Partners in Professional Development: Initial Results from a Collaboration Between Universities, Training Programs, and Professional Societies

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Abstract

This paper describes initial results from a collaborative effort to develop a flexible, open-source professional skills training program for engineers and scientists. The collaboration was initiated by Michigan State University (MSU) as part of a (successful) training grant proposal to the National Science Foundation. MSU proposed to lead efforts to develop new professional development training materials focused on communication, teamwork and leadership skills. Tau Beta Pi, the Engineering Honor Society, joined the collaboration and provided access to a national network of well-trained, volunteer facilitators who were eager for new curriculum materials. Several national organizations that offer technical training in various areas of expertise also joined the collaboration, including the National Research Mentor Network (NRMN), the Center for the Improvement of Mentored Experiences in Research (CIMER), and the Carpentries. Their contributions included experience managing large repositories of curricula and ensuring quality control while allowing materials to be updated regularly.

During the first year of this collaboration, new curriculum was developed at MSU and pilot tested by facilitators from Tau Beta Pi (TBP). Several of the collaborating training programs helped to advertise or host these pilot tests. While the project is funded for another two years, the benefits of this unique collaboration are already apparent and new partners are expressing interest in expanding this project to develop a national framework for sharing resources, facilitators and curriculum between programs.

Introduction

As "big data" emerge from nearly every domain, supercomputers and other cyberinfrastructure (CI) are becoming ubiquitous in engineering research and practice. Consequently, many scientists and engineers are now considered "CI Users" – individuals who need to use advanced computational tools but who do not have broad expertise in CI. These CI Users frequently request the support of CI Professionals, who are experts in computational tools and methods. The assistance provided by CI Professionals ranges from brief, routine interactions (e.g., providing accounts and access to CI resources and training) to in-depth, long-term collaborations (e.g., creating new computational tools or contributing to multidisciplinary research projects).

As the integration of CI in research continues, CI Professionals find themselves tackling problems and consulting on projects that are increasingly complex and collaborative. In order to respond to these various requests, CI Professionals need both the expertise to solve computational challenges and the professional skills to work effectively with individuals and teams who have diverse backgrounds, experiences, and goals. Developing these "professional skills" is the focus of the National Science Foundation (NSF) funded CyberAmbassadors project (Award #1730137), which seeks to provide training in communications, teamwork, and

leadership skills in order to advance multidisciplinary, computationally-intensive research in science and engineering.

The CyberAmbassadors project received 3 years of funding from the National Science Foundation to pursue the following objectives:

- **Objective 1: Develop Curriculum**. New training materials will be developed with a focus on professional skills (communications, teamwork, leadership) within the context of large scale, multi-disciplinary, computational research across science and engineering. The curriculum will be developed in consultation with an External Advisory Board of CI Professionals and domain experts drawn from academia, industry and national research laboratories.

- **Objective 2: Pilot, Evaluate and Revise Curriculum**. The CyberAmbassadors training will be piloted on university campuses, at appropriate CI conferences, and at other institutions and laboratories. During the pilot process, at least 75 individuals will be trained as CyberAmbassadors and the curriculum will be evaluated and refined based on these experiences.

- **Objective 3: "Train the Trainers."** The CyberAmbassadors program will collaborate with groups that provide technical CI training (XSEDE, Blue Waters, Software/Data Carpentry, etc.) and that provide facilitation skills training (Tau Beta Pi) to "train the trainers" and prepare a cohort of at least 20 facilitators to offer the CyberAmbassadors training at their home institutions and other facilities nationwide. During this training process, an additional 100-150 participants will complete the CyberAmbassadors program, resulting in 200+ CyberAmbassadors trained during this 3-year project.

The CyberAmbassadors program seeks to advance science and engineering research and practice by training CI Professionals and CI Users to support and lead diverse teams using advanced computational resources. In the short-term, training participants will be prepared to serve as CyberAmbassadors and enhance collaborative work at their home institutions. In the longer-term, the "train the trainers" component of the CyberAmbassadors project aims to make this professional skills curriculum available nationally through local or regional trainings. This paper reports on results from the first year of the CyberAmbassadors project.

