Initial impact of Evaluation in Blue Waters Community Engagement Program

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Abstract
The external evaluation activities in the first three years of the Blue Waters Community Engagement program for graduate fellows and undergraduate interns are described in this study. Evaluators conducted formative and summative evaluations to acquire data from the participants at various stages during this period. Details regarding the evaluation methodology, implementation, results, information feedback process, and the overall program impact based on these evaluation findings are outlined here. Participants in both groups were selected from a variety of different scientific backgrounds and their high performance computing expertise also varied at the outset of the program. Implementation challenges stemming from these issues were identified through the evaluation, and accommodations were made in the initial phases of the program. As a result, both the graduate fellowship and undergraduate internship programs were able to successfully overcome many of the identified problems by the end of the third year. The evaluation results also show the significant impact the program was able to make on the future careers of the participants.

CCS CONCEPTS
Social and professional topics: Computational Science and Engineering Education

Keywords
Education, Program Evaluation, High Performance Computing, Blue Waters

1. Introduction
This paper describes the evaluation efforts regarding the Blue Waters Community Engagement program and relevant outcomes. The focus is on the first three years of the program, when challenges were identified and solutions implemented based on the evaluation results. Details regarding the evaluation methodology, implementation, results, information feedback process, and the overall program impact based on changes made in response to evaluation feedback are mainly outlined here.

The Blue Waters Community Engagement program is a high performance computing-based outreach program centered around the Blue Waters High Performance Computer at the University of Illinois Urbana-Champaign. Blue Waters was funded by the National Science Foundation, and managed by the National Center for Supercomputing Applications (NCSA). The system opened to the scientific community at large in March, 2013, and at the time of construction, was the fastest supercomputer on a University campus [1]. The Blue Waters Community Engagement program was created to support and educate computational science teams to make effective use of the unique and novel capabilities of Blue Waters. The community engagement program includes a graduate fellowship program, an internship program, webinars, workshops, annual symposiums, education allocation services, and community outreach efforts. The evaluation results presented here will focus only on the community engagement aspect involving Blue Waters graduate fellowship and internship programs.

The Blue Waters program is uniquely challenging, requiring a flexible and adaptive evaluation strategy to determine the effectiveness of both implementation and impact. The challenging aspects are that the program involved participants (both fellows and interns) who came from very different research backgrounds and are expected to interface with the same Blue waters supercomputing program structure from different scientific domains. Also, all participants had varying degrees of pre-knowledge regarding high performance computing. Based on these facts, a carefully planned initiation process and support was required in adjusting to the program. Additionally, this program also aims to achieve a goal of diversity and inclusion of various institutions with an emphasis on engaging women and minorities.

In this study, we implemented a flexible formative and summative evaluation strategy to capture the program implementation and effectiveness, as well as program impact and sustainability over the first 3 year period. A series of pre, mid, and post session surveys and focus groups were used

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for the formative evaluation during the program. Additionally, annual follow-up surveys and focus groups with program participants, mangers, and stakeholders were conducted for the summative evaluation and data collection. The results show that in such a program, providing detailed support plans and program expectations based on the entering knowledge level and background of the participants at the outset is important. Also, extended training and networking opportunities are critical in enhancing a positive learning experience and encourages pursuing further education and training required for a stronger next generation HPC community. We show that the evaluation feedback over the initial 3 years and subsequent changes have led to dramatic improvements in experience for most of the attendees.

2. Blue Waters and Program Outline

Blue Water is one of the most powerful supercomputers in the world and is also the fastest supercomputer on a university campus. The machine architecture balances processing speed with data storage, memory, and communication within itself and to the outside world in order to cater to a wide variety of scientific endeavors. It is supported by the National Science Foundation and the University of Illinois at Urbana-Champaign, and its projects are managed by the National Center for Supercomputing Applications. The NCSA provides expertise to help scientists and engineers take full advantage of the system for their research.

