

LIGO Science Education Center (LIGO SEC) SUMMATIVE EVALUATION REPORT

Prepared by Inverness Research
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EXECUTIVE SUMMARY

The Laser Interferometer Gravitational-Wave Observatory (LIGO) is a cutting edge, emergent scientific research facility located in the remote and rural town of Livingston, Louisiana. This facility is one of two national and five worldwide research facilities dedicated to the detection of cosmic gravitational waves and the harnessing of these waves for scientific research. In an effort to share this exciting basic science research with the public, LIGO created the LIGO Science Education Center Partnership (LIGO SEC Partnership)—a partnership among the LIGO lab, a local university, a state educational reform office, and a museum renowned for its approaches to engaging the public with physical science phenomena.

Using the context of the LIGO research, the LIGO SEC Partnership seeks to provide rich physical science inquiry learning experiences for students, educators and the public. Unlike many science research facility outreach efforts that exist for the duration of their grants, the LIGO SEC Partnership seeks to build enduring educational capacities that can continue to provide support for science education activities across the state. These enduring capacities are found in the forms of a new science education center facility (LIGO SEC Facility) on the LIGO site, and in ongoing partnerships among LIGO Livingston (LLO), the Exploratorium in San Francisco, Southern University Baton Rouge (SUBR) and the Louisiana Systemic Initiative Program (LA SIP) and the Louisiana Gaining Early Awareness and Readiness for Undergraduate Program (LA GEAR UP).

The LIGO SEC Partnership faces at least five major design challenges to accomplish its ambitious outreach and education mission:

- (1) The LIGO research entails rather abstract physics and engineering concepts that are not easily accessible to the average person.
- (2) The outreach effort is attempting to create productive working relationships between scientists and educators.
- (3) LIGO SEC needs to develop strong partnerships that can provide an interface between this abstract science and multiple diverse audiences.
- (4) The LIGO facility and the SEC are not easily accessible, as they are located in a remote and sparsely populated region (an hour's drive from Baton Rouge).
- (5) The outreach effort needs to find creative ways to reach and serve underrepresented groups in science.

Each one of these challenges is difficult, and LIGO SEC is attempting to address all of them simultaneously. In addition, they are doing so in the larger context of Hurricane Katrina and post-Katrina issues in the state of Louisiana.

Four years into the five-year project, the LIGO SEC partnership has made significant strides toward addressing these challenges. The partnership has created an informal science Center, complete with exhibits, programs, and staff; this achievement cannot be underestimated. They have served over three thousand school children and eight hundred teachers around the state with custom-tailored programs and experiences. The use of exhibits, Exploratorium table-top activities or “snacks,” and other informal learning strategies are beginning to take hold as a powerful approach to science teaching and learning among the teachers and school children that have visited from across the state. Moreover, “LIGO science” has entered the lexicon of those involved in the Center as a context for strengthening the learning of certain physical science concepts. LIGO SEC has also made considerable progress toward its aim of reaching underserved audiences in a state that has high numbers of underrepresented populations. In sum, LIGO SEC is offering services and building capacity at an opportune time in a needy region.

Key to all of these achievements, the project has created a context within which “win-win” arrangements can be developed between and among the LIGO partners. Each of the partners, while strong in their own right, would not be able to achieve the LIGO SEC mission alone. Each partner brings a particular strength and perspective that contributes to the collective strength of LIGO SEC. Partners are able to use the LIGO SEC context to: design innovative exhibits, increase the quality and quantity of professional development for teachers in physical science, redesign undergraduate science and math courses, and create innovative programs for K-12 and college students. The establishment of “win-win” partnerships is not easy and requires persistence; just as each partner brings its strengths, it also brings a particular mission, working culture, and proprietary interests. Within this context, win-win arrangements have to be created, debated, refined, and accomplished.

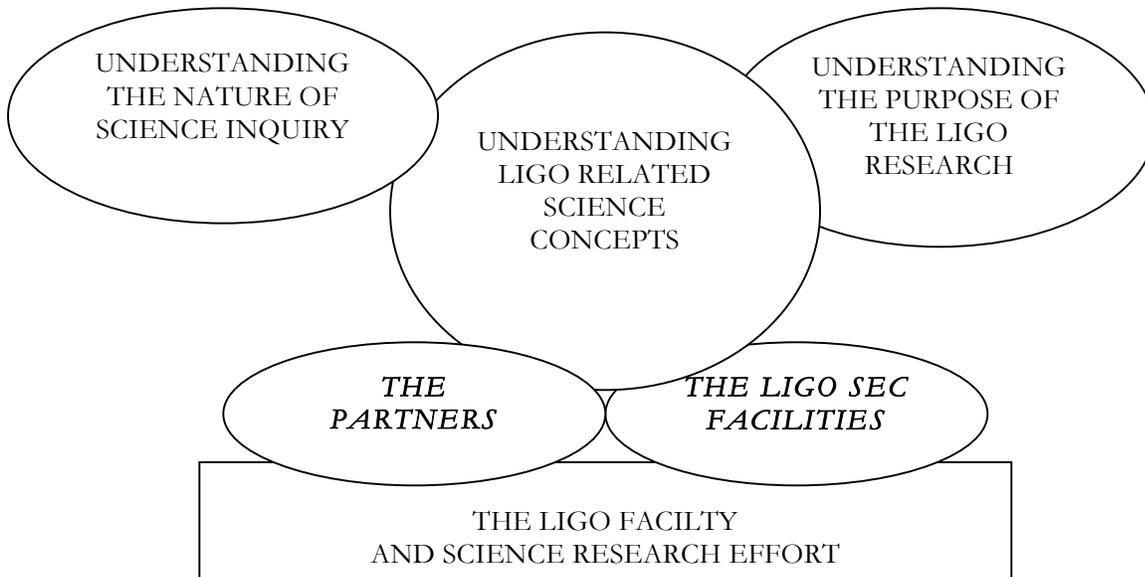
In light of the progress made, the LIGO SEC Partnership is now positioned to build on its successes and expand its work in the future. LIGO SEC can continue to expand its own impact by involving more faculty and scientists, and by working with new partners. With more capacity, we believe that there are specific ways that LIGO SEC can build on what it has done to date: First, the LIGO SEC Partnership can continue to build its own capacity to become a professional development “hub” or resource for physical science teachers in the state. This can be done in partnership with the Math-Science Partnership efforts and others in the state that serve physical science teachers. Second, it can continue to work with SUBR and other universities in the state to build their capacity for serving their students, through restructuring undergraduate courses, designing opportunities for faculty development, and creating a broader range of experiences for undergraduate students (i.e., the docent program). Finally, refining existing and piloting new programs for students, educators and the public can increase the effectiveness, impact and reach of LIGO SEC. We also believe that LIGO SEC Facility has the potential to be a national center for LIGO science education: the source and authority on LIGO research and how its principles and findings can be translated for different audiences.

