Science Gateways Incubator: Software Sustainability Meets Community Needs

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Abstract—The main goal of the US Science Gateways Community Institute (SGCI) is to serve science gateways to achieve sustainability and growth. Science gateways allow science and engineering communities to access shared data, software, computing services, instruments, educational materials, and other resources specific to their disciplines. Thus, science gateways are a subgroup of scientific software and the means for addressing software sustainability are also suitable for science gateways and vice versa, e.g., best practices for software engineering. Since science gateways are tailored to specific communities, understanding users' requirements is critical for sustainability.

SGCI consists of five service areas that closely interact with each other. The Incubator acknowledges the value of business strategy to inform well-designed science gateways and offers two main types of services: individualized consultancy, tailored to specific challenges a gateway faces, and the Science Gateways Bootcamp. The cornerstone of the Bootcamp is a one-week onsite intensive workshop where participants create their own roadmap for a sustainable science gateway via sessions with experts, hands-on exercises, and group work.

This paper offers an overview of the work of the Incubator and shares lessons learned from the inaugural session of the Bootcamp in April 2017.

keywords—*science gateways community institute, sustainability, incubator, science gateways bootcamp, community*

I. INTRODUCTION

Addessing sustainability of scientific software includes many diverse topics [1]: from development and community building to increasing incentives for better software to making the existing credit and citation ecosystem work better for software. Some topics can be tackled in the short term by software creators themselves such as following best practices for sustainable software. Other topics such as improving the credit and citation ecosystem for software are long-term goals, which require a large supportive community, the awareness of the importance of software for science and reassessing traditional reward systems in science. The US Science Gateways Community Institute (SGCI) [2] approaches short-term and long-term topics for sustainability of science gateways, which are a subordinate group of scientific software tailored to the specific needs of diverse communities. To reach the goal to support science gateways to attain sustainability, SGCI consists of five areas: the Incubator, Extended Developer Support, the Scientific Software Collaborative, Community Engagement and Exchange as well as the Workforce Development.

While all five areas address topics that influence sustainability in diverse ways, the Incubator offers support in business strategy, strategic planning and other forms of customized support. Creators of science gateways can receive support for thinking through how to make their gateways sustainable past the initial funding and guidance about key components such as a value proposition, audience, market landscape, competitive environment, and goals. This support is offered in two ways. An intensive week-long residential workshop coaches teams from ten different gateways in business strategy basics; for those teams requiring urgent intervention on specific questions, personalized consulting engagements may be possible.

The creation of science gateways is a complex process. Since the goal is to serve communities with various backgrounds and creating solutions hiding the complexity of computing and data infrastructures, they require diverse expertise for a good design. The science supported in a gateway is often already complex in its own right and the software created for a scientific problem as well. The goal of a

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science gateway is to offer platforms for such software applications and add value for researchers, for example, via easy-to-use interfaces, pre-configured reasonable parameterization, visualization of results, and enhanced monitoring for submitted jobs independent of the underlying computing infrastructure. Thus, science gateways need experts such as usability specialists, security specialists or quality assurance specialists. The challenges for science gateways are manifold. The concept of SGCI and its service areas is based on a large survey with about 5000 responses [3] conducted in 2014 to investigate the needs in the science gateway community. The survey elucidated that projects would benefit greatly from having access to different experts. The SGCI Incubator steps into this gap for projects - which have a lack of a needed expertise - and consult projects customized to their requirements.

The paper is organized as follows. We first present some background on related work on software sustainabiliy and existing training programs in the field. In the subsequent section we discuss the goals of the SGCI Incubator. Section IV offers an overview of the concept behind the science gateways bootcamps. Section V then presents lessons learned and results from the inaugural session of the bootcamp held in April 2017 and the paper closes with an outlook on further work.

