

# BLUE WATERS

SUSTAINED PETASCALE COMPUTING

Evaluating the Effectiveness and Impact of Advanced Cyber Infrastructure: Lessons Learned from Blue Waters

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GREAT LAKES CONSORTIUM  
FOR PETASCALE COMPUTATION

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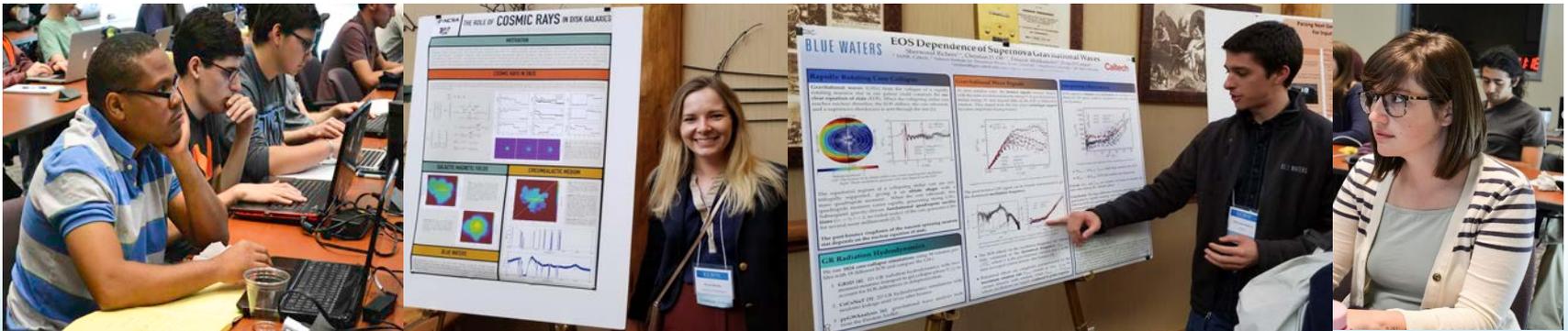
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## External Evaluation

- Conduct **formative and summative** evaluations of all Community Engagement activities (2013-present) and User Satisfaction/PI Impact (2016-present)
  - Programs are improved based on this feedback
  - Longer term outcomes/impact assessed
- Evaluation framework addresses five aspects:
  - Implementation
  - Effectiveness
  - Impact
    - Creating a database for **longitudinal** individual/institutional impact studies
  - Sustainability
  - Diversity/Inclusion

# Assessment Targets

- **Fellowship Program:** Focus groups (Fellow/POC), Surveys, Interviews, Advisor interviews, Follow-up Surveys (2014-present)
- **Internship Program/Petascale Institute:** Focus groups, Observations, Daily Surveys, Monthly Reports, Follow-up Surveys (2014-present)
- **Symposium:** Post Event Survey, Observations, Interviews (2014-present)
- **Users' Satisfaction and Impact:** Surveys (2017, 2018)
- **PI Satisfaction and Impact:** Interviews (2016, 2018)



## 2017 Graduate Fellows Program Findings (N=26)

- The Fellows Program enhanced the Fellows' **research productivity** by utilizing the unique power of Blue Waters.
- The Fellows pointed out that the strengths of this program were **diversity of the science** and **research independence**.
- Faculty advisors believed that the programs provided Fellows with very **valuable computational resources**, along with **personalized technical assistance**.
- The Fellowship Program also provided Fellows with **technical skills** and **broadened their career spectrum**.
- The follow-up survey with the previous cohorts (2014, 2015, 2016) of Fellows showed that the program's impacts were **unique learning opportunities, broader network, and wider career spectrum**.

## Enhanced research productivity by utilizing the unique power of Blue Waters

- *“...the project that I tackled for the Blue Waters Fellowship was really something that I hadn’t proposed in my original PhD program, because it was something I couldn’t accomplish with the scope of resources that I had. So that was absolutely a positive, I just would not have been able to do this work without the Blue Waters’ Fellowship.” – Fellow*
- *“...we’re able to go in a very different direction now because it’s almost unprecedented to run the kind of biogeochemical model that we want to run at this resolution. That’s going to turn out to provide the dataset that other researchers will use.” – Fellow*
- *“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 . . . is not something that would be feasible . . . with the types of systems that I’ve been using up to this point.” – Fellow*