Background and Related Work

The CyberAmbassadors project focuses on professional skills training rather than technical training, and specifically seeks to develop high-quality, low-cost training by leveraging the efforts of universities, training organizations and professional societies. It is presumed that trainees already have expertise in their disciplinary areas, whether they are CI Professionals (with expertise in computational tools and methods) or experts in other areas of science and engineering. This focus was deliberate, as there are many excellent technical training programs that provide ongoing support for CI Professionals and CI Users. There is also a wealth of research and training available in professional skills – but few programs that offer this training specifically for scientists and engineers, at the low- or no-cost that make such programs

accessible to researchers at universities, national laboratories, and other organizations with limited budgets for professional development. Thus the CyberAmbassadors project is designed to fill an emerging need to help CI Professionals and CI Users develop communication, teamwork and leadership skills to support increasingly complex, interdisciplinary science and engineering. The remainder of this section provide an overview of related technical and professional skills training programs to set the CyberAmbassadors project in a broader context.

A variety of training is currently available to assist CI Professionals in developing and expanding technical skills for applying CI in science and engineering research. For example, Advanced Cyberinfrastructure Research and Education Facilitator (ACI-REF) works directly with researchers to advance the computing- and data-intensive aspects of their research, helping them to make effective use of CI [1]. XSEDE [2] and HPC University [3] maintain lists of workshops and online resources covering topics like Globus online, MPI (message passing interface), and R programming. The Great Lakes Consortium for PetaScale Computing (GLCPC) [4], which is also known as Blue Waters, sponsors additional CI training programs [5]. One example is the Virtual School of Computational Science and Engineering (VSCSE), which provides distance learning courses (spanning from one session to week-long events) on topics such as Scientific Visualization Big Data, MPI, and GPGPU (general purpose graphics processing unit). In addition to these workshops, the GLCPC provides for-credit courses in collaboration with universities across the US, allowing graduate students to participate in hybrid online/in-person courses in CI, such as introduction to HPC, exascale programming and GPGPU.

In addition to this technical training, several national groups encourage resource-sharing and ongoing training for CI Professionals. One is the highly successful XSEDE Campus Champion program [6], which connects CI Professionals at institutions across the US and provides access to shared information, training and resources to help keep their technical skills up-to-date. The Data Carpentry [7] and Software Carpentry [8] communities are also valuable sources of technical training and support for CI Professionals. Data/Software Carpentry also provide a model for successfully "training the trainers" as their programs are sustained by creating a community of highly motivated volunteers who are dedicated to advancing the use of computational tools in science. These volunteers have completed the Data/Software Carpentry program and additional facilitation training, so that they are now able to offer the Data/Software Carpentry courses at little to no cost at their home institution and surrounding region.

The idea of "professional skills" (or "soft skills") training is not new: Dale Carnegie was one of the first well-known proponents of training in interpersonal communications, leadership and teamwork, and the books [9]–[11] and courses [12] that bear his name are still common training materials in many industries. More recent offerings by Stephen Covey [13], Kerry Patterson [14], and Daniel Coleman [15] have refined our understanding of the importance of communication, teamwork and leadership skills for working successfully with people who have different backgrounds, experiences and skills. Many fee-based training programs are available to companies and individuals who are interested in developing the professional skills outlined by these and other authors.
In the 1980s, Tau Beta Pi (the Engineering Honor Society) [16] established the Engineering Futures (EF) Program [17] to provide the same type of professional skills training at no cost for college students. The original EF materials were donated to Tau Beta Pi by Interact Performance

Systems, which was founded by Kerry Patterson [14], and have been modified and expanded over the last three decades. Currently, the EF program serves more than 3,000 students annually and provides half-day seminars on interpersonal communications; team building and management techniques; creative problem solving; and effective presentation skills. The EF Program won the 2007 Excellence in Engineering Education Collaboration Award from ASEE, and is offered free of charge to students across the country by a network of volunteer facilitators who are trained by Tau Beta Pi.

The CyberAmbassadors project is a response to emerging demand for CI Professionals to transition from "CI experts" to "collaborative consultants." This shift parallels what happened several years ago in the field of Statistics: as the demand for rigorous statistical analysis increased in many domains, research institutions began to hire professional Statistical Consultants [18]. These Statistical Consultants lend their expertise and train researchers in appropriate statistical methods for their domains; consulting services range from providing advice and a "double-check" for routine analyses to collaborating on new research proposals that extend knowledge both in Statistics and the collaborating domain area.