II. BACKGROUND

Software sustainability has gained more and more attention in the last 10 years in academia, which is evident in workshop series such as WSSSPE (Workshop on Sustainable Software for Science: Practice and Experiences) [4], the uptake of hackathons by projects and the founding of journals such as JORS (Journal of Open Research Software) [5]. WSSSPE working groups are concerned with diverse aspects of software sustainability and the workshops are designed with interactive sessions on a variety of topics such as software engineering best practices or career paths for developers. While areas of SGCI have a broad overlap of topics with the WSSSPE working groups, the Bootcamps are designed to lead the participants through steps for achieving sustainability for their specific projects. Thus, the timeline of the bootcamp allows for discussing the project of each participant in detail. The WSSSPE working groups aim at addressing scientific projects and common aspects for sustainability more generally. These two approaches complement each other.

Funding bodies have recognized the importance of software sustainability. In 2010, the National Science Foundation (NSF) [6] started the SI2 program (Software Infrastructure for Sustained Innovation) [7]. SGCI is one of the two currently funded software institutes in the US and is concerned with the sustainability of science gateways to enable researchers to use complex infrastructures and data more easily, more efficiently, more effectively and more reliably. The other institute funded under this call – MolSSI (Molecular Sciences Software Institute) [8] – focuses on supporting the sustainability of molecular simulations. SGCI and MolSSI collaborate and plan to partner on events, where the topics have a wide overlap and are suitable for both institutes.

The UK SSI (Software Sustainability Institute) [9] was funded in 2010 and serves the UK's research software community as well as partners on international level. Its goal is to cultivate better, more sustainable, research software. Both institutes are collaborating with each other and can complement their portfolios. They work on best practices for software sustainability and partner on events, for example. The UK SSI offers hackathons, which have some overlap in topics regarding good software engineering practices and user-centered designs with the Incubator Bootcamps. While the hackathons are tailored often to developers and bringing them in touch with the needs of a community on a spedific tool, the Incubator is concerned with the different roles in a project and follows a business approach to address sustainability and reach and grow communities.

The consortium Advanced CyberInfrastructure - Research and Education Facilitators (ACI-REF) [10] has the goal to establish campus champions in a coordinated network. Its mission is to leverage existing resources and support their local campus researchers while unifying member institutions under common objectives. The tasks of science gateway creators have a broad intersection with the tasks of cyberinfrastructure facilitators such as good software engineering practices and the design of computational solutions tailored to the needs of a specific community and research topic. ACI-REF offers also workshops with some overlap on topics with the Incubator Bootcamps such as the landscape of funding opportunities. The overall concept of the workshops is different though. ACI-REF workshops are designed for a large number of participants and has been proven to be very successful as well. The 2015-2016 workshops attracted 128 research computing facilitators from 84 institutions in 37 US states and territories and 3 other countries. The concept of the bootcamp and the ACI-REF workshops complement each other.

III. THE INCUBATOR

The Incubator was created to address the operational and strategic questions that many software initiatives face. Supporting science gateway creators includes not just guidance on implementing the technical details, but all aspects of the science gateway lifecycle from planning and design through sustainable operation (see Fig. 1).

At each stage, the Incubator offers a variety of services, each of which was determined valuable to the community by respondents of the 2014 survey [3] (see Section Introduction). Key findings of the survey include that community engagement is crucial for the success of a science gateway, that approaches of the incubator should be technology agnostic and that gateway creator teams aim at using APIs and standard web technologies or complete solutions suitable for their use case. Examples for technologies are:

- RESTful APIs and support of multiple programming languages in widely used frameworks (Apache Airavata [11], the Agave platform [12], etc.)
- Reused interface implementations such as the one of CIPRES [13] with its RESTful API (CIPRES has served more than 20,000 users to date)

- Science gateways as a service with provision of hardware in the background such as SciGap [14] (Science Gateway Platform as a Service)
- Widely used complete frameworks (Galaxy [15], HUBzero® [16], Open Science Framework [17] etc.)
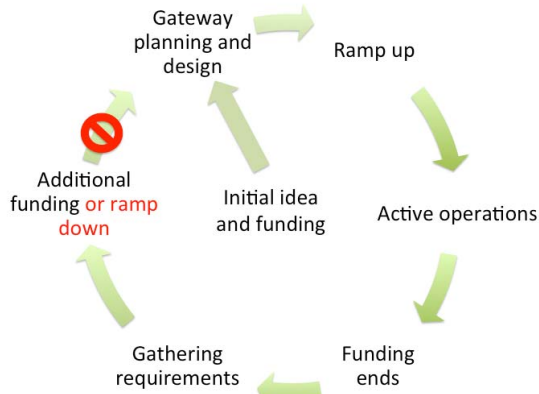