Blue Waters Symposium

## Provided technical skills with personalized technical assistance

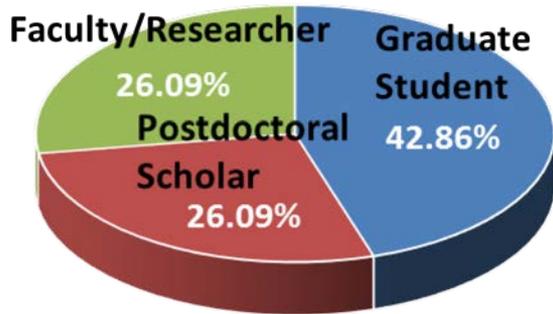
- “For a scientist, it’s actually quite **rare to have this level of computational knowledge..**” – *Faculty Advisor*
- “I think it’s very **marketable**. It’s a rare skill, and it’s very **valuable**.” – *Faculty Advisor*
- “ I think the Blue Waters fellowship is an excellent program. The graduate student I mentor who had the fellowship benefited from both the **access to the resource, but also by networking with students in other fields**. In particular, having help directly from someone at Blue Waters was very important...” – *Faculty Advisor*
- “It was a great opportunity for my student, and the **computational resources and help provided were excellent**. It made a positive difference in the research accomplished.” – *Faculty Advisor*
- “The computational resources provided were excellent and allowed the fellow I advised to **accomplish much more than would have been possible otherwise**, and also at a much faster pace.” – *Faculty Advisor*



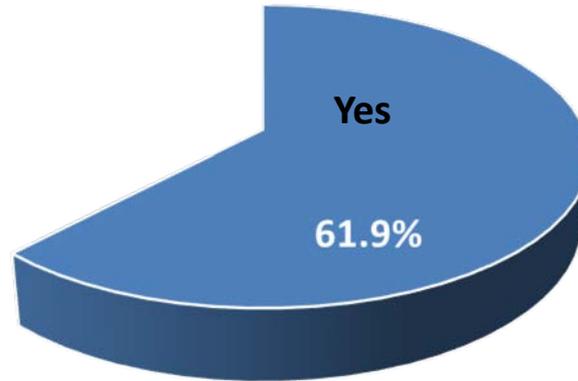
Super Computing 2015

## Broader Impact achieved by previous fellows (N=23)

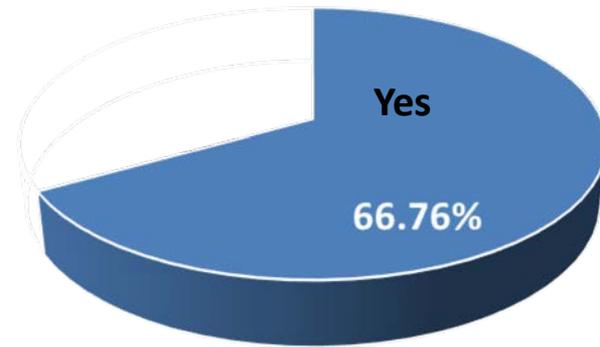
Status



Using Blue Waters



Using HPC



*“The BW Fellowship was very important to my current and future professional endeavors. The fellowship allowed me the freedom and opportunity to propose and conduct 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 help our careers advance**. **Currently another BW fellow and myself are brainstorming a 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.” – Previous Fellow*

## Fellows Program Lessons Learned

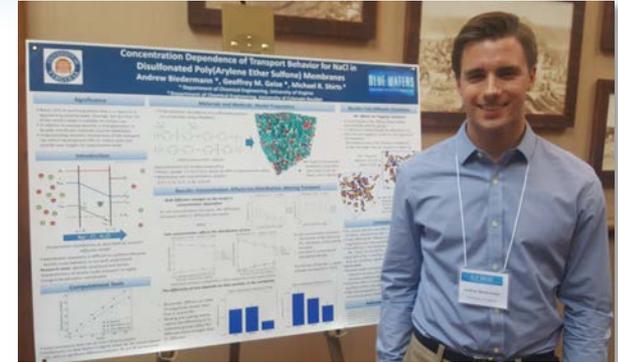
- BW Fellows Program transforms not only the speed and size of computing, but changes **the nature of questions asked** and the increases the **interdisciplinarity** of the research; impacts **PI lab**
- Connecting Fellows to **resources** beyond Blue Waters (e.g. XSEDE, ACI-REF, Campus Champions, etc.) enhances their capacity post-fellowship
- Face to face contacts (NCSA visit, symposium) and monthly meetings build **connections** within and across cohorts; increase **interdisciplinarity**
- **POCs** are critical partners; Fellows seek continued support
- Aggressive **recruiting and personal contact** needed to recruit higher proportions of women and **underrepresented students**

## 2017 Internship Program Findings (N=60)

- The Internship Program provided undergraduate interns with **hands-on research experience** which allowed them to develop stronger HPC background and practical skills
- Most of the interns are planning to participate in **more HPC-related programs/classes** after this experience
- **The Petascale Institute** was very effective at providing overall concepts and knowledge for interns.
- The follow-up survey with previous cohorts (2014-2016) of interns showed that the program encouraged students to **pursue CS majors/minors, increased their interest computational research, and expanded their career choices.**