To achieve the vast potential of the Blue Waters system, well-educated and knowledgeable computational scientists and engineers are required. In an attempt to train and educate current and future generation of scientists and engineers who possess the extraordinary capabilities required at Blue Waters and other petascale computing systems, the Blue Waters established an expansive community engagement program engaging researchers, educators, HPC center staff, campus staff, and undergraduate and graduate students across all fields of study. As an effort to pursue growth and expertise in extreme scale computing for students, a graduate fellowship program and an internship program for undergraduate students were created as part of the a community engagement agenda. These initiatives were evaluated by an external evaluation team (Dr. Lizanne DeStefano, Executive director in CEISMC, Georgia Institute of Technology and Jung Sun Sung, Visiting Evaluator Specialist, University of Illinois at Urbana-Champaign). The community engagement program in total includes the graduate fellowship program, internship program, webinars, workshops, annual symposium, education allocation services and community outreach efforts. The evaluation results presented here will focus only on the community engagement aspect involving the Blue Waters graduate fellowship program and the undergraduate internship program.

2.1 Graduate fellowship Program

The Blue Waters Graduate fellowships provides PhD students with a year of full-time research support, including an annual stipend, an allocation of up to 50,000 node-hours on the powerful Blue Waters petascale computing system, and funds for traveling to the Blue Waters symposium to present research progress and results. The applicants are evaluated based on related experience and services, research plan in relation to Blue Waters, along with academic record. The fellows would work with assigned point of contacts at NCSA through regular meetings. The point of contacts are responsible for facilitating the fellows' access to Blue Waters, working with the fellow to solve computational problems, and helping fellows to connect with other sources of support. Six to ten fellows were accepted every year as Blue Waters fellows from 2014 to 2017, and a total of 26 fellows completed the program by the spring of 2018.

2.2 Undergraduate internship program

This program sponsors about 20 undergraduate research interns every year. A stipend, a two-week intensive Petascale Institute at the beginning, and an education allocation on Blue Waters are provided for each intern. Selected interns are able to travel to the Blue Waters symposium. Accepted students work with a faculty mentor either in their home campus or at another campus for one year. This program is also open to faculty who are willing to mentor undergraduate students in the internship program that involves teaching or research in the use of high performance computing. Faculty can participate in this program with assigned student(s), otherwise students and faculty mentors are matched by program managers. A total of 60 students completed the program between 2014 to spring 2017.

3. Evaluation Strategy

The external independent evaluation team conducted formative and summative evaluations to improve the programs and activities based on continuous feedback, while collecting appropriate data and information to conduct a longitudinal analysis of the impact of the programs over the life of the project. The ultimate goal of the evaluation is to validate and document the effectiveness regarding a new model of an education training program, and disseminate this model through publications and presentations. The evaluation utilized the 'Educative, Value-Engaged Approach' [2]. This approach, developed with NSF-EHR support, defines high quality STEM educational programs as that which effectively incorporates cutting edge scientific content, strong instructional pedagogy, and sensitivity to diversity and equity issues. In the Educative, Value-Engaged Approach, a key role of the evaluator is to work closely with program implementer to promote their understanding of program theory, implementation and impact.

The evaluation for Blue Waters community engagement program was specifically designed to answer four questions:

- Implementation: Is program being implemented on schedule and as planned?
- Effectiveness: Are key components of the program model operating effectively? How might they be improved?
- Impact: What outcomes (e.g. scientific knowledge, technical skills, and employment) are associated with participation in the program? How does impact vary across groups? What is the value-added from participation in the program?

- Sustainability: How and to what extent are elements of the program becoming institutionalized to ensure sustainability of program components? What opportunities and barriers exist?

3.1 Methods

In our approach, the external evaluators' functions were as educators as suggested in Lee J. Cronbach and associates Tower Reform of Program Evaluation [3]. The value of the evaluation would not be judged by accuracy of answers to the questions, but growth of understanding of others involved. As such, the evaluation results should be consumed in the progress of understanding the program and in discussions of alternative plans, not so much in determining if the current program is right or wrong. In acquiring a response to each question, the evaluation employed multiple methods.