LIGO Science Education Center (LIGO SEC) SUMMATIVE EVALUATION REPORT

OVERVIEW

The Laser Interferometer Gravitational-Wave Observatory, LIGO, is a cutting edge, emergent scientific research lab with two Observatory facilities. The LIGO SEC Partnership uses the LIGO Livingston Observatory (LLO) located in the remote and rural town of Livingston, Louisiana. This observatory is one of two national and five worldwide observatories dedicated to the detection of cosmic gravitational waves and the harnessing of these waves for scientific research. In an effort to share this science research with the public, LIGO Lab created the LIGO SEC Partnership—a partnership between the research lab, a local university, a state educational improvement office, and a museum renowned for its approaches to engaging the public with physical science phenomenon.

LIGO has explored multiple ways to make the science of LIGO accessible to the public. One approach is to provide a summary outline of the purpose and work of LIGO – why the lab was created and the basic question(s) it is seeking to answer. The outreach goal in this case is to help teachers, students and the public get at least a rudimentary sense of what the LIGO facility is trying to accomplish. Another closely-related approach is to share the excitement and adventure of the LIGO research effort, to convey the nature of the inquiry that is happening, and to personalize the experience of working on the groundbreaking research. A third approach is to use the context of LIGO science to help people experiment with and come to better understand some basic (related) science principles. In this way LIGO seeks to create an exploratory context where people can “do some science” and get a sense of what the scientific inquiry process is all about. These approaches – all of which LIGO SEC has attempted to undertake – are indicated in the diagram, below:



Inverness Research and This Report

Inverness Research (IR) was contracted by LIGO to conduct both formative and summative evaluation of its work. IR is a small research and evaluation firm based in Inverness, California. IR has been working with LIGO PIs and staff since 2004 to study and provide feedback on their efforts. (See the Appendix for details of our evaluation perspective and our data sources.)

The purpose of this report, produced by Inverness Research, is to summarize the development of the LIGO SEC Partnership to date, highlighting its unique assets, capacities, and contributions to the region. In this report we describe how the multiple strands of work of the Partnership address the many challenges it faces, identifying those that are most promising and that have yielded significant educational benefits. We also describe the ways in which we believe that LIGO might serve as an important dimension of a state-wide infrastructure for improving science teaching and learning.

The audiences for this report include the project partnership leaders, as well as the National Science Foundation, which is funding the current LIGO SEC Partnership effort. In addition we believe that the report could be useful to other research centers as they design their own outreach and education programs. Finally, we think that the report might help inform other funding agencies potentially interested in continuing and expanding this Partnership effort.

In the following sections, we outline the educational challenges that the LIGO SEC Partnership faces, and how this collaborative partnership is designed to address those challenges. We also identify and describe the specific contributions of this partnership over the past three years. Finally, the report ends with a summary of our view of how the LIGO SEC Partnership can serve as an improvement infrastructure for science education in Louisiana.

THE EDUCATIONAL CHALLENGES FOR LIGO SEC

A central part of the mission of the LIGO SEC Partnership is to make the science of LIGO accessible to the public. This is not a trivial task, and there are several significant design challenges to accomplishing this mission. The first, and perhaps most obvious, challenge is that the underlying science of LIGO is highly abstract and complex. The science of gravitational waves and their detection is not easily conveyed to the general public or even to science teachers and students. The notion of gravitational waves and how and why they could (or should) be detected is grounded in Einstein's Theory of General Relativity and advanced and sophisticated mathematics. Hence, it requires artful portrayal and description to simplify the science without misrepresenting it, and thus help public audiences understand the mission, purpose and design of LIGO.

A second major educational challenge for the Partnership is one faced by all research outreach efforts: the challenge of connecting scientists and educators in meaningful ways, and in ways that are mutually beneficial. Historically, scientists contribute to science education through mostly superficial interactions, and in the process educators often feel intimidated by their lack of knowledge. Too often, scientists have limited skills and tools to communicate their science appropriately to particular audiences so that the scientific ideas are actually accessible. Equally, educators are sometimes too removed from the science and do not have the depth of scientific understanding needed to create

powerful educational exhibits and programs. What is needed is a strong connection, with both scientists and educators contributing their strengths.

Third, the LIGO SEC Partnership is complex - involving institutions of higher education, museums, statewide educational entities, and science research facilities. As in many partnerships of this type, each institution has its own working culture, priorities, and unique language. Assembling the leadership of these entities to discuss the purpose, goals, program activities, interfaces, and challenges within the partnership is an enormous and difficult task.

Fourth, the LIGO Livingston Observatory exists in a very remote location. Access to the facility has and continues to be a significant challenge to fostering the involvement of the public, teachers and students. The “remoteness” of the location—and the incongruity of the LIGO facilities in an otherwise empty woodland—further exacerbates the “strangeness” of the science and the work that is happening there.

Fifth and finally, the LIGO SEC Partnership seeks to entice underrepresented participants to engage in science and, for some audiences, to choose a path that would lead to a career in STEM—either as a science educator or researcher.

These five challenges are not unique to this partnership. Other research centers share some or all of these difficulties. Hence, we believe that the study of this partnership may well produce knowledge and insights worthy of consideration by other scientific research facilities. Further, each one of these challenges is difficult on its own, and the LIGO SEC Partnership is attempting to address all of them simultaneously, and is doing so in the larger context of Hurricane Katrina and post-Katrina issues in the state of Louisiana.