As Statistical Consulting units became a routine resource at many universities [19]–[23], it became clear that additional training was required in order for statisticians to become effective Consultants. A variety of formal training programs and textbooks [7], [8] were developed to provide statisticians with training in the professional skills that are needed to communicate effectively with researchers from diverse cultures, backgrounds and domains. In addition to these external training programs, many universities have incorporated courses in Statistical Consulting into their graduate curricula [24]–[26] in order to help their students learn to work collaboratively with researchers from many domains.

The CyberAmbassadors project builds on this successful model from Statistics: by providing professional skills training in communications, teamwork and leadership, we will help develop "CyberAmbassadors" who are better prepared to collaborate effectively to advance multidisciplinary, computationally-intensive research. The curriculum and evaluation materials developed as part of the CyberAmbassadors project will be distributed openly, and the "train the trainers" effort will prepare facilitators to make the training available nationally at little or no cost to participants. By partnering with universities, training organizations, and professional societies, the CyberAmbassadors program is well-positioned to have a national impact.

Pedagogical Framework

The CyberAmbassadors training will offer opportunities for CI Professionals to learn about and practice skills for communicating effectively, working in diverse teams, and leading and mentoring interdisciplinary researchers. All of the training materials will focus on preparing CI Professionals to use these professional skills in the context of complex, multi-disciplinary research involving advanced computation. This pedagogical approach is grounded in two complementary educational frameworks: **constructivism** and **socioculturism**. At its core, constructivism is the idea that learning is an active process where trainees create meaning from information and experiences [27], [28]. Similarly, socioculturism is founded in the idea that "learning is enculturation, the process by which learners become collaborative meaning-makers

among a group defined by common practices, language, use of tools, values, beliefs, and so on" [29]. In the context of scientific research, this enculturation includes background knowledge of the data, terminology, tools and research methods of the discipline; analytical and technical skills for developing and evaluating experiments; and meta-cognitive skills to review progress, assess challenges and plan future explorations [30], [31].

Both constructivism and socioculturism are rooted in the social constructivism theory developed by Vygotsky [32], who argued that knowledge and meaning-making activities cannot be divorced from the context in which the learning takes place. Building on the idea that knowledge is constructed in a sociocultural context, the core of the CyberAmbassadors program will be a series of individual and small-group activities, many of which will incorporate role-playing scenarios. Role-playing encourages active learning [33] and has been used successful to teach communication skills in a variety of settings, ranging from healthcare [34]–[37] and business [14], [38], [39] to science and engineering [40], [41]. The CyberAmbassadors curriculum will incorporate role-play scenarios developed from the real-life experiences of CI Professionals and CI Users from science and engineering, all in the context of multidisciplinary, computationally-complex research. These scenarios will pilot tested and refined with input from participants, along with guidance from an External Advisory Board comprised of experts from academia, national laboratories, CI training programs and resource providers (such as XSEDE and Software/Data Carpentry), and industry.

Interpersonal Communications Curriculum

The CyberAmbassador training will include a substantial component (6+ hours) focusing on understanding and practicing effective interpersonal communications in the context of multi-disciplinary, computational research. Communication skills and strategies can differ widely between individuals who vary in age, background, culture, language or discipline [42]. Thus, the CyberAmbassadors training will begin by introducing basic concepts in interpersonal communications, including: listening and responding; verbal communication; non-verbal communication; electronically mediated communication; and conflict management [14], [39], [43], [44]. In addition, the CyberAmbassadors training will address specific challenges that can arise when communicating with individuals who come from different cultures and with individuals who are experts in other disciplines [45]. Example topics and learning outcomes for the interpersonal communication skills component of the CyberAmbassadors training are outlined in Table 1. Participants will have opportunities for individual and small-group experiences, and learning outcomes will be evaluated through pre- and post-testing (this evaluation is detailed later).