## Provided hands-on research experiences and stronger HPC background

▪ *“Very meaningful! The connections I've gained during the program were integral in helping me approach my research. Blue Waters has **provided me with a strong background in HPC.**” – Intern*



Blue Waters Symposium

▪ *“It was a very enlightening experience. This experience **introduced me to an area of research that I had very little knowledge about.** I was able to apply what I learned from the workshop to my passion for Aerospace Engineering, and I learned a great deal about both HPC and trajectory modeling.” – Intern*

▪ *“**This is the most meaningful project I had the opportunity to carry out in my undergraduate program, considering my background from a small liberal arts college.** I gained a lot of experiences working with large-scale distributed systems.” – Intern*

# 2017 Petascale Institute was very effective at increasing technical skills and content knowledge for interns.

5 Rating Scale (1=Strongly Disagree--5=Strongly Agree)

Statements	Mean	N	Std
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 Blue Waters as a result of this experience.	5.00	15	0
h. I have a better understanding of supercomputing as a result of this experience.	5.00	15	0
i. Overall, I would rate this experience as successful.	5.00	15	0

# Internship Program has involved under-represented communities

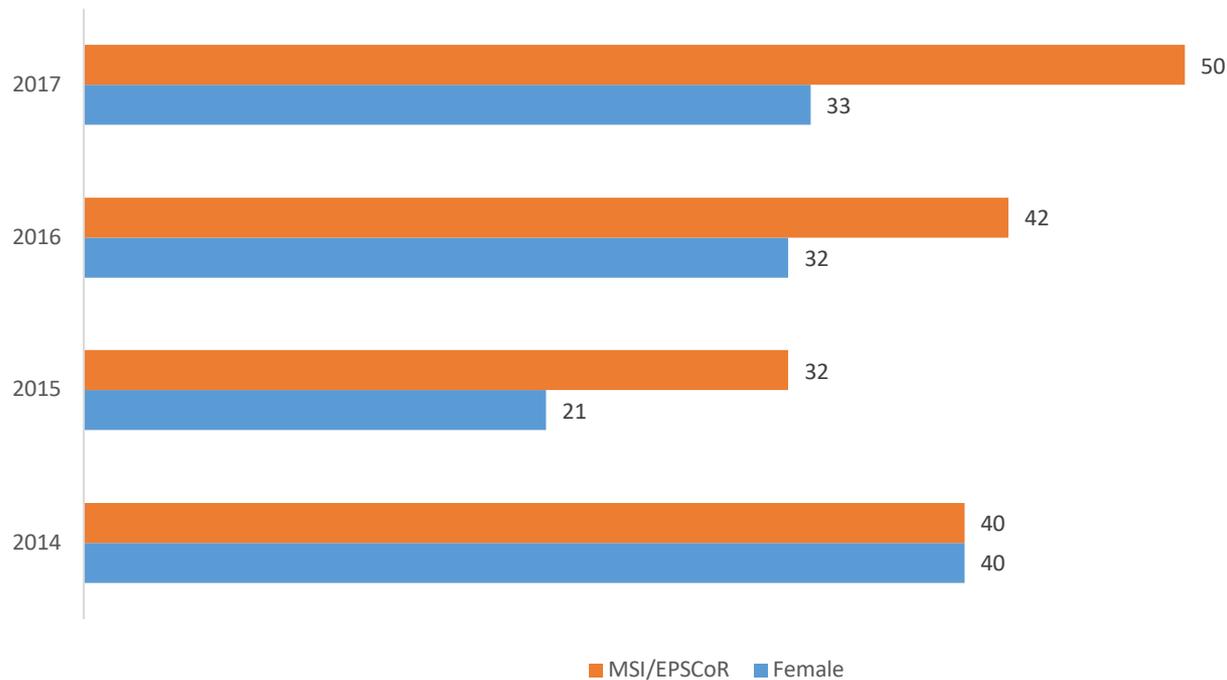
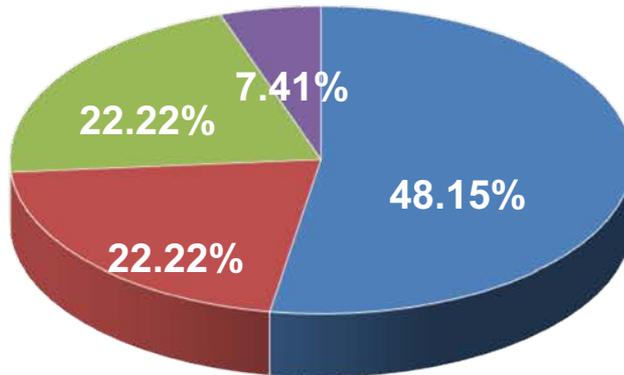