Figure 1: The science gateway lifecycle starting from initial idea and funding, to contemplating the science gateway development, then ramping up the process via hiring and/or organizing staff, followed by fully staffed project in active operations. The transition with initial funding nearing its end leads to gathering requirements for additional funding or ramping down the activities. Additional funding leads again to contemplating the further development of the science gateway.

The Incubator delivers its services through two primary means. The first is short term consulting arrangements lasting on the order of less than 3 months. Each consulting arrangement can focus on one or more of the topics listed in Table 1, and is defined upfront through the development of a statement of work, vetting the proposing project, and assignment of a consultant with expertise in the needed areas contemplated in the work.

TABLE I.   INCUBATOR SERVICES –
A FRAMEWORK FOR DECISION MAKING

Incubator Services	Activities
Technology Planning Service	Choosing technologies Cybersecurity Software engineering Interfaces to compute and data
Business Planning Service	Business model development Financial planning Project management Software licensing Staff and sustainability planning
Client Interaction Service	Usability studies Web/visual/graphic design Impact measurement Community engagement Support for education

The second means of Incubator service delivery is the formation of cohorts of people that interact with each other as and after they undergo initial incubation training [18]. The subsequent section goes into detail for the concept behind the cohort training sessions offered via the Bootcamps. The Bootcamps offer focused training and exercises that are divided into three functional areas: (1) technology planning services, (2) business planning services, and (3) client interaction planning (see Table I). The chosen activities resulted from highly ranked activities out of the 2014 survey. The uptake of such services in the first year of operation of SGCI exceeded expectations in the number of applications for the inaugural Bootcamp (20 teams from which 10 were accepted) as well as for individualized services.

IV. THE CONCEPT BEHIND THE BOOTCAMP

The Incubator-organized Bootcamp is a week-long, intensive workshop for leaders of gateways who want to further develop and scale their work. Participants will engage in hands-on activities to help them articulate the value of their work to key stakeholders and to create a strong development, operations, and sustainability plan. Workshop participants will work closely with one another and, as a result, have the opportunity to network and establish relationships with people who are engaging in similar activities. The overall concept behind the Bootcamp is to foster community to help, support, and learn from each other and to take away specific action items for the future. Participants are encouraged to think about their science gateway like an entrepreneur. The Bootcamp coaches all project leaders in techniques that are accepted practice in the business world. While not every team member is expected to be transformed into a web entrepreneur, the Bootcamp encourages a strategic mindset, and introduces a specific set of questions to ask and tools that can help answer them. While it may seem that more mature projects like HUBzero® and Apache Airavata [19] may have more obvious need for business strategy, the Bootcamp stresses that even early-stage project leaders can learn a lot from asking some hard questions and seeking answers if they are planning for long-term success.

Achieving sustainability of science gateways is a continuous process, a community problem and not an individual problem, and involves many topics, which are seldom tackled in academia in software creation projects, e.g., customer relationships or marketing of software. The areas of the Incubator services (see Table 1) functioned as starting point for the selection of topics. While we were aware of that sustainability strategies could fill weeks of lectures and hands-on sessions, we had to find a trade-off between number of topics, depth how each topic can be visited, duration of the Bootcamp and mixture between lectures, hands-on sessions and group work.