Table 1: Example Communication Learning Objectives and Activities

Example Learning Objectives	Example Activities
Participants are able to identify challenges to interpersonal communications	• Discuss the similarities and differences between verbal, nonverbal, and electronically-mediated communications • Watch videos of common interpersonal communications problems
Participants are able to identify specific communications challenges common to CI	• Discuss interdisciplinary communications challenges • Role-play common communications scenarios involving CI Professionals and CI Users
Participants are able to employ effective listening and response methods in CI communications	• Review listening and responding techniques in the context of CI • Practice paraphrasing as a response to complex conversations • Role-play listening and responding roles in CI scenarios
Participants are able to identify and respond appropriately to high-emotion communications	• Discuss the challenges of communicating in high-pressure situations involving deadlines, funding, degree completion, etc. • Role-play effective response techniques for high-emotion problems

Interdisciplinary Teamwork Curriculum

The CyberAmbassador training will spend considerable time (4+ hours) focusing on skills for working effectively in interdisciplinary teams. CI Professionals are often asked to participate in or provide substantial support for research teams that include disciplinary experts from one or more domains outside of the CI Professionals' experiences. Working effectively in interdisciplinary teams requires the types of interpersonal communication skills described above, as well as an understanding of the way that working in a team can impact individual and team behavior. The CyberAmbassadors training will introduce basic concepts of teamwork, including: the life cycle of teams (forming, storming, norming, performing); key characteristics that differentiate a "team" from a "group;" tools for working effectively in teams; and roles and methods for managing productive meetings [46]–[49]. CyberAmbassadors will also explore the benefits and potential pitfalls of using electronically-mediated communications within teams [50].

A key component of the CyberAmbassadors training will address specific challenges to and approaches for working in diverse teams. For example, team members from different disciplinary backgrounds frequently bring different expectations and "best practices" for research, which need to be reconciled in order for the team to communicate and function effectively [51]. Interdisciplinary teams need to balance a focus on task with a focus on relationship-building [54], and offering appropriate training to team members can help promote a "diversity mindset" [52] that encourages understanding and appreciation of the various contributions of team members.

Table 2 offers example topics and learning outcomes for the teamwork component of the CyberAmbassadors training. Participants will have opportunities for individual and small-group experiences, and learning outcomes will be evaluated through pre- and post-testing (this evaluation is detailed later).

Table 2: Example Teamwork Learning Objectives and Activities

Example Learning Objectives	Example Activities
Participants are able to identify challenges to and solutions for interdisciplinary teamwork	• Discuss the stages of team formation and growth • Examine tools for team growth (charters, ground rules, etc.) • Engage in team-forming and team-building activities
Participants are able to employ effective meeting management strategies	• Identify when a meeting is required / alternatives to meetings • Practice preparing an effective agenda • Discuss and practice key roles for meeting management
Participants are able to employ effective listening and response methods within a team	• Review common communication issues in the context of teams • Role-play methods for keeping meetings on track • Role-play listening and responding roles in team contexts
Participants are able to describe benefits and challenges to working in diverse teams	• Discuss benefits of diverse backgrounds, skills and experiences • Discuss challenges of working in diverse teams • Role-play leading teams to develop a "diversity mindset"

Collaborative Leadership and Mentoring Curriculum

Approximately a half-day of the CyberAmbassador training will be spent helping participants enhance their leadership skills in the context of interdisciplinary teamwork. Recognizing that computationally intensive research often requires the expertise of many different individuals, the CyberAmbassadors training will focus on leadership in collaborative teams. This is an approach favored by companies like Google, which expects "that over a team's life, different skills will be needed at different times, so various people will need to step into leadership roles, contribute, and—just as important—recede back into the team once the need for their specific skills has passed" [53, p. 99]. Rotating, collaborative leadership methods have been shown to increase innovation and technological advancement [54] particularly in globally competitive contexts [55].

The CyberAmbassadors training will focus on leadership skills for working in diverse, interdisciplinary teams. Training will include information about common leadership styles [56], [57], personality types [58], and communication preferences [62], [63], as well as how to manage competing goals and resolve conflicts between team members [59]–[61]. The CyberAmbassadors program will also talk about **leading through mentoring** [62]–[64], particularly as it relates to working in diverse, interdisciplinary teams [65]–[68]. Key lessons in the leader-mentor-learner triad will be adapted from existing research [69]–[71], and role-playing and discussion exercises will explore methods to develop and mentor CI Users and CI Professionals from diverse backgrounds.

Table 3 provides examples of topics and learning outcomes for the leadership and mentoring training that will be developed as part of the CyberAmbassadors program and evaluated through pre- and post-testing (as detailed later in this proposal).