Certainly there is a deep belief on the part of the LIGO leadership and partners that it is possible to use the science and science capacities at LLO and the other partners to create a rich context for science learning. By designing and implementing a strategic partnership, LIGO SEC has begun to create an effective interface between LLO and multiple educational audiences. For these reasons, the evaluation work of Inverness Research has been focused on providing formative evaluation—that is, helping the LIGO SEC Partnership evolve its design, and also on documenting and portraying the evolution of the organization and work of this partnership.¹

THE LIGO SEC PARTNERSHIP

To address the challenges outlined above, LIGO created a partnership between (1) the Laser Interferometer Gravitational Wave Observatory, Livingston, Louisiana (LLO); (2) Southern University and A&M College, Baton Rouge, Louisiana (SUBR); (3) the Exploratorium, San Francisco, California; and (4) the Louisiana Systemic Initiatives Programs/Louisiana Gaining Early Awareness and Readiness for Undergraduate Programs (LaSIP/LA GEAR UP). According to the strategic plan (dated 2004), the goals for the SEC partnership are to:

¹ See the Appendix for details of our evaluation perspective and data sources.

- (1) communicate LIGO-related science concepts to the public;
- (2) strengthen pre-service and in-service science teaching;
- (3) reach a broad audience of students in Louisiana and the surrounding region; and
- (4) create a national model for ways in which scientists and educators in universities, systemic programs, school districts, and informal learning environments can work together to support inquiry-based teaching and learning.

The specific focus of this outreach work has been to bring the best of informal science learning approaches to the formal environments of K-12 and university science classrooms. And, importantly, the science that is associated with LIGO research—gravitational wave astronomy—provides the content backdrop for all of the LIGO SEC Partnership programs.

Each partner has a specific role in working to achieve the project goals. SUBR has been chiefly responsible for pre-service teacher education in LIGO science concepts and learning approaches, as well as the development and implementation of a LIGO SEC Docent Program for undergraduates, complete with training and internship responsibilities. Importantly, as a historically black college, SUBR pre-service teachers are predominantly from underrepresented minority populations. LaSIP/LA GEAR UP has been responsible for supporting professional development for practicing teachers across the state. The Exploratorium has designed, built, and provided training on the exhibits that are the heart of the LIGO SEC Facility. LIGO Livingston has provided financial support, scientific expertise, program assistance, and project leadership. Finally, LIGO SEC Facility staff play a key coordinating and delivery role in providing the opportunity for teachers, students, and the public to engage with LIGO science concepts in an informal environment.

While each partner fulfills specific roles, there are important relationships among and between the different partner functions.

The Exploratorium worked closely with LIGO SEC Facility staff to identify the science concepts that could be highlighted in the exhibits they developed. Once they were developed and delivered to the LIGO SEC site, Exploratorium staff provided several in-depth training workshops for LIGO SEC, SUBR staff and others so that the spirit of inquiry and all that is essential to informal learning approaches would translate in the SEC context. This relationship continues, even though the exhibits and initial training have been delivered.

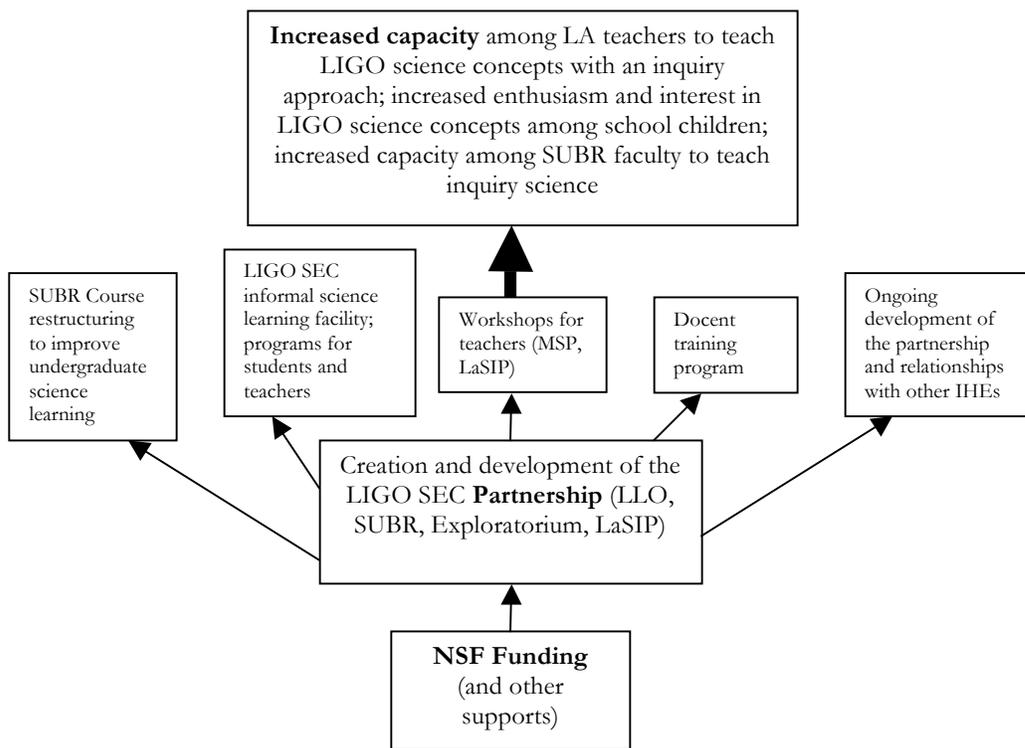
LaSIP/LA GEAR UP has taken a lead role in defining and supporting quality professional development for participating teachers. Through a request for proposals process, LaSIP has provided opportunities for teachers around the state to attend in-depth professional development. LaSIP has also been instrumental in connecting other universities, MSP programs and other special initiatives with the LIGO SEC Partnership.

SUBR created a program for teachers funded through this process, called Project MISE (Modeling Inquiry in Science Education). In addition, recently, SUBR received additional funding to purchase LIGO-inspired exhibits from the Exploratorium for the campus-based science learning lab for undergraduates. Further, SUBR has, in collaboration with SEC Facility staff, created and launched a successful docent training program whereby SUBR science and science education students are trained to facilitate the science learning of school groups using the exhibits at the SEC Facility.

Overall, the LIGO SEC partners have sought to establish “win-win” relationships and interactions to maximize their potential to create the highest quality programs and services. While there have been ups and downs in this process, the commitment and dedication of each partner has enabled positive outcomes. The next section explains in more detail the role of the partnership in achieving the goals of the project.