Considering the most high-ranked topics in the 2014 survey, we assembled a team of experts in diverse areas (for example, an entrepreneurial programs manager, a sustainability expert for digital resources, senior software

engineers, a security expert, a usability expert) and defined following goals for the participants:

- To gain a better understanding of the strengths and value of their gateway, specifically, to the audiences, users, customers, and stakeholders who will make it a success
- To articulate a "sustainability hypothesis" that includes their best thinking on what will make their gateway thrive
- To create an action list of things they still need to explore, study, research, decide, to prove the hypothesis to be correct and put it into action

The sessions include diverse methods and illustrations to create the action list, the so-called pitchdeck, filled during the Bootcamp by each participant for their own science gateway and presented on the last day to the whole group for feedback.

A. Topics, Format and Duration of the Bootcamp

The sessions and the topics of a Bootcamp are listed in Table II with the objective of each session.

TABLE II. THE SESSIONS, TOPICS AND THEIR OBJECTIVES

Topic	Objectives of session
Introduction to Sustainability [20]	1. Understand the full scope of the workshop, and what participants can expect to do over the course of the week. 2. Define the notion of sustainability in terms of a set of key characteristics. 3. Start to consider how these characteristics can be applied to their own gateway.
"Napkin" Drawing [21]	1. Explore the possible customer sets for their gateway other than originally intended customer. 2. Discover specific customer subgroups. 3. Determine which customers truly value the differentiator of your gateway. 4. Identify potential lead customers and early adopters.
Defining the Value Proposition	1. Value the importance of shaping a value proposition. 2. Define a first-pass value proposition for their gateway, using a simple template. 3. Consider how different audiences may need different value propositions.
Audiences and Stakeholders	1. Define primary and secondary audience segments for their gateway. 2. Identify key stakeholders. 3. Define key value each segment will require; and begin to prioritize segments. 4. Pinpoint the open questions they will need to research (in a later phase of work).
Mapping the Landscape	1. Demonstrate where their gateway fits in the existing landscape 2. Illustrate the relationships between the existing solutions 3. Identify the key forces that drive the marketplace 4. Express the difference between (and name) their actual direct and indirect competitors

Topic	Objectives of session
	5. Identify several relevant "competitors" to their gateway, and in what ways they compete 6. Determine the key differentiators that set them apart 7. Outline a next phase of work, to further explore their competitors and potential partners
Market Development	1. Explore the possible customer sets for their gateway other than originally intended customer. 2. Discover specific customer subgroups. 3. Determine which customers truly value the differentiator of their gateway. 4. Identify potential lead customers and early adopters.
Technology, Open Source and Sustainability	1. Compare buy versus build options for technology. 2. Identify a best fit software governance model. 3. Consider an Open source model with an eye towards sustainability. 4. Use DevOps practices for the gateway. 5. Identify legal aspects surrounding gateway building software.
User-Centered Design	1. Value the importance of user experience design and usability. 2. Plan, conduct, and derive actionable insights from an informal usability test.
Goal Setting	1. Articulate the long-range aims of their gateway 2. Define (in quantifiable terms, where possible) how success will be measured 3. See how Goals-based planning will help develop appropriate budget and funding levels
Budgeting	1. Understand the value of building an activity-based budget. 2. Use the impact-driven Goals (from the Sustainability Planning Framework) to start to develop this budget 3. Identify several relevant methods for "cost management" and understand the additional costs they entail
Cybersecurity for Gateways	1. Identify and document the assets and risks associated with their gateway. Expand their cybersecurity vocabulary and understanding. 2. Identify (and appreciate the importance of) software engineering best practices as a way to make software more secure. 3. Value tools and services that can help improve security for gateways.
Sustainability via On-Campus Teams	1. Create a roadmap for using free resources and/or building on-campus groups at their home campus 2. Present the benefits of on-campus teams to key people on their home campus 3. Identify suitable funding mechanisms for their campus
Funding Models	1. Brainstorm relevant funding models that are best-fit for their Gateway 2. Develop a first-pass "sustainability pie" that suggests what their ideal balance of revenue