Figure 1: The ratio of female participants and those from MSI/EPSCoR Institutions each year

## Broader impact of Internship Program (N=27)



**Respondents' Classification**

- Working Professional (e.g. Software Engineer, Researcher, Software Consultant)
- Master's Student (e.g. Computer Science and Applied Physical Science)
- Doctoral Student (e.g. CS, Theoretical/Computational Chemistry, Condensed Matter Physics)
- Junior/Senior

## Internship Lessons Learned

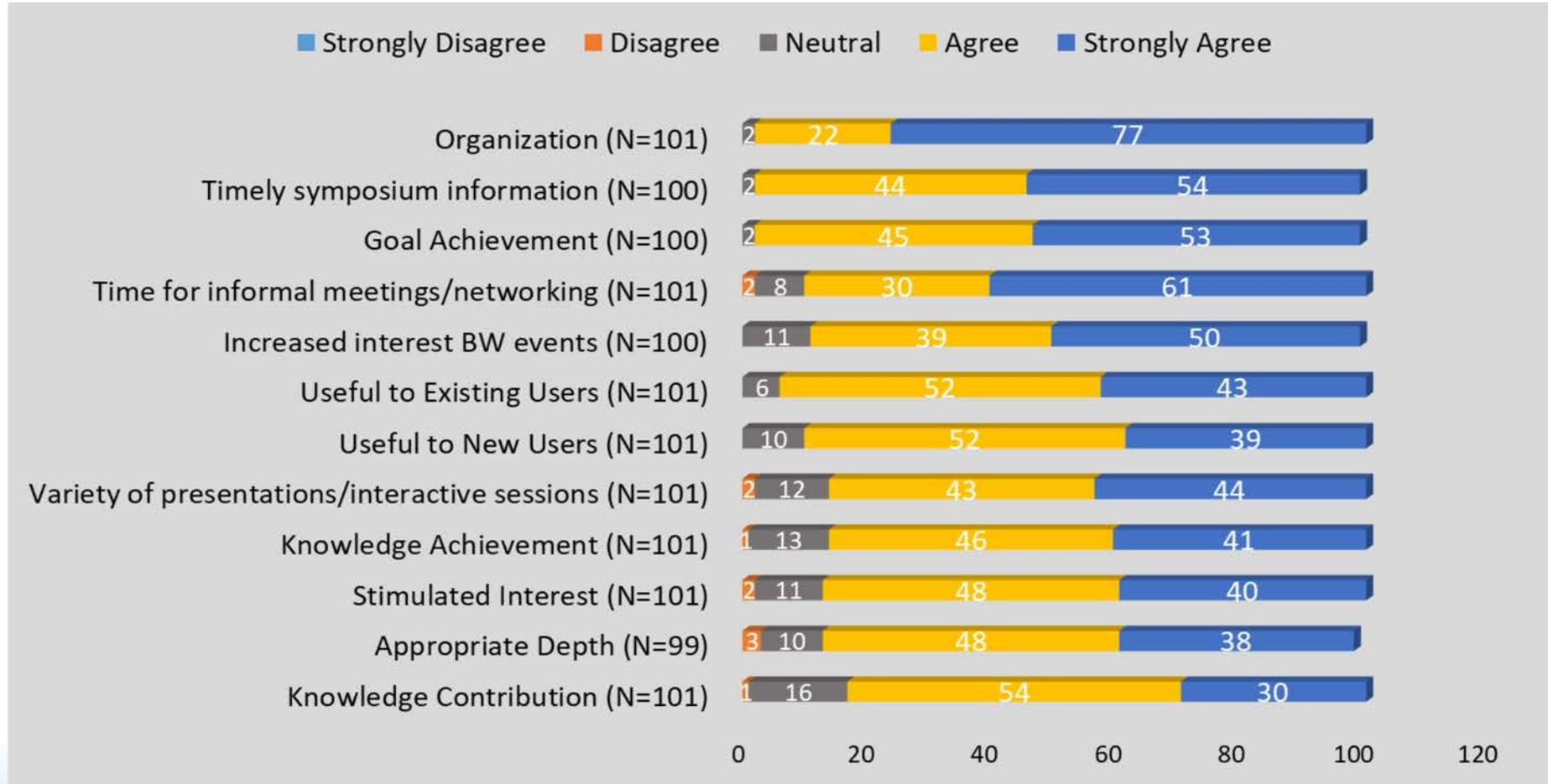
- Evidence of motivation of participants to **pursue further studies and careers in CS and related fields**
- Two-week **Petascale Institute** is extremely valuable preparing students for year-long research experience
- **Sustained learning opportunities** throughout academic year help students apply and strengthen HPC skills
- Local and central **mentoring** critical
- Internship had most impact on **non-CS majors or students at PUIs**
- Need more **direct program recruitment** to increase diversity of participants