LIGO SEC Partnership Theory of Action

Part of the work of Inverness Research is to help the LIGO SEC Partnership surface and articulate its own *theory of action*. A theory of action describes how a project or program translates public funding to public benefits. In the case of the LIGO SEC Partnership, it links the NSF investment to the ultimate public benefits that accrue from the investment. A theory of action illustrates the logical steps of the strategies and activities that lead to the outcomes. Based on our observations over the last two years, we have identified the LIGO SEC Partnership theory of action—at its most basic level—as represented in the following flow diagram:



NSF and other funding sources have invested in a partnership of institutions whose goal is to support the improvement of physical science education in the region and state. This partnership creates programs, structures, and opportunities including undergraduate and pre-service courses, on- and off-site workshops and professional development trainings for teachers, docent training programs, and informal learning opportunities for the public at the facility. These programs provide opportunities to learn about and engage in activities related to LIGO research and in turn, increase the capacity of classroom teachers and university faculty to improve teaching and learning of LIGO science-related concepts.

In summary, the LIGO SEC Partnership has developed a collaborative partnership whose shared mission is to create a wide-ranging set of well-designed accessible opportunities to learn science.

It is with this frame that we approached our assessment of the investment of the LIGO SEC Partnership. The following sections highlight ways the partnership tackled the challenges it faced, and how their work contributed to increased opportunities to learn science across the state.

TACKLING THE CHALLENGES

Making the strange, familiar

Bringing years of experience in making science accessible to the public, the Exploratorium has contributed guiding expertise to the overall outreach effort. The collaboration with the Exploratorium has been central to designing hands-on exhibits and demonstrations that illustrate the basic science concepts involved in LIGO science (e.g., waves, resonance, interferometers). The exhibits created by the Exploratorium, the professional development that was provided by expert staff, the approach to curriculum through “snacks,” and the approach to inquiry as a pedagogy all have contributed substantially to the effectiveness of the SEC Facility. (The Exploratorium has provided six trainings to LIGO SEC Facility staff and teacher leaders from statewide networks, engaging approximately 120 participants.)

Exploratorium designs, we believe, have made the underlying physics concepts associated with the “cutting edge” nature of LIGO science accessible and exciting for teachers and students. The “snacks” teachers are able to build that demonstrate concepts presented in the large exhibits at the LIGO SEC Facility are key curriculum tools teachers use in their classrooms to “bring LIGO science home.” (“Snacks” are small versions of large-scale exhibits; the term and approach is a hallmark of the Exploratorium.) One professional developer who attended Exploratorium training talked about the purpose for and value of the “snacks:”

I tell the teachers that, first of all, hopefully we have exposed them to at least understanding what LIGO is. These large exhibits [at the LIGO SEC Facility] teach wonderful concepts using inquiry. Not only can they take advantage of them, but they can also reproduce smaller versions of this same exhibit in their classroom, and this year, I plan to make sure that teachers commit to either using snacks to teach a lesson and then try to get them to LIGO, or go to LIGO and come back and teach a lesson using the snacks... I want them to understand, even if they never get to LIGO, that the snacks can actually teach that lesson; those concepts can be brought out, thoroughly, using those miniature versions of the large exhibits.

A challenge remains for the LIGO SEC Partnership in terms of making the “snacks” and tabletop models more accessible and available to teachers via the web. Hope for a more comprehensive web-based resource, in terms of the LIGO curriculum resources and other LIGO SEC resources, was voiced by several people we interviewed:

More models for their exhibits that teachers can take back with them, or instructions on their website for how to make that type of thing, would be good. They are all based on the Exploratorium...

The ongoing connection with the Exploratorium is critical, we believe, to maintaining the quality and freshness of the exhibits and programs at the SEC Facility, and to reaching into new territory as well. For example, one of the program leaders imagined a slightly different kind of workshop for LIGO:

Maybe if we had some kind of a week-long session with LIGO scientists, given by the Exploratorium, that might change how we work together to do our outreach. I think having the Exploratorium work with scientists would be interesting.

Thus, the Exploratorium proved to be a critical partner in helping the partnership bring key concepts of the science behind LIGO into a realm within which the public, students and teachers could engage.

Bringing Scientists and Educators Together

The LIGO research facility sits within a stone's throw from the SEC Facility, making it easy for LIGO scientists to interact with students and teachers during tours of the research facility. The outreach leader of the SEC Facility has a vision for how science research around physical science concepts can become an integral part of the experience:

We want to be a regional resource, but I think the way to become a regional resource that really impacts people is to go down this path of doing science research. I would like to see not only teachers, but also students involved in real research here. I don't mean necessarily involved in the LIGO science research, because that will never happen—the tools they use are tools that teachers don't normally have, and certainly students won't have them. For example, MAT Lab is not a common teacher software package. But we have 40 exhibits out there [in LIGO SEC] and those exhibits are interesting. They have science questions attached to them that could be neatly answered, but they won't be answered unless somebody does some basic research and collects some data and can draw some conclusions. I believe you can actually use those exhibits to instill in teachers an idea of what science really is, and that of course has a flow-down effect to the students.

While the scientists have not been heavily involved in the day-to-day work of the SEC, there is a strong and collegial connection between the SEC Facility programs and LIGO leadership. The LIGO Lab Director who is also a scientist has facilitated and led the work of the partnership along with the other PIs. That the LIGO SEC facility is on the same premises as the actual LIGO research lends an element of excitement and intrigue to the visitors, and helps maintain a close connection between the staffs of the Observatory and the education center.

Creating and Maintaining a Functioning, Generative Partnership

Bringing the leadership from the partnering institutions together to meet face-to-face has been a challenging, but fruitful aspect of the LIGO SEC story. As previously mentioned, one of the major challenges of the LIGO SEC project was the creation of a partnership that would generate “win-win” arrangements such that each partner both contributed and benefited in ways that made the partnership stronger and work better. From the beginning, it was no secret that the partnership was comprised of, as a former LIGO Director remarked, “strange bedfellows.” It took time, and concentrated effort, but over the years the partners have developed strong working relationships and good communication structures that have led to a greater understanding of what each has to offer, as the LIGO SEC Facility Outreach Leader reflected:

People who never tried partnering will often list things for the other partners to do, out of good will. And people who have tried partnering know that things that are listed as things to do out of good will don't get done. The point is, if you are going to have a viable partnership, you better have something that everybody brings to the table and everybody takes away something. ... So, in terms of our partnership, I think after a couple of years, we are to the point where we understand each other and we understand the needs of one another, and I think we understand the strengths and weaknesses of individual partners. I think that you see some really outstanding contributions from all the partners.