Topic	Objectives of session
	sources will be 3. Pinpoint the open questions they will still need to answer, to go forward with testing
Marketing and Outreach	1. Articulate the basic principles of marketing 2. Develop a plan for locating target audiences 3. Utilize the tactics and tools learned during the session to begin to reach and engage your target audience
Pitch Deck Alpha	1. Explain the value of their science gateway and identify the customers that want that value 2. Share their go to market plan and the necessary steps to be successful 3. Communicate the resources needed to build a successful gateway (technology, community, partnerships)
Impact Measurement	1. Learn about the value of collecting raw data on their gateways 2. Benchmark against known data that categorizes their audience 3. Consider meaningful derivations from their data 4. Consider the message and target audience of metrics without limiting the outcome by the collection process

Each session aims to have participants make real progress in thinking about what will make their gateway sustainable. Sessions may offer best practices to implement, encourage leaders to re-think their current assumptions or brainstorm new ideas, or identify the open questions they may still need to answer. The session "Marketing and Outreach", for example, was designed to provide science gateway developers with marketing tools and tactics that could help them locate and engage with their target audiences. Bootcamp attendees learn about the basics of marketing, what it takes to execute a marketing campaign successfully to get the word out about the existence of their gateways, how to build their communities both in person and online, and an overview of effective content strategy for social media and other communication efforts. This session also touches on ways to use analytics and surveys to inform future marketing decisions. At the end of the session, participants have the opportunity to put the lessons learned to use by creating a marketing campaign that addressed their gateway's specific needs.

The sessions build often on knowledge gained in one or more preceding sessions or complement each other in content and suggested methods. Thus, the pitchdeck can be created during the duration of the Bootcamp for the diverse aspects. See extracts of forms and questions in Fig. 2. Further reading material, references and hand-outs are provided to the participants to dig deeper into topics and/or to use them for their outreach to colleagues (see Fig. 3 for one example).

The sessions are organized with a mixture of lectures and different types of exercises to achieve a lively and active work atmosphere. Studies show that a mixture of measures is more successful for keeping the attention span high of the audience and them remembering the content more deeply and insightful [22, 23]. The diverse components of the Bootcamp are
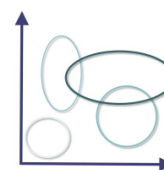
- Lectures with limited length
- Break-out discussions asking participants to form small groups and discuss a topic
- Hands-on activities executed by each participant, in small groups or as whole group
- Role plays encouraging participants to think out of the box
- Whole group debriefs about each session where participants can share thoughts, take-aways and questions with the entire group
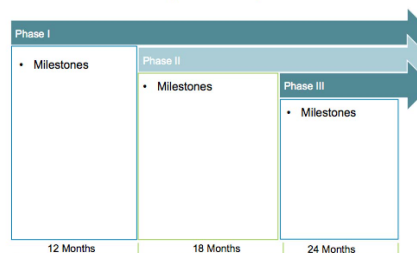
The duration of the Bootcamp is five days - a half-day program at the beginning and at the end and three full days in between. The days are work intense consisting of the 16 sessions described in Table II.

Figure 2: Extracts of forms and questions for the pitchdeck

B. Selection process of participants

Since the Bootcamp should be as beneficial as possible for all participants and allow for discussing each use case in depth, we restricted the number of participating teams collaborating on a science gateway project to a total of ten

teams. We received 20 applications and developed following criteria for the selection process of the participants.

Figure 3: The flyer addressing the topic of sustainability of on-campus teams.

Expectations of applicants regarding the benefits of their participation in the Bootcamp; The goal of the Bootcamp is to provide strategies for developing, operating and sustaining science gateways. While the concept involves hands on for various topics and aims at motivating science gateway creators to think out of the box as well as to take the strategies in, goals such as learning software development in depth or in-depth strategies how to write successful proposals are beyond the scope of the Bootcamp.

Team or single person application: The creation process of a science gateway involves in general interdisciplinary work with team members in diverse roles from PIs of the project to software developers to domain researchers applying the science gateway. Thus, we aim at receiving team applications with 2-3 team members. The goal is to support their exchange of ideas and view points on the creation of next steps for their science gateway and close collaboration under consideration of each other's role, effort and responsibilities in the project.