# 2017 Blue Waters Symposium Findings (N=106)

5 Rating Scale (1=Strongly Disagree--5=Strongly Agree)

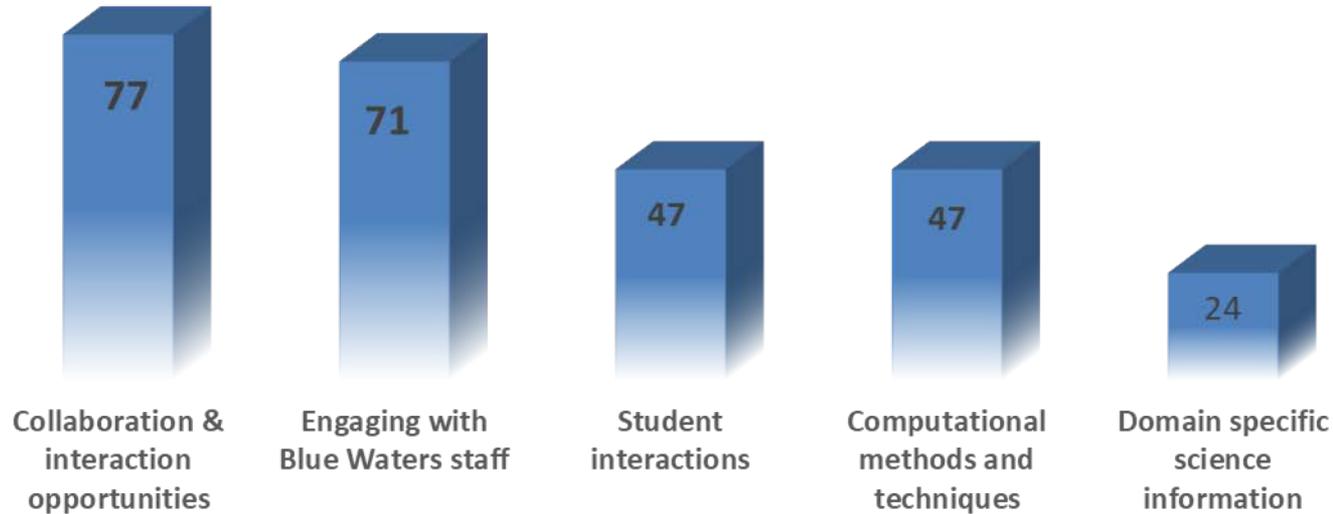
- Participants expressed **high satisfaction** on overall experience (mean=4.74, SD=0.48) and **achieved goals** for attending the Symposium. (mean=4.51, SD=0.54)
- **Diversity of topics** (30%) and **opportunities for interaction** (26%) were the strengths of the symposium.
- “**Collaboration and Integration Opportunities**” (selected 77 times), and “**Engaging with the Blue Waters Staff**” (selected 71 times) were the most important resources offered by last year’s symposium.