To be successful, partnerships of any type require ongoing attention and nurturing. The LIGO SEC leadership understands that maintaining healthy and productive relationships among the partners is an ongoing and critical aspect of the work of this Partnership. Also, Partnership recognizes that it is important to evolve the partnership as it progresses. As one partner put it:

The resources should be allocated based on where our imagination takes us, not just based on the way the programs were funded before. What if new partners need to be involved and engaged in order for LIGO SEC outreach to reach its potential? We should freely engage those new partners, and not just be bound by these [current] constricted relationships. That is the way I think about the program. My commitment is really towards statewide learning and teaching enhancement. Those are the kinds of programs that we imagined. I see LIGO SEC outreach as a golden opportunity to help promote that.

As core partners, SUBR and LaSIP aimed to use the context of LIGO to catalyze new improvements and programs, in SUBR's case, in their undergraduate courses, and in LaSIP's case, in their professional development offerings and opportunities. These efforts are described below.

IMPROVE UNDERGRADUATE AND PRE-SERVICE SCIENCE EDUCATION AT SUBR

The focus of the work at SUBR has been the restructuring of undergraduate courses in physics, math, and education; the creation of the Science Education Learning Lab; and the creation of a LIGO SEC Docent Program.

While we did not study the course restructuring directly,² we talked with key players involved in this process. In our interviews with SUBR faculty who worked on improving courses, we learned that there is a great deal of motivation and commitment to bringing the resources of the LIGO research to the learning experiences of SUBR students. A SUBR physics professor and LIGO scientist, explains:

[SUBR] primarily has been education-oriented, rather than big research. We have this major research project next door now that can serve as a medium for stimulating faculty and student interest in science.

The course restructuring continues to evolve and be refined. As would be expected, some professors are more amenable to change than others. Improvement of established courses is an ongoing process, and those at SUBR who have committed to seeing it through are anxious to continue:

² All of the LIGO project work taking place at Southern University (pre-service education, undergraduate education, the Science Learning Lab, the online learning, and the docents program) has been evaluated by an internal evaluator.

We have gotten off to a good start with regard to the revamping of the courses in physics. We have now three faculty members who are actively involved in that process. That has to be sustained. That also has to be broadened, even in physics. I have two faculty members who I have targeted—new people—one I want to keep onboard and get him involved in this too, beginning in the fall. So, I have unfinished business in physics, to be honest with you. We have gotten off to a good start, but I think there is a lot more to be done in physics itself.

One of the purposes for restructuring the physics courses, in addition to capitalizing on the local nature of the LIGO research, is to introduce inquiry as a means to bring coherence and structure to the undergraduate physics curriculum, particularly those courses that are taken by future teachers. One professor explains:

There is a lot of fragmentation between courses within the discipline, and goodness knows, between disciplines. So I think this kind of inquiry-based approach, where we involve the mathematics department, will help us bring that barrier down. ...I am trying to remove barriers around this fragmentation, and [to show] how in an interconnected way, different concepts come into play with one simple, interesting demonstration.

The Dean of the College of Education is equally committed to seeing the course restructuring through and sustained into the future. She emphasized the pedagogical aspects of the improvements over the content, even though she also recognized that the physical science topics are often de-emphasized in teacher preparation. She explains:

We are not going to change the content as much as we are looking at how we teach. Our focus is looking at best practices for teaching anything, no matter what it is. If we do not teach them in that way, they are not going to remember it; they won't learn it. We are teaching them in ways that make it fun; it is making it a learning game for all involved. So, I don't think that as we look through the standards for all of the standard areas, we could find our matches for what we are doing in LIGO. There is nothing different there, we are just taking a different spin on it, I think, and bringing it to the forefront. A lot of times when it comes to physics, we didn't place a lot of emphasis in math and science. Teachers will put it on the back burner. So what we are doing is bringing it out again and focusing attention on it.

The SUBR LIGO Project Director is hopeful that more and more faculty will participate in opportunities to learn about LIGO. To date, several faculty members have attended trainings run by the Exploratorium at the SEC Facility. During spring semester of 2008, there are plans to hold a half-day event at the SEC Facility for SUBR faculty.

The Docent Program, while slow to start due to unforeseen challenges and barriers, recently completed the training of 14 SUBR undergraduates in math, physics, education, and engineering. The program provided opportunities for docents to learn LIGO science concepts using exhibits and “snacks.” These docents will serve as exhibit “explainers” during school visits to the LIGO SEC.

The SUBR LIGO Project Director has been very committed to ensuring this program is realized. She strongly believes that the docent program provides a unique and potentially life-changing experience for participants, as explained below:

The docent program is a great opportunity for SUBR students that would not have existed had it not been for this project. They are getting the opportunity to experience hard-core research, and to understand that in the context of explaining an exhibit and the science it describes. The opportunity is great—without the

partnership they wouldn't get that. The docent adds value to the training our students are receiving in their programs, in that typically during the summer students will do summer research experiences somewhere. With this program, they have the opportunity to receive some type of training year-round, and it ties directly to what they are learning in the classroom. It has a real-world connection to their learning.

The docent program provides an opportunity not only to involve SUBR undergraduates more as SEC exhibit explainers, but also to help potential future scientists or future teachers enhance their pedagogical and content skills—their science communication skills—through informal learning approaches and techniques. One docent described his experience this way:

My desire is to do research, and [my docent training experience] not only reinforced that, but also gave me an insight as far as how many people really don't understand these mechanisms. Not only just the students, but we have a lot of teachers and professors that don't really understand. Not only do we need more researchers, but we also need research/teachers, to do the research and at the same time be able to translate the information.

Another docent remarked:

[Improving teaching] is what really got me interested in LIGO, because my friend and I, we always get into discussions about teaching and teaching methods, even though we started out as science majors. But as time progressed, we kind of focused more on the teaching aspects, and with LIGO, it gives you a chance to get fresh ideas about how to teach and how to communicate the science.

At the time of this writing, it is not clear how the “explainer” role will influence the paths of the SUBR undergraduates in this docent program. So far, two physics majors and one math major have decided to pursue their teaching certificate. The SUBR LIGO Project Director believes their decisions can be attributed to their experience as docents:

It is highly unlikely they would have known that teaching was an option. Because of the LIGO partnership, they are now looking toward teacher education.

Based on our interviews with a sample of the docents and SUBR faculty, we believe the docent training has, at the very least, impressed these students and opened their eyes to the importance of being able to communicate science to the public.³

Finally, SUBR created a Science Learning Laboratory (SLL) for faculty and student use. In the first year of partnership, the SLL temporarily housed five exhibits that would later be transferred to the SEC. Recently, SUBR received a \$105K award from NSF to purchase replacement exhibits from the Exploratorium. These exhibits have been chosen and will be delivered in June 2008.