Diversity of goals and domains of the science gateways: To broaden diverse approaches and foster community building with various use cases, we are interested to bring in a wide range of different science gateways to each Bootcamp.

Maturity level of the science gateway: The Bootcamp supports science gateways at any stage of the lifecycle from initial gateway planning to transition phases. Our goal is here to have a mixture of science gateways with different maturity levels for a lively exchange of experiences and new approaches.

The criteria have been developed to support especially the community building under consideration of diverse roles, diverse domains and diverse stages of the science gateways lifecycle.

C. Follow-up activities

The Bootcamp is meant as start for teams to incorporate novel approaches in creating science gateways and to tackle sustainability challenges. To reach sustainability, it is important to provide the stage for more community interaction and further distinctive tasks. Thus, we have set up a slack channel for the cohort to easily chat with each other. Additionally, we organize webinars for them on topics, they would like to deepen from the Bootcamp or new topics, which could not be integrated into the Bootcamp because of the time constraints. The goal is also to connect the different cohorts with each other by inviting participants of preceding Bootcamps to report on their experience and progress in their science gateways. We encourage all participants to participate and contribute to the yearly Gateways Conference of SGCI. A further short time goal is to publish papers together on specific topics.

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V. LESSONS LEARNED AND EXPERIENCES FROM THE INAUGURAL SESSION

The inaugural session of the Bootcamp took place in April 2017. This first cohort consisted of 24 participants and the distribution of the maturity level of their science gateways were in the ranges from 25% "Not implemented yet" to 25% "Early Stage" to 21% "Mid-stage (operational for 2-4 years)" and 29% "Well-established (operational for more than 4 years)". 33.33% described their motivation for attending the Bootcamp in a pre-event questionnaire as "Our project is in urgent need of a sustainability plan or we may not be able to continue", 33.33% as "The project is in sound shape, but we want it to grow and need support in doing that." The remaining 33.33% mentioned several reasons with four out of six answers referring to the need of a sustainability plan. On the question about their most urgent sustainability needs (multiple answers could be selected), 78% are in need of new or more sources for finances, 56% need to grow the user or participant base and 39% need a governance model.

We gathered feedback during the Bootcamp in the whole group debriefs, daily surveys and a survey on the last day covering topics considering the whole event and the overall experience for the participants. Overall, most participants (79%) felt that the Bootcamp met their expectations extremely well or very well. (see Fig. 4).
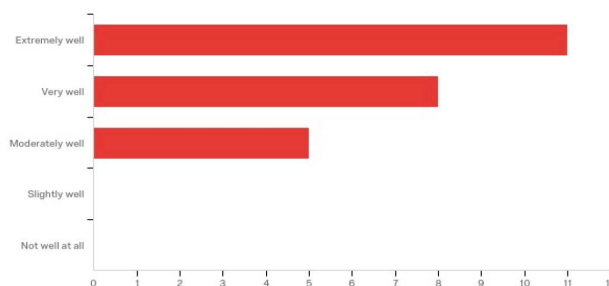

Figure 4: Answers to the question whether the Bootcamp met the expectations (all 24 participants answered this question).
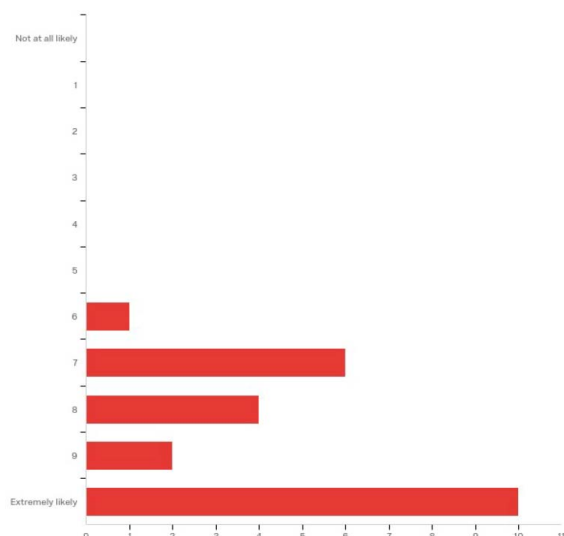

Figure 5: The answers on the question regarding the likelihood to recommend the Bootcamp to a colleague (23 out of 24 participants answered this question).