- Implementation: Using a simple monthly reporting software and interviews with key implementers (at the University of Illinois and partner institutions), evaluators routinely monitored program implementation and reported on the progress, challenges, and slippage at each program staff meeting. When implementation problems or slippage occurred, the program staff determined strategies for overcoming barriers and keeping the program on track through communications with the Blue Waters Project Office.
- Effectiveness: All key components were routinely evaluated and continuously refined to improve the participants' experience. For example, to quantitatively assess the extent to which the program is creating training and education materials to address knowledge gaps among the HPC community, evaluators (1) conducted a formal review by stratified random sample of participants, oversampling under-served groups, (2) obtained expert endorsement of the quality of materials and services, (3) documented a reduction in training needs, and (4) assessed improved educational and research outcomes associated with training and education materials and activities, especially in under-served groups. For all new training and education materials and activities, evaluation included direct assessment of student knowledge and skills, observation of instruction, review of content, and measures of student and instructor satisfaction. All key components were routinely evaluated in this manner and evaluative information was used to continuously refine and improve program implementation.
- Impact: The external evaluation implemented a web-based survey system for carefully tracking all program participants over time. The system captured entry characteristics, program participation, subsequent use of materials and services; application of knowledge and skills gained, research, educational, and career outcomes. The value-added in program participation was evaluated by comparing key outcomes (e.g. diversity, research, publications, presentations, awards, retention, continued education, satisfaction, and within the timeline of funding time to degree and initial employment) where baseline data from each institution was identified. Impact data was reviewed by the Blue Waters User Advisory Committee to obtain an independent assessment of the quality and impact of the program.
- Sustainability: Through annual surveys, interviews with institutional leadership and key stakeholders, review of program requirements, and other means, the evaluation also examined the institutional changes that occurred as a result of the program including: changes in student knowledge and skills, increased diversity in targeted programs, institutionalization of elements of the program as routine university practices, etc. In addition to regular, informal reporting, the evaluation team produced an annual compilation of evaluation findings and work with the PIs to prepare the relevant sections of the annual report to NSF.

Table 1 and Table 2 show examples of the evaluation process for the graduate fellowship program and the internship program. Each activity was flexibly conducted depending on the year (e.g. the first year, the program managers, instructors were also invited to the interviews and surveys for initial implementation) and number of participants at each events.

Table 1. Example of overall evaluation process for graduate fellowship program

Time	Evaluation activities	Fellows	Faculty Advisors	Point of contacts
June	First Focus group at annual symposium	√		
September	Focus group at NCSA meeting		√	
February	Mid-Survey	√	√	
	Focus group			√
May	Final focus group	√		
	Post-survey		√	
After one year	Follow-up survey	√		

Table 2. Example of overall evaluation process for internship program

Time	Evaluation Activities	Interns	Faculty Advisors

May	Pre-Survey	√	√
May-June	Petascale Institute Daily Survey	√	
June	Focus group	√	
Aug-April	Monthly Report	√	
May	Final focus group at annual symposium	√	
August	Post-survey		√
After one year	Follow-up survey	√	

Informing and educating the program participants regarding the importance of their feedback, and goals of evaluation activates were found to be very effective. Participants who experienced immediate changes due to their feedback actively participated in the evaluation activities. Also, the formative evaluation results indicate the importance of maintaining flexibility in program implementation particularly in the early stages as the results show specific problems that can be changed. Evaluators also found the challenges of maintaining a longitudinal study and keeping perspective as seeking conclusive results regarding the impact of a year long program can be limiting and the response rate for the follow-up survey tends to decrease each year.

3.2 Findings

These findings are mainly focused on the challenges in the first year of the program revealing issues at the outset of program implementation.

3.2.1 Graduate fellowship program.

The first cadre of fellows were accepted in spring 2014 and the program period started in August for 1 year. These fellows were invited to the Blue Waters symposium in May, 2014 at the start of the program where they were introduced to the program model. The main context of the fellows were that each of them came from a very different science domain and their lab or faculty advisors may have had limited experience in HPC resources. Each fellow had an assigned point of contact to discuss technical difficulties and the general project progress. The initial process of starting the Blue Waters program and timelines of the research progress were the main focus of implementation at this stage.

Table 3. Findings from 2014 Blue Waters fellows at the initial phase of the program.

Fellows needs	Point of Contacts needs
• Keeping allocation on Blue Waters • One-On-One discussion with point of contacts • Basic tips and guidelines at the beginning	• Regular basis communication • Job description • Work plan from fellows
• Clear expectation for the symposium and conference	

Table 3 lists the needs from both the fellows and the point of contacts at the very early phase of the program. The main needs from fellows were connected to the context of the program. Since all fellows were from different scientific fields and generally new to the HPC domain, they required specific guidance to HPC conferences or symposia and in learning how to use the useful but enormous resources. Some of the faculty advisors had not used computational resources for their research data, and fellows definitely needed more technical support from their point of contact. Many of them desired one-on-one discussions along with regular group meetings to allow them to focus more on individual issues. Once they had experienced the power of Blue Waters, many of them wished to keep their data and work on Blue Waters to create further research outcomes beyond this program.