Table 3: Example Leadership Learning Objectives and Activities

Example Learning Objectives	Example Activities
Participants are able to identify collaborative leadership styles and methods	• Discuss pros and cons of different leadership approaches • Examine case studies of successful collaborative leaders • Practice leading a group in a collaborative style
Participants are able to identify how diverse personality traits can impact teamwork	• Discuss Myers-Briggs Type Indicator and identify personality traits • Examine strengths and weaknesses of the individual's style • Role-play communications strategies for different personality types
Participants are able to describe how effective mentoring can increase diversity in CI	• Discuss mentoring styles and differences in leading and mentoring • Discuss value of multiple mentors and diverse pairings • Role-play mentoring interactions
Participants are able to identify mentoring strategies to help prepare new CI Professionals	• Discuss role of mentors in training new CI Professionals • Identify key skills and experiences that mentors should encourage • Role-play mentor-mentee interactions

Pilot Testing and Curriculum Refinement

During the first year of the CyberAmbassadors project, a number of curriculum modules were developed and pilot-tested on the campus of Michigan State University, as part of the professional development programming offered by Tau Beta Pi, and as part of the annual training sponsored by ACI-REF. In addition, the project investigators participated in several conferences to share information about the CyberAmbassadors program and gather input from external partners. Survey instruments were also piloted and refined, with appropriate IRB oversight from MSU, based on participant feedback from these pilot sessions.

There were some initial setbacks, mostly due to the timing of the grant: funding did not begin until November, at which point it was difficult to find an appropriate graduate student to assist with the project and past the submission deadlines for several relevant conferences and workshops. However, by the end of the first year the communications curriculum had been piloted and the remaining curriculum (focusing on teamwork and leadership) was in various stages of development and testing. We also developed and piloted an evaluation instrument to evaluate the efficacy of the curriculum and the impact on participants. A key success from the first year was introducing 200+ CI Professionals, scientists and engineers to the CyberAmbassador project and engaging them in various pilot tests of curriculum materials.

“Train the Trainers” Process

A key component of the CyberAmbassadors proposal is the “train the trainers” effort, which seeks to prepare at least 20 volunteer facilitators to offer the CyberAmbassadors training. Volunteer facilitators have been used successfully by Software Carpentry [8], Data Carpentry [7] and Engineering Futures (EF) [17] to provide high-quality training programs to CI Professionals. Typically, volunteer facilitators are reimbursed for travel expenses but not for their time, which allows the programs to propagate at low cost.

One key to keeping training costs low is to recruit individuals who have already developed at least a moderate level of skill at facilitating interactive seminars and workshops (generally learned in their professional or other volunteer roles). By recruiting individuals who already have the interpersonal and communication skills to be effective facilitators, the training costs are limited to ensuring that they become familiar with the content of the CyberAmbassadors program. As an example, consider the “watch one, do one, teach one” training method for new facilitators that is used by the EF program (which has trained several hundred facilitators over nearly 3 decades). Interested volunteers are interviewed by phone about their prior facilitation experiences. Strong candidates are invited to participate in or observe an EF session, then to teach the session with support, then to “solo” facilitate and begin training others. Typically, individuals who have some experience in facilitating professional skills training programs are able to “solo” facilitate new content after one or two co-teaching experiences.

In January, 2018, the CyberAmbassadors project partnered with the National Research Mentor Network (NRMN) and the Center for the Improvement of Mentored Experiences in Research (CIMER) to provide facilitator training for 20 volunteers from the Engineering Futures program. While the focus of this training was on introducing content from NRMN and CIMER related to training research mentors, by partnering in this program the CyberAmbassadors team both gained valuable insights for developing “train the trainer” curricula and furthered relationships with these training organizations and professional society. Developing and deploying a standalone “train the trainers” program for the CyberAmbassadors curriculum will be a focus of the third year of this project.