Most participants responded that they were likely or extremely likely to "recommend the Bootcamp to a colleague." (see Fig. 5). Asked to comment on the length of the Bootcamp, 62.5% found it just right, 25% a bit too long and 12.5% a bit too short. Feedback on the community building aspect was positive, as well: 54% answered that they strongly agree to have made social connections beneficial for their work on their science gateway, 42% agreed and 4% somewhat agreed. Nobody was undecided or disagreed. Since the need for a sustainability plan and for sustainability strategies was one of the major concerns of the participants and main goals of the Bootcamp, the survey included also the question how confident they felt to implement the action items they generated during the Bootcamp. The outcome was that 79% felt "Extremely confident" or "Very confident" (see Fig. 6).

Q14 - How confident are you that you will be able to implement the action items you generated at the Bootcamp?
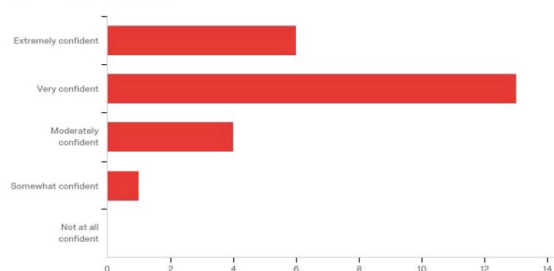

Figure 6: The answers on the question whether the participant feel comfortable to implement the sustainability strategies developed at the Bootcamp (all 24 participants answered this question).

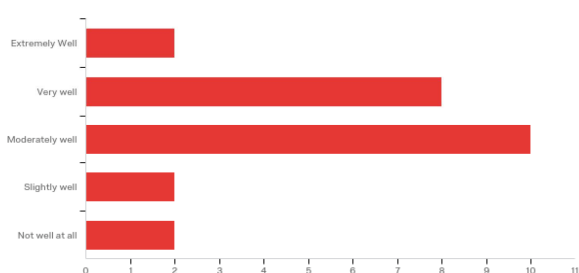Q4 - How well did the information you received prior to the Bootcamp prepare you to participate?

Figure 7: The answers on the question whether the information before the Bootcamp prepared the participants well (all 24 participants answered this question).

There were some areas for improvement, as well. The survey and group discussions held at the end of the session elucidated that the participants would appreciate more detailed information prior to the start of the Bootcamp. 42% felt moderately well prepared but 8% not well at all prepared (see Fig. 7).

Participants also felt strongly that having the time to fully discuss and work through the topics was extremely important. For some it was positively mentioned that there was enough time, for some sessions participants would have liked to receive more time. This experience corresponds to the experience of the trainers, as well. We recognized positively the lively and energetic discussions during interactive parts– despite the fact that the days were filled with a tight program of lectures and interactive parts with limited breaks.

VI. Outlook

The inaugural session of the science gateways Bootcamp showed that participants found the concept beneficial and also enjoyed the experience even though it was quite intense. The feedback of the participants was highly valuable for us and will help us in adapting the schedule and weighting of topics as well as more detailed material sent to teams before a Bootcamp. Due to the positive feedback, future Bootcamps will be planned similar regarding the selection of topics, duration of the events and accepting applications for participation. The next Bootcamp will take place in October 2017 and we intend to offer the Bootcamps twice a year Furthermore, we plan to enhance the community building activities by bringing the cohorts together for webinars, follow-up consultations, and publishing papers on diverse topics of the Bootcamp incorporating use cases and best practices.

Besides improving the sustainability of science gateways, we intend among other means to address the sustainability of SGCI itself via the continuous implementation of such events. SGCI is funded by NSF for a limited number of years to offer the incubator services for free. But similar to single science gateway projects we will need to find alternative funding resources beyond the initial funding and to develop strategies to sustain SGCI in the long term.

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