In the first year, the point of contacts were not very clear about how to provide specialized support for the fellows which were different from other allocation users. They expressed the need to have a clear research plan for the fellows at the beginning, and clear expectations for their roles as point of contact. The point of contacts also addressed the limits of their support, in that they lacked understanding of the scientific content in the research.

3.2.2 Internship program.

The main context of the internship program is to provide the undergraduate students with their first experience in the HPC field. As such, pursuing the goal of engaging and sustaining involvement by under-represented communities is also important. The participating students had very different levels of pre-knowledge on HPC, and some of them would have limited resource/programs to continue their education at their home campuses. There was an assumption that for the first time users to be successful, they would need (1) training, (2) practice, (3) user support, (4) extended collaborative support, (5) software tools and environment including science gateways to join the HPC community [4].

The pre-survey was conducted with students and faculty mentors a few weeks before the two-week workshop which started at the beginning of the program to find out the students' knowledge level. The daily session surveys had an important role in analyzing students learning experience from session to session during the institute. The interns were also invited to a face to face focus group at the end of the two-week institute to discuss their plans, needs, and concerns for the upcoming year-long internship. The evaluators also reached out to the faculty mentors, program managers, and instructors to find out the logistic challenges especially in the first year. The interns also responded with a monthly progress report and select interns participated in the focus group at the annual Blue Waters symposium to discuss the main impact of the program. Table 4 shows the main findings from interns each year.

Table 4. Findings from Blue Waters Interns for each year.

2014	2015	2016
• Over loaded daily schedule for two-week Institute • More resources for the session contents • More hands-on activities	• Detailed information before the start of the program • Improvement in evening lab • Insufficient program advertisement directly to the students	• Insufficient program advertisement directly to the students

In the first year, as interns had different levels of pre-knowledge in HPC, some found certain topics to be easy, while others struggled to keep up. Also, in daily session surveys and focus groups, many of the interns mentioned that the daily schedule at the institute was overloaded and covered too much content in too short a time. More handouts and hands-on activities were strongly suggested by the interns. In the second and third year, while content issues diminished, evaluators found out that faculty mentors heard about this program in a variety of ways, while only a few students were able to found out about this program on their own. As a result, it was became obvious that (1) if students could participate in this program only through their faculty mentors, this program would not be able to reach diverse institutions, and (2) the selection process is more likely to be strongly affected by the 'intern-faculty matching' process.

3.3 Program Adjustments

The findings from the preliminary evaluations were reported and the program managers and Blue Waters leadership were very flexible in adjusting the program implementations based on the feedback and discussing the future direction of the program. This part summarizes the main implementation changes based on the evaluation activities.

3.3.1 Fellowship program Adjustments.

These were the adjustments for the fellowship program

- Visiting NCSA: to overcome the challenges regarding lack of clear expectations, and starting/setting up close communication relationships, the fellows were invited to the NCSA in early fall to have a meeting with their assigned point of contact(s). The fellows are also were introduced to other resources and faculty at the University of Illinois campus.
- Connecting with other resources: to support more fellows' regional issues and context, either program managers or point of contacts started helping the fellows to connect with other possible technical staff at NCSA or other HPC student programs at their home campuses.
- Extended allocation: Blue Waters allowed fellows to extend the allocation period after the end of the program to continue conducting research.
- More face to face opportunities: More face to face meetings and activities were added to the beginning of the program to provide networking opportunities at the symposium.

3.3.2 Internship program Adjustments.

These are the adjustments for the internship program

- Fewer topics at the two-week institute: Based on the interns' feedback, the instructors narrowed the content topics for the two-week institute and researched the most/least desired topics every year through the post-survey.
- More hands-on activities: More hands-on activities were added into the less intensive schedule at the institute so that students had enough time to learn and attend the open-topic evening lab for catching up.
- More communication and workshops during the year: Interns expressed a desire to be connected after the institute and program. The webinars and workshops were provided to the interns during the year to share their experience and build a community.
- Inviting guest speakers from career development and HPC fields: The specialist, NCSA directors, HPC program directors, graduate program advisors were invited to the petascale institute sessions.