# Overall Satisfaction with Symposium (N=106)



# Value of Symposium Resources

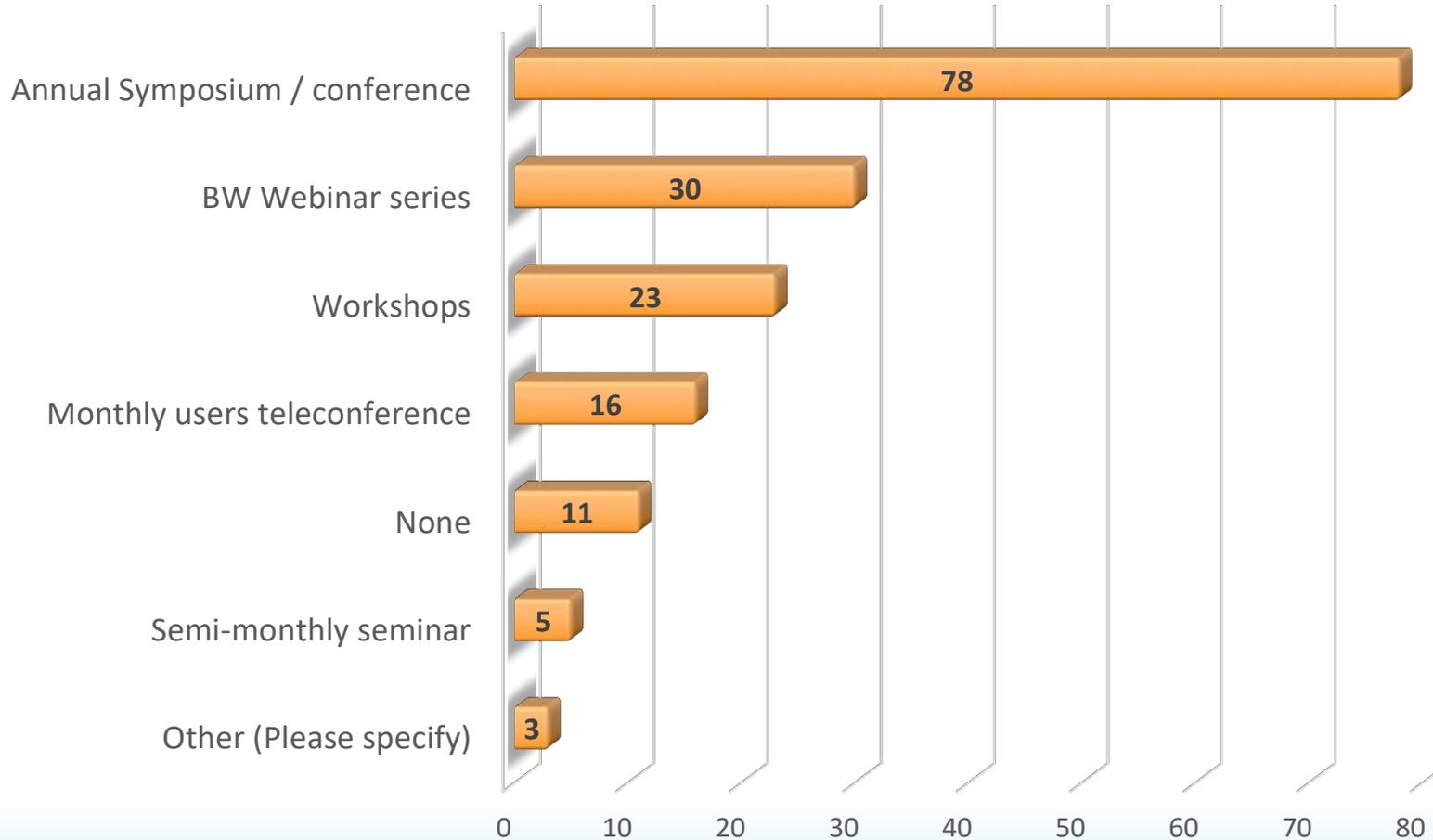
## Frequency of the most valued resources



N=266

# Most Useful Events from the past year

## Frequency



N=166

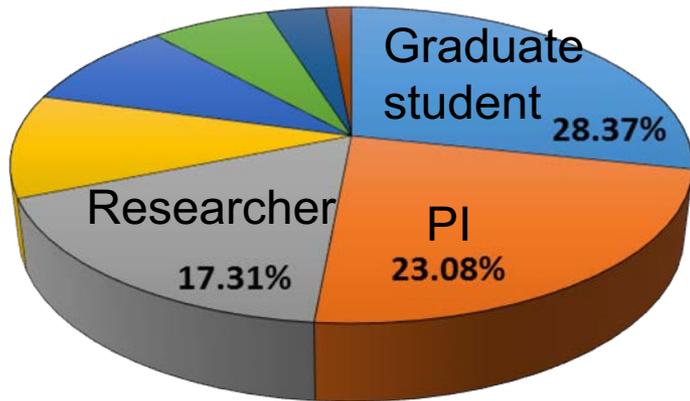
## Symposium Lessons Learned

- Value of **interdisciplinary** content increased GREATLY since 2014. (2014 Mean: 3.34; SD: 1.07; 2017 Mean: 4.74; SD:0.48)
  - Diverse topics now seen as strength rather than weakness.
- Annual Symposium given credit for creating a **community** of Blue Waters users.
  - Facilitates collaborations, recruitment, grant funding, networks
- Great appreciation for meeting with **BW staff**; seen as a unique experience

# 2018 User Survey Respondents

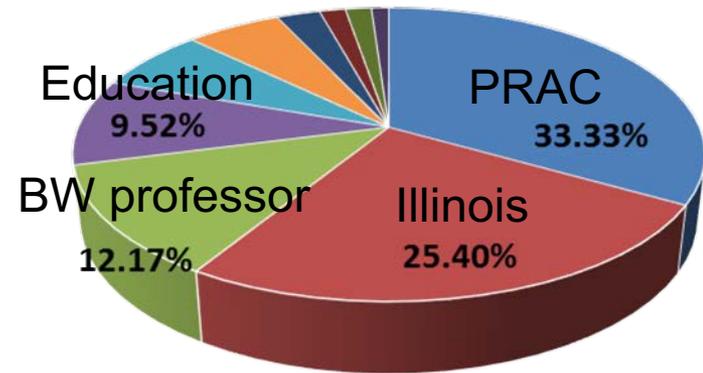
- Survey Response Rate **25.3%** (175/690)