Meanwhile, the SLL has provided SUBR undergraduates, faculty, and K-12 students (during the summers and field trips) with hands-on “snack” versions of the exhibits, as well as other experiences using traditional materials and resources. These activities allow participants an informal science

³ One of the major challenges for the docents is transportation: the SEC is a one-hour drive each way from the SUBR campus. The partnership has attempted to address the transportation problem by granting stipends to help pay for fuel as well as providing the use of a SUBR van to take students to the SEC.

learning experience in a formal classroom setting. To date, approximately 1300 students have visited the Lab. SUBR LIGO Project Director reflected on the value of the lab:

[The SLL] has given them exposure to informal science and math teaching and learning in a formal setting. It strengthens that interface of informal and formal—which they would not get in a traditional lab setting, a physics lab or a methods class. And, in light of the national effort to increase minority participation in science disciplines at the undergraduate level, or increase their interest in teacher education, we feel the lab is an important component. ...What we have done before this partnership has not worked, as far as increasing numbers of math teachers, or physics education majors. We think it is important that they don't step into the classroom with traditional methods of teaching alone. The Lab has provided our teacher education majors with an awareness of how to integrate informal methods, and it has given science majors an awareness of opportunities in teacher education.

In summary, the LIGO SEC Partnership has increased the opportunity to learn science at SUBR in multiple and profound ways, most specifically the undergraduate course restructuring, the hands-on science learning laboratory, and the docent program. These opportunities would not have been possible without the support of the LIGO partners.

LASIP: LOCAL AND STATEWIDE TEACHER PROFESSIONAL DEVELOPMENT

I just can't tell my teachers enough about why they need to go [to the LIGO SEC Facility]. It has to do with the actual experience, the hands-on activities, and the content that is delivered. It is not just come and play around and have fun and go home. There is always content involved and they bring back to their classroom ideas and activities to reinforce the content that they have learned there.

- LA Professional Development Leader

SUBR has been the major university partner since the beginning of the partnership. Recently, there have been attempts to involve other universities in the LIGO SEC work. The professional development programs, described in what follows, have enabled the partnership to reach out to Louisiana Tech and Southeastern Louisiana University through the LaSIP request for proposals process, and the connections to the state MSP programs.

Professional development efforts at and through the LIGO SEC Partnership began before the SEC facility was completed and have been ongoing. In the last year alone, grants from La SIP/LA GEAR UP,⁴ state Math/Science Partnership-sponsored groups, and other independently sponsored events have enabled 821 teachers (including a handful of pre-service teachers and administrators) from around the state to attend professional development sessions at the SEC.

In 2006, Inverness Research surveyed teachers who participated in professional development at the SEC as either part of a La SIP-funded project or an MSP.⁵ We asked teachers to reflect on their experiences at the SEC Facility, the quality of the program they attended, the extent to which their

⁴ Recipients were SUBR, Louisiana Tech, and Southeastern Louisiana University)

⁵ 69 teachers responded to the survey for a response rate of 49%. Teachers involved in the two LaSIP sponsored programs (SUBR (Project MISE) and Louisiana Tech (Project RIPPLE)) as well as state-supported MSP programs were surveyed.

program contributed to their knowledge of science, and the usefulness of their experience to their teaching practice. The focus of teachers' content area ranged, as indicated by the table below:

| Subject Area | # | % |
|-----------------------|----------|----------|
| Math | 29 | 43% |
| Life Science | 20 | 29% |
| Physical Science | 37 | 54% |
| Earth/Space Science | 19 | 28% |
| English/Language Arts | 11 | 16% |
| Social Studies | 5 | 7% |
| Technology/computers | 2 | 3% |
| Other | 8 | 12% |

Overall, the teachers who responded to our survey believe that the professional development activities they experienced at the LIGO SEC were of very high quality, as the table below reveals:

| LIGO SEC PD Activity | % High quality |
|-----------------------------|-----------------------|
| Tour of LIGO SEC | 96 |
| Investigations/inquiry | 92 |
| Exhibit-based learning | 92 |
| Q&A with LIGO scientists | 90 |
| Video-based learning | 86 |
| Web-based learning | 83 |

In terms of the extent to which these LIGO SEC activities and experiences contributed to their science content knowledge, teachers responded:

| LIGO SEC PD Activity | % contributed great to very great extent |
|-----------------------------|---|
| Tour of LIGO Sec | 80 |
| Investigations/inquiry | 71 |
| Exhibit-based learning | 80 |
| Q&A with LIGO scientists | 81 |
| Video-based learning | 62 |
| Web-based learning | 70 |

We also asked teachers to respond to the extent to which the LIGO SEC activities were useful to them in their teaching:

| LIGO SEC PD Activity | % quite or very useful |
|--------------------------|------------------------|
| Tour of LIGO Sec | 69 |
| Investigations/Inquiry | 72 |
| Exhibit-based learning | 81 |
| Q&A with LIGO scientists | 64 |
| Video-based learning | 74 |
| Web-based learning | 76 |

One area that could be addressed in greater depth, from the teachers' perspective, is the gap between teachers' understanding and seeing the relevance of the LIGO activities, and applying what they learned to their own classroom teaching. This is a very common phenomenon in professional development: teachers must first understand a concept and see how it is relevant before they can incorporate it in the classroom. Moreover, there can be many external barriers to implementation and use of new approaches.

Nonetheless, some teachers reported that they have attempted to incorporate what they learned into their teaching practice, as these comments illustrate:

I was able to explain exponential growth giving a real-life and local reference to its importance, and why this comprehension is critical to scientific exploration of everything around us. It led to discussions of the other things at LIGO.

My knowledge of waves was enhanced, and I have brought that to the classroom. I have specifically incorporated the scientific inquiry approach that was used at LIGO.

I've used some of the ideas from the experiments and demonstration books. I have also felt a bit more confident about some of the physical science concepts in my classroom.

I am teaching low-level special education students 10 to 12 years of age, so many of the concepts are above their understanding. However, I have used the hands-on things to interest them, and try and develop some understanding on their part of the world around them. We have used the pan pipes, the soap film, and a variation of gravity's rainbow. They have enjoyed them all and I could see learning taking place. Every gain with this kind of student is a success. Thanks.