3.4 Impact of program

3.4.1 Impact of the fellowship program.

The impact of the program was mainly assessed from the focus groups, interviews, and post-surveys with fellows, point of contacts, and faculty mentors right before the completion of the program. We also utilized annual surveys with fellows a year or two after the end of the program.

Overall, the fellowship program enhanced the fellows' research progress by utilizing the unique power of Blue Waters. Fellows expressed that using Blue Waters allowed them to ask different types of questions with totally different physical scales in their research and bring about unforeseen results. After one year of the program, fellows pointed out that Blue Waters added a whole new dimension to their research and that it allowed them to make the best use of their resources. They emphasized not only the additional computational power and speed as a result of using Blue Waters, but also that the fellowship was a valuable learning experience. Fellows' comments regarding the program includes

– "For me, this fellowship is enabling a project that I just wouldn't be able to tackle without it. So getting started and beginning to move forward on Blue Waters itself, it's definitely letting me tackle science questions that I couldn't if I didn't have this fellowship…. Different types of questions and different scales of questions, so being able to resolve ends in my model with the biogeochemistry is not something that would be fiscal on the scale of my whole domain with the types of systems that I've been using up to this point."

Fellows also believed that the most prominent strengths of this program would be embracing all different fields of science and allowing the fellows to work on their research independently. They explained that one of the most powerful aspects of this program was learning the possibilities of multidisciplinary research (by using Blue Waters). They also expressed that the financial support helped them to conduct research independently for their degrees.

Hands-on experience on the powerful Blue Waters was emphasized as a benefit of this program by both faculty advisors and fellows. Attending the Blue Waters symposium provided the fellows with networking opportunities and helped them broaden their perspectives on HPC. The Fellows said that they had opportunities for interacting with other professionals, scientists, and also with other fellows through this program. Attending the Blue Waters Symposium is a good example of this. The networking opportunities helped them to broaden their field of research and expand their career choices as well.

The Fellows expressed their appreciation for the support from the point of contacts. The personalized technical assistance from point of contacts was greatly appreciated by the fellows. The fellows pointed out the importance of the communication with point of contacts, and how this help actually impacted their research progress. The meeting at NCSA enhanced the understanding of the research goal and detailed plan for both fellows and point of contacts.

On the post survey, faculty advisors reported that this program provided fellows with excellent computational resources along with personalized technical assistance, and a great opportunity for networking. They said their fellows were able to accomplish their research goals because of this program. At the follow-up survey, the fellows emphasized how this fellowship enhanced their skills in conducting research independently, and helped them to build a strong network with other scientists for their current and future careers. The comments from the previous fellows include

- "The BW fellowship was very important to my current and future professional endeavors. The fellowship allowed me the freedom and opportunity to propose and tackle my own research projects. Establishing this confidence and experience helped me obtain my faculty position without a postdoc. Moreover, the connections with NCSA staff and other BW fellows have been useful and will continue to be useful going forward. In particular the opportunity to collaborate with NCSA and other fellows our careers advance. Currently another BW fellow and myself are brainstorming and joint cross discipline NSF proposal coupling our work. We plan to write and submit once they complete their PhD and are either a postdoc or a junior faculty."

3.4.2 Impact of the internship program.

The impact of this program was gauged mainly from the pre, exit-surveys, focus groups, and annual follow-up surveys.

Overall, the internship program provided undergraduate interns with hands-on research experience which allowed them to have a strong HPC background and practical skills. Every year, more and more of the interns were planning to participate in the HPC-related programs/classes after this internship. In addition, a majority of the interns said that this internship program motivated them to pursue further research/career in this field.

The faculty mentors believed that this internship program was worthwhile in terms of providing interns with a very positive research experience and themselves with a professionally rewarding opportunity. The two-week institute at the beginning helped the interns in developing their technical skills and learning the overall concept of parallel computing through high-quality communication with the instructors. Table 5 shows that each item on the survey was highly rated by interns at the end of the two-week institute.

Table 5. 2016 Blue Waters internship program: Two-week Petascale Institute Exit- Survey.