Respondent Status  
(N=168)



- University faculty or equivalent 10.58%
- Postdoctoral scholar 9.13%
- Co-PI 6.73%
- Undergraduate student 3.37%
- Other 1.44%

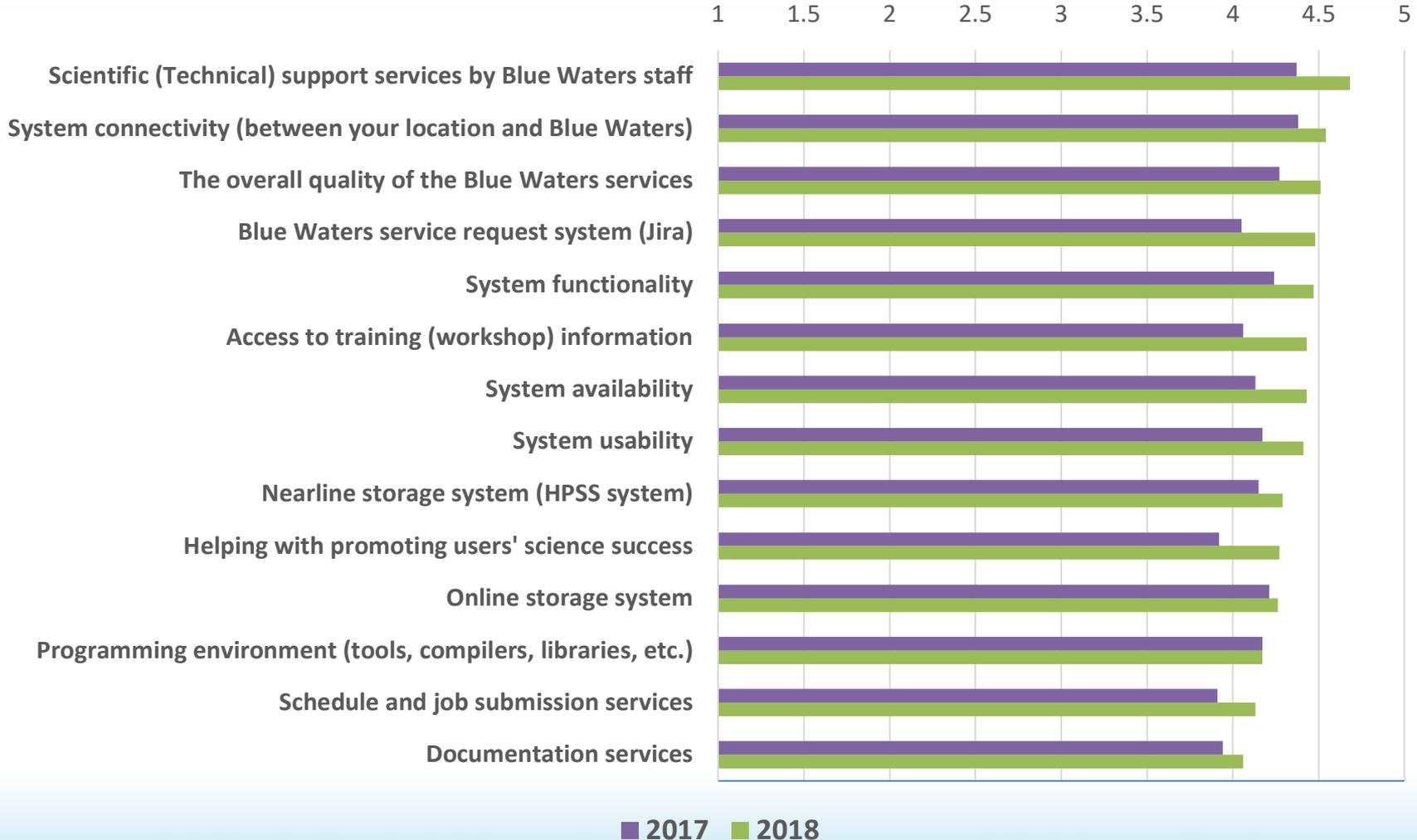
Respondent Allocation type (N=159)



- Graduate fellows 6.88%
- GLCPC 5.82%
- Other 2.65%
- Innovation 1.59%
- Broadening Engagement 1.59%
- Industry 1.06%

# Users satisfaction with Blue Waters (2017-2018)

5 Rating Scale (1=Very dissatisfied--5=Very Satisfied)



# Blue Waters Impact

- 99.3% respondents said Blue Waters is essential or very important to their research (N=151)

