis of Variance by Grade level, Teacher, and NSF Fellows for STEM Beliefs (N = 1145)

Source	df	F	η^2	P
Between Subjects				
Intercept	1	14286.728	.928	.000
Teacher	1	.128	.000	.721
Grade	2	9.520	.017	.000
NSF Fellows	8	2.923	.021	.003
Teacher * Grade	0		.000	
Teacher * NSF Fellows	0		.000	
Grade * NSF Fellows	0		.000	
Teacher * Grade * NSF Fellows	0		.000	
Error	1113	(25.109)		
Within Subjects				
Beliefs	1	5.571	.005	.018
Beliefs * Teacher	1	2.271	.002	.132
Beliefs * Grade	2	3.784	.007	.023
Beliefs * NSF Fellows	8	2.981	.021	.003
Beliefs * Teacher * Grade	0		.000	
Beliefs * Teacher * NSF Fellows	0		.000	
Beliefs * Grade * NSF Fellows	0		.000	
Beliefs * Teacher * Grade * NSF Fellows	0		.000	
Error(Beliefs)	1113	(81.491)		

Note. Values enclosed in parenthesis represent mean square errors.

Within subjects analysis indicated there were statistically significant ($\alpha = 0.05$) differences between pre- and post-test means for students' interests in STEM. Within subjects analysis indicated statistically significant interaction effects ($\alpha = 0.05$) between grade level and STEM interest, and between NSF Fellow and STEM interests. No statistically significant interaction effect ($\alpha = 0.05$) was indicated between teacher effect and students' STEM interests (Table 8).

Table 8

Analysis of Variance by Grade level, Teacher, and NSF Fellows for STEM Interests (N = 1145)

Source	df	F	η^2	P
Between Subjects				
Intercept	1	22540.123	.953	.000
Teacher	1	.237	.000	.626
Grade	2	4.702	.008	.009
NSF Fellows	8	2.837	.020	.004
Teacher * Grade	0		.000	
Teacher * NSF Fellows	0		.000	
Grade * NSF Fellows	0		.000	
Teacher * Grade * NSF Fellows	0		.000	
Error	1109	(27.120)		
Within Subjects				
Interests	1	4.477	.004	.035
Interests * Teacher	1	.201	.000	.654
Interests * Grade	2	5.808	.010	.003
Interests * NSF Fellows	8	2.598	.018	.008
Interests * Teacher * Grade	0		.000	
Interests * Teacher * NSF Fellows	0		.000	
Interests * Grade * NSF Fellows	0		.000	
Interests * Teacher * Grade * NSF Fellows	0		.000	
Error(Interests)	1109			

Note. Values enclosed in parenthesis represent mean square errors.

Discussion

One would think that teachers would be the main factor affecting student STEM beliefs and interests, due to their daily classroom interaction with students. However, the results in this study indicated that NSF Fellows and student grade level, not teacher, affected the rate at which students' STEM beliefs and interests changed, supporting the findings of Wildman and Torres (2001). Previous research that students become more negative at higher grade levels (Weinburgh, 2003) may account for the grade level effect on student attitudes in this study and explain the overall decrease in students' STEM beliefs and interests, but the effect that NSF Fellows had on students' STEM beliefs and interests shows much promise for the GK-12 project. This effect indicates that content specialists interacting with middle school students have the potential to affect students' beliefs and interest in subject areas. It is possible that agricultural science programs promoting agricultural professionals interacting in middle school classrooms could achieve the same effects. Further research is recommended on possible effects that agricultural professionals may have on middle school students' attitudes toward math and science, or on pursuing careers in agriculture.

The results indicated that the active, consistent involvement of NSF Fellows in the classroom had a significant effect on middle school students' STEM beliefs and interests, supporting similar research on scientists' influence on high school and college students (Caton et al., 2000; Davis et al., 2003; Evans et al., 2001; Finson, 2002; Munn et al., 1999; Tanner et al., 2003; Weinburgh, 2003; Wildman & Torres, 2001). Although this research indicated that NSF Fellows affected the rate at which middle school students' STEM beliefs and interests changed, it did not indicate if that change retarded or accelerated student negativity toward STEM subjects, when accounting for the grade level effect (Weinburgh, 2003). If the interaction of NSF Fellows positively affects student attitudes, these types of collaborations have the potential to reverse the current negative trends in STEM subjects and positively affect student enrollment in those same subjects. It is possible that similar results would occur in agricultural science programs. Therefore, additional research on students' STEM beliefs and interests in agricultural science classrooms is needed.

Despite the overall decrease in students' STEM beliefs and interests, students' interest in technology increased. Students expressed increased positive attitudes on more of the individual technology belief and interest statements than in either science or mathematics. Further research might help illuminate why technology would show such marked improvement over math and science.

Further research is recommended on specific effects NSF Fellows have on student beliefs and interests in STEM subjects. The Fellows' classroom effect should be studied at elementary and high school levels, as well as the middle school level to determine the true effect of Fellows' consistent classroom involvement at the different grade levels. Research on short-term exposure to scientists in the classroom have indicated positive results for increasing positive student attitudes (Caton et al., 2000; Munn et al., 1999; Lindner et al., 2004), but more research is needed to determine the effect of consistent, long-term interactions between scientists and public school classrooms. The results of this study may be applicable only to a specific population and caution should be used in generalizing these results to a broader population.

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