Evaluation

The overarching evaluation question for the CyberAmbassadors program is: “How does professional skills training impact the ability of CI Professionals to work collaboratively on multidisciplinary research involving advanced computation?” This question will be investigated by collecting and analyzing data measuring the impact of the proposed training program. The evaluation will utilize a mixed-methods approach to analyze questionnaire, observational, and interview data in order to measure and document impacts of the CyberAmbassadors training on participating CI Professionals. **Quantitative methodologies** will include questionnaires about the CyberAmbassadors training; participants’ experiences using the professional skills after returning to their home institutions; and information on participants’ demographics and CI expertise. Quantitative data analyses will include appropriate descriptive statistics and will be analyzed using repeat-measures ANOVA, regression and/or structural equation modeling as appropriate. **Qualitative methodologies** may include participant interviews/focus groups and

artifact/document review. Instruments developed and validated by similar NSF-funded projects (i.e., Assessing Women and Men in Engineering) will be used or modified for use in this project. Qualitative data will be coded and analyzed with the assistance of NVivo. Data will be triangulated to provide a more rigorous assessment of project impact. **Summative evaluation** will assess implementation quality and impact and report progress to the National Science Foundation. **Formative evaluation** will track quantitative measurements (numbers and backgrounds of participants, etc.) and also capture attitudinal data pre- and post-training, as well as after CyberAmbassadors participants have returned to their roles as CI Professionals. For example, participants will be asked about their goals for participating in the training and what they anticipate will be the most rewarding and challenging aspects of the training program. This formative evaluation process will (1) help ensure that our CyberAmbassadors training support participants' goals, and (2) help clarify participants' expectations, allowing us to correct any misconceptions.

In order to evaluate the curriculum, we utilize Kirkpatrick's Hierarchy Levels as a framework, encompassing (1) reaction, (2) learning, (3) behavior, and (4) results. During the first year, we focused on evaluating the first two levels, reaction and learning respectively. The reaction phase was evaluated by the extent to which participants reacted favorably to the training event [72], including the content and the facilitators' ability to effectively deliver said content. On the other hand, the learning phase was measured by comparing the participants' knowledge, skills, and attitudes before and after training. Generally, we found that this framework was commonly used in evaluating educational events and is also applicable for our training program.

Initial Results and Future Work

A year into the project, we have helped increase awareness of the need for professional skills training for CI Professionals and CI Users, including scientists and engineers from all domains. We have also identified an opportunity to study the efficacy of small-group, role-playing exercises for professional skills training when delivered in-person versus remotely (via videoconference). The original project proposal focused on developing and evaluating curriculum for in-person professional skills training, which remains the primary focus of the project. However, the CyberAmbassadors team had the opportunity to experiment with the use of virtual "breakout rooms" to allow remote participants in the ACI-REF workshop to try the same interactive, small-group exercises as the in-person participants. This effort was largely successful and feedback was quite positive, so the CyberAmbassadors team has added a goal to explore the use of videoconference technologies (like zoom) to provide interactive, professional skills training. Adding some virtual trainings to the in-person schedule offers a unique opportunity to conduct a direct comparison of the efficacy of each training method, as well as the pros and cons of the two approaches. Given the increasing use of videoconferencing in the workplace, this study may also offer insights about communication strategies for making effective use of this technology. If successful, virtual trainings could increase the impact of the CyberAmbassadors project - and in particular could offer additional opportunities to "train the trainers" beyond periodic in-person sessions.

In addition to developing and piloting curriculum, we have developed collaborative relationships with a number of training and professional organizations that are interested in supporting and/or

contributing to the CyberAmbassadors project. Several of these organizations are interested in adapting or building on materials developed for the CyberAmbassadors project to expand training opportunities beyond this project's focus on CI Professionals. For example, this fall the Tau Beta Pi Association will pilot an adaptation of the communication training materials we have developed that focuses on using these skills in the context of engineering. Another example is the CIMER/NRMN community, which focuses on training research mentors and mentees in STEM (science, technology, engineering, math) disciplines. One of the CyberAmbassadors team members has been trained as a Master Facilitator for CIMER/NRMN and is working with these national training organizations to identify ongoing opportunities for collaboration.

During our interactions with CI Professionals during year one, we also identified a broad need for trained facilitators to support professional development programs covering a variety of skills. To this end, we plan to develop the "train the trainers" component of the CyberAmbassadors project in a modular fashion, with individual components focused on specific facilitation skills. If successful, this approach would allow other organizations (like CIMER/NRMN or Tau Beta Pi) to adapt part of all of the facilitator training materials to train their own volunteers. These "train the trainer" materials will be designed, evaluated, and revised using the same pedagogical approaches and general guidelines as our professional skills training curriculum.

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