I discussed what we had learned at a staff meeting. I spoke individually to our science teachers about the workshop. I put out several display books on the subject and invited students to discuss them with me.

We also asked teachers to reflect on the extent and ways their LIGO SEC experience influenced their personal understanding of and attitudes about science:

| Statement about understanding/attitude | % reporting significant contribution |
|--|--------------------------------------|
| Conceptualization of what LIGO science is | 75 |
| Enjoyment of learning science | 74 |
| Interest in LIGO science | 68 |
| View of self as science learner | 64 |
| Overall understanding of the nature of science | 62 |

When asked to reflect on the importance of their LIGO SEC professional experience compared to other influences on their teaching practice, teachers responded:

It gave me a better understanding of what research scientists do. That is different from other professional development experiences.

It opened my eyes to the importance of inquiry and it being okay to not get the correct answer all the time. I also learned the importance of trying experiments over and over again.

I am so impressed that LA is on the forefront of physics research! I am amazed to think that in the next couple of years, the LIGO center will have proof of the existence of gravitational waves. I cannot wait to bring my students to show how science really works! I look forward to the new level of understanding that will be made with this research. I know in the near future that the information will be in our textbooks!

I would like to have more explanations and handouts on what we did so I could set things up in my classroom. I would love to have a handout on the electromagnetic spectrum to incorporate into my lessons, but need more directions and background info to relate it to my students. It was an excellent lab, but I really need the directions for all parts of the lab.

The activities were fun and very informational, but to incorporate them into my course work, I needed to leave LIGO with a lesson/activity description in hand. And, all activities needed to be related to the NSES and the LA GLEs.

While I have gotten some ideas and a slightly deeper understanding of concepts in physics (my weaker area), I am very limited in how much of this I can take back to my under-funded classroom. I would love to bring my students when we study waves, but if I can't bring all 91 of them at the same time, I don't believe that I can get parish approval. And I certainly cannot get approval to do three field trips over the course of three days.

I wish I had more time to incorporate what I did at LIGO into my curriculum. With the Comprehensive Curriculum I don't have time to add huge amounts of supplemental material.

Finally, a state-level leader in professional development talked about what teachers learn through the inquiry-based approach and the impact it has on their enthusiasm and motivation for teaching science:

There are tremendous things about the whole rejuvenation of the teacher's spirit and their own desire to learn, and their own willingness to ask more questions... so that if they leave the site and even riding home they look at the forest and the changes that are occurring, they are more ready for some of the questioning. It helps them become better teachers in an inquiry method.

Based on the successes so far with teacher professional development, we believe there is great potential for the LIGO SEC Partnership to help teachers increase their capacity to improve their teaching practice, particularly in topics that are relevant to the LIGO science research. Other professional development-oriented projects that we have studied, in addition to LIGO SEC, show that long-term, focused work with teachers can yield measurable results in terms of change in teacher beliefs and practices. We believe the LIGO SEC Partnership is uniquely positioned to extend its reach to other areas of the state and increase exposure as well as engage in in-depth, long-term support for area teachers. Several interviewees we talked with indicated a stronger web-based presence would assist teachers who are interested in the facility but do not have the resources to go themselves, or to take their students:

With gas prices the way they are, and everybody having to follow those standardized tests, schools are less likely to let us from northern Louisiana go down to southern Louisiana on field trips. I really wish they would have more of an Internet approach. You could show them these exhibits on the Internet and [the students] can see them... an Internet component would be wonderful for those if us in north Louisiana.

The type of sessions that John delivers when we go there would translate into distance learning professional development very easily. Also, visiting and moving around the different exhibits in the hands-on museum would translate very well. Just taking them on a [virtual] field trip of the facility [would be great], explaining what is there and what is going on. ...Also they really need to have different versions of that orientation video. If they could develop an orientation film that is geared more toward the lower grade..."

In addition to serving K-12 teachers, the LIGO SEC Partnership plans to provide professional development opportunities for SUBR faculty in the sciences and education. The SUBR team feels strongly that for the course restructuring to be successful, and to address the improvement of teaching across the campus, faculty need to participate in activities that help them improve their own teaching practice. The Dean of the College of Education describes it this way:

Our meetings [at SUBR] most recently have been about how to set up training seminars with our new faculty members to use some of the snacks that we have with the funds that we have received from LIGO. We have been getting ready to set that up and start the new training for faculty here. But our whole project includes ... the physics department, the mathematics department and we all work together to brainstorm on these ideas, we want to make the project sustainable. We need to train as many people as possible across colleges to utilize the information and the materials that we have in order to enhance the learning of the students. So the training is to make sure we bring other people into these different courses, making sure they get trained and understand what this new information is all about.

Thus, professional development work for the LIGO SEC Partnership can extend to higher education faculty. So far, several faculty members from SUBR attended the Exploratorium trainings. There is currently a plan to have faculty come to LIGO SEC this spring for an entire Saturday to learn more about inquiry and using exhibits to teach science.

Programs for K – 12 Students: Serving the Underserved

The programs at SUBR and funded through LaSIP have made great strides in engaging students and teachers of color in science. Most notable is the growth in the number of teacher education candidates at SUBR; this increase has been attributed by the teacher education program faculty to the increased attention to inquiry and hands-on learning in the undergraduate program.

In addition to SUBR undergraduates and teachers, LIGO SEC has engaged impressive numbers of students in the region. Indeed, the majority of LIGO SEC staff resources and time are devoted to developing programs for student field trip visits. In the last year, approximately 3,474 students visited the SEC Facility as part of a school field trip. A total of 77 school groups visited the SEC, with 57 of those groups being from middle or high school. In terms of the diversity of the student population visiting the SEC, the numbers reflect the general Louisiana public school population: 52% White, 45% Black, 1% Asian, and 2% Hispanic.

Typically, teachers who plan to bring their students on a field trip work closely with the LIGO SEC Facility staff in advance, so that the program they experience is relevant to what the students are doing in the classroom at that time. This is an extremely intensive process for the LIGO SEC staff, as each school group program is customized to some extent.

A teacher who has been bringing her students to LIGO for several years remarked in an interview that the quality and nature of the programs the SEC Facility offers students has steadily improved over the years. She stated that the staff has grown considerably in their ability to deliver quality programs for students, and has increased their repertoire of activities to include in their programs. The teacher reflects:

I tapped into LIGO the first year. It was a good experience, and since then they have tweaked it and made it better. The staff always goes a little farther. I've watched the development of the facility. The first time, they really had nothing, and then they got some exhibits. Last year, with the grand opening, it continues to get better and better. The staff takes the feedback they get and use it to make what they have better.