Statements	Mean	N	SD
a. My goals for attending the 2-week training institute were achieved.	4.93	15	0.25
b. I am interested in attending similar programs as a result of this experience.	4.93	15	0.25
c. I am satisfied with the interaction and communication with other participants during the institute.	4. 87	15	0.34
d. I am satisfied with the interaction with instructors during this institute.	4.93	15	0.25
e. This institute helped me to develop my technical skills.	4. 73	15	0.44
f. I have the resources that I need in order to accomplish my goals during this program.	4. 73	15	0.44
g. I have a better understanding of the topics discussed as a result of this experience.	4. 87	15	0.34
h. I have a better understanding of Blue Waters as a result of this experience.	5.00	15	0

i. I have a better understanding of supercomputing as a result of this experience.	5.00	15	0
j. I have a better understanding of my future career as a result of this experience.	4. 00	15	0.82
k. The project presentation helped me understand my project better.	4.00	15	0.63
l. I know the next steps for me to proceed with my assigned project.	4. 47	15	0.50
m. I know the next steps for me to build on what I learned during this institute.	4. 53	15	0.50
n. Overall, I would rate this experience as successful.	5.00	15	0

(*5Rating scale: Strongly Disagree=1, Disagree=2, Neutral=3, Agree=4, Strongly Agree=5)

This program also includes a diverse group every year in an effort to reach out to underrepresented ethnic and gender group in STEM education. Figure 1 and Figure 2 show the underrepresented ethnic and gender group fractions of each year's participants.

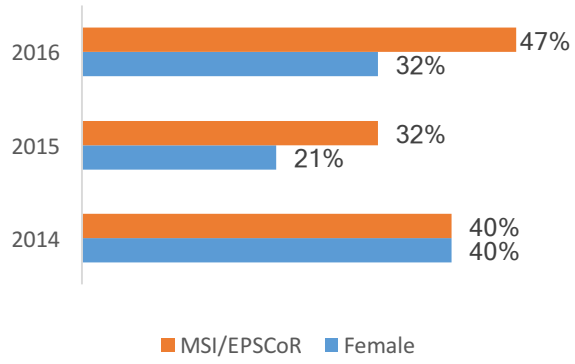

Figure 1. The ratio of female participants and MSI/EPSCoR Institution each year

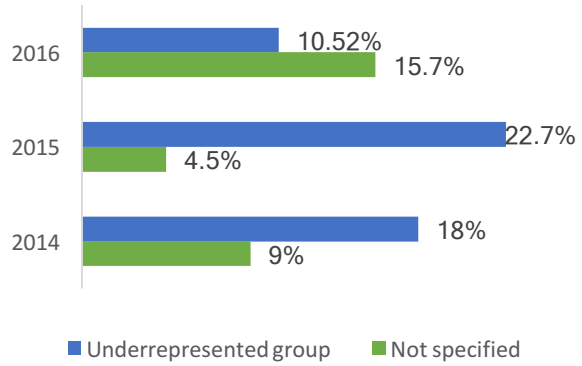

Figure 2. The ratio of participants from underrepresented group each year

(*Underrepresented ethnic group includes here African-American, American-Indian, Alaskan, and Hispanic)

3.5 Lesson learned

The evaluation process with Blue Waters community engagement program in the initial 3 years confirms some of the important program features which not only enhanced the fundamental goals of the program, but also led to critical adjustments at the early stage of the new program model. The evaluators tried to focus on analyzing data quickly to provide instant suggestions and feedback which directly affected the program directions.

- Complementary activities: In order to maximize the HPC education and training program, the importance of combining efforts with other complementary activates were emphasized by the results of the evaluation. Fellows expressed that attending the conferences, NCSA meeting, and symposium helped them to expand their networking, to expand their career spectrum, and how to cooperate with other scientists. For interns, adding professional development activities to the technical workshop allowed the interns to be encouraged to learn about the new career choices in HPC fields and advanced education potentials.
- Direct dissemination to students: to reach out to more diverse institutions, and underrepresented populations, it is important to have more direct information routes for the students who are in smaller colleges with limited HPC resources.
- User support: Providing close connection with point of contact for fellows were recognized as a huge success model for learning how to use the power of Blue Waters by providing a physical individualized support in addition to virtual resources.

4. Conclusion

The evaluation plans, activities, findings significantly affected the fellowship and internship program implementation, and program impact. The evaluation findings enhanced achieving the mission of educating a new and young generation for utilizing the powerful Blue Waters and other petascale computing systems in the future. Careful assessment of the program implementation and flexible adjustments can contribute to a successful outcomes in future HPC education and training programs.

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