**Essential**  
**68.21%**

**Very Important**  
**27.15%**

- *“We were able to run ensembles of high resolution climate simulations on BW that would not have been possible without this machine access.”*
- *“BW has provided a unique platform for the computational needs of my research program”*
- *“We managed to simulate a type of storm that hasn't been simulated before, not with the fidelity we've managed on Blue Waters. Further, the Blue Waters software environment enabled high quality volume rendered images/movies of the simulation data that are highlighting new flow features.”*
- *“For the first time we have been able to provide a large-scale atomistic picture of compositional changes induced by ion irradiation in III-V semiconductors which can lead to morphological structuring such as quantum dot formation.”*

## Blue Waters Impact

*“My project has been the seed for **several completely novel research directions**. What may be unconventional in the impact Blue Waters has had was providing **direct contact with like-minded, computing-oriented experts in otherwise disparate fields that has spawned new ideas and research directions**. This would not have been possible without the **supportive, diverse community of researchers and staff that comprise the Blue Waters project**.”*

## 2016 Principal Investigator Interview Findings

- On-going interviews with Blue Waters PIs (N=37) to assess satisfaction with Blue Waters, impact on research and education, and suggestions for improvement.
- Respondents uniformly expressed **high satisfaction with Blue Waters services and cited significant positive impact on productivity and research quality.**
- Respondents described Blue Waters as “*a revolutionary concept in “user-focused” design and support*”.

## 2016 Principal Investigator Interview Findings

- PIs attribute Blue Waters utility and productivity to NCSA's **intensive work with multiple user groups in the early stages of development and continued attention to user needs and feedback.**
  - *“In my two decade academic career, I have never experienced such attention to the user community. There seems to be a pervasive willingness (coming from the top) to work with the users to create a truly leadership-class, research-oriented supercomputing infrastructure.”*
  - *“In the early days, there was some concern about how long things were taking and whether Blue Waters would really fill a unique void in supercomputing infrastructure. Now I would say there is no doubt that Blue Waters has achieved the original vision and perhaps surpassed it.”*

## 2016 Principal Investigator Interview Findings

- Across all disciplines, PIs reported that access to Blue Waters had “**greatly accelerated**” their science. In no case was Blue Waters engagement cited as negative.
- 85% of PIs believe that Blue Waters is **NECESSARY** to their research.
  - *“Blue Waters is literally the only place where our group can run the type of large scale simulations necessary to advance discovery in our area.”*
- 100% of those interviewed reported that Blue Waters **improved efficiency and enhanced their research capacity.**
  - *“We can finally routinely use data sets large enough to accurately simulate phenomena with fidelity. This has been transformational for our field.”*

# 2016 Principal Investigator Interview Findings

- PIs reported that Blue Waters allowed them to:
  - increase precision,
  - conduct more advanced multi-scale, multi-dimensional simulations,
  - perform critical calculations in real time,
  - focus and greatly reduce the need for empirical testing,
  - reduce research time, and
  - control research costs.
- *“I would say that Blue Waters has **changed the way we approach scientific problems** in my group. My current students propose bigger, bolder, more complex projects than the last generation before Blue Waters. It has definitely changed our view of what is reasonable.”*

## 2016 Principal Investigator Interview Findings

- PIs appreciate the **Blue Waters Fellows program, educational allocations, and other educational aspects** of Blue Waters and encourage their expansion.
  - *“Graduate students and post docs who have experienced Blue Waters are going to want continued access to that level of computing. We have to develop a way to scale the community and its resources.”*
  - *“The Fellows program is one of the best opportunities for students interested in integrating HPC into their research. It is quite unique, I believe. We could use many more of these--perhaps by discipline.”*

## 2016 Investigator Interview Findings

- Pls assessment of the value and impact of the **Annual Symposium** has increased over time.
  - *“At first I was not sure we needed another meeting—especially for a service provider—but now I see it is a mechanism for advancing supercomputing and for building a professional community. A different approach---but very valuable.”*
  - *“The Symposium is a great chance to interface with Blue Waters leadership and staff. It gives a very personal feel to the project. I have also been able to look at advanced simulations in other disciplines and learn from them. That is a unique function, I believe.”*

## PI Interviews Lessons Learned

- Blue Waters efforts to obtain **stakeholder input**, maintain highly trained staff and establish **personal connections** is appreciated.
- Blue Waters has changed the way computational research is done in significant ways.
- Annual Symposium and emphasis on **interdisciplinary** computation is now highly valued by community
- Desire to **expand and sustain education and community engagement** opportunities

## Blue Waters Evaluation Lessons Learned

- Formative evaluation facilitates **continuous improvement** and refinement of programs to very high level over time
- Longitudinal tracking allows for assessment of longer term (and possibly more meaningful) **impact**
- Qualitative/Quantitative, Multi-Method provides **rich picture** to guide action
- External Evaluation permits objectivity and “**critical friend**” coaching; must engage leadership
- Human data **complements** other commonly used HPC metrics.

# Questions