She told a story of a recent trip to LIGO with her 6th graders, where the LIGO SEC staff tailored the visit to meet the educational needs of her students and at the same time highlighted the unique resource of the LIGO research:

We were getting started on a unit on forces and motion. When we go out there, John and Kathy know what we are studying, and they tailor the activities to our topics. They developed an engineering design project for us, and they facilitate it all. They tailor our experience to what we are doing, including forces motion, gravity, and Newton's three laws. Back in the classroom, I can reference back to that. Now we are doing light, sound, color, energy—and I can connect back to our experience at LIGO. I can refer to the giant slinky and the waves, how energy moves through the waves, the color lights and the red yellow and blue, mixing them around, straight line motion and curve motion, balls, and how gravity helps the ball move faster.

...[LIGO staff] help me connect real-life activity to what we are talking about in the classroom. Before we go, they send us a packet that explains what is going on at the observatory. They touch on it a little, John talks about it a little, Kathy talks about it, PhD scientists bring it to [the students'] level. Four years ago, I would go into the control room and the scientists would talk to the kids, and it was not that interesting. This year they really brought it to their level.

...One thing John did this past year was highlighting cutting edge science ‘in your back yard.’ He did a nice job of advertising the fact that this is in your back yard. Sixth graders don’t really appreciate that, but we encourage the parents who want to come to spend the day with us and expose them also to what is happening at LIGO.

The student experience remains a major focus of the LIGO SEC Facility. The staff has amassed a library of age-appropriate activities, and they continue to solicit feedback from teachers and students to help them refine and improve the programs they offer. In addition, a local education psychology researcher has partnered with LIGO SEC to study the students’ experience, particularly the change in attitudes toward science as a result of visiting the SEC.

The staff of the SEC Facility has been very responsive and flexible as they learn from their experiences. However, as mentioned earlier, they continue to operate on a case-by-case basis, customizing the student group experience each time. While staff believe it is a good strategy to best serve the schools that make the long trip out to the SEC, there is little time to reflect on their practice and ways to improve their programs, as one staff person remarked:

We are always running behind the next group. It is always [planning for] the next group, so we have three to four groups a week, and then we have to spend time planning the programs.

We heard in several interviews of LIGO SEC staff and others that there is a danger of “burnout” among the SEC staff due to the overwhelming response and request for programs and visits. This is a positive development—it also suggests that it would behoove the partnership to reserve the resources to provide ongoing professional development and planning time for SEC staff.

ESTABLISHING A STATEWIDE INFRASTRUCTURE FOR SCIENCE EDUCATION IMPROVEMENT

In the last three years, the LIGO SEC Partnership has generated a multifaceted Center that has engaged in arrangements and modes of work that have resulted in different kinds of contributions to teachers, K-12 students, university students, university faculty and the public. A system is now in place to make the most of what they have designed and generated available to a broader audience.

From our perspective, the LIGO SEC Partnership has the potential to become part of the infrastructure for supporting science education improvement activities throughout Louisiana. That is, LIGO SEC can provide opportunities for increasing the capacity of those engaged in science education to improve science teaching and learning. LIGO SEC has developed and offered programs, resources, connections, and leadership for helping teachers and others employ informal approaches and supports to their classroom science teaching that reflect the ideas and inspiration of the LIGO gravitational wave research. The unique asset of the LIGO research sets the stage for real-world, relevant, and cutting-edge science that can be translated to the public through the engaging hands-on exhibits and activities.

To get a better understanding of how the LIGO SEC Partnership could serve as a statewide infrastructure to improve science education, we conducted telephone interviews with science education leaders in the state and asked them to reflect on both the quality and value of the current

programs offered by the SEC as well as its future potential. Everyone we spoke with agreed that the facility is a critical step in improving the quality and availability of science teaching resources in the state: Statewide leaders see having such a unique and prestigious facility in Louisiana as a unique asset and opportunity. One state and national leader who has worked with LIGO SEC since its inception states:

It is a community resource to provide a window on the science that is being done by LIGO, and to help us create a more scientifically knowledgeable community of people—of children, but also adults in the area. We were looking to improve science literacy and what we have got is a world-class resource and a research center that is just top notch. What LIGO is doing needs to be understood by the local people to be appreciated, and then what we are able to learn from that particular type of site truly needs to be something that helps us in the science community increase or raise the bar for our students.

Another state-level leader shares her excitement and enthusiasm for having this kind of a facility “in our own backyard” and the power the connection to the research facility has for bridging classroom science and real-world science:

[The goal of LIGO] is to bring students close and help them understand what is going on right here in our own backyard. Who would have ever thought here in Louisiana we would have had a huge research facility looking for gravitational waves? So, it is linking what we learn in the classroom with the real world. It is like a full circle. We teach it. [Students may ask]: Well why do I have to learn it? Well, let me tell you what is going on right next door...’ and so the SEC is trying to make that contact, that liaison between the actual research facility and teachers.

In summary, the LIGO SEC Partnership has been successful in creating a dynamic facility and in establishing a unique community-based partnership structure designed to positively impact science education of K-12 students and teachers, preservice education, undergraduate education, and the public in the state of Louisiana. These past three years it has focused on clarifying and mobilizing the roles and work of its partners; designing and delivering programs for teachers and students; and is now carefully considering how to broaden its impact.

APPENDIX: BACKGROUND OF INVERNESS RESEARCH ROLE AND WORK

Inverness Research was contracted by the LIGO SEC Partnership into its first year of operation to conduct external evaluation. Our focus since the beginning has been on the structure and function of the partnership, monitoring and providing feedback around the SEC's evolving vision of its current and future work.

Over the last two years, we have:

- conducted numerous interviews with LIGO SEC partners, advisors, advocates and participants;
- surveyed teachers who have attended the SEC for professional development;
- conducted a small study of other research institution's outreach organizations to learn more about challenges and issues facing these programs;
- conducted several site visits where we met with and interviewed partners, teachers, docents, and advisors; and
- attended LIGO SEC Directorate face-to-face meetings.

Over the course of our two-plus years gathering data about the structure and function of the partnership, we have seen tremendous growth in both the nature and quality of the partnerships within the SEC, as well as an evolving sense of itself as a unique and high-quality science education resource for the state of Louisiana.