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An Analysis of How an Inquiry-Based Professional Development Informed the Instructional Practices of Science Teachers

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Abstract

This study explored how Project MISE, an inquiry-based professional development, impacted the instructional practices of science teachers. A qualitative research design was used for this study to collect data from ten Project MISE participants. The significant findings that emerged are presented as themes supported by the participants' voices. These participants explained how Project MISE informed their instructional practices, which uncovered the emergence of the following themes: hands-on teaching and learning, the 5E instructional model, student-centered classrooms, changes in teaching style, and formative assessment. The participants provided compelling evidence that Project MISE had a profound impact on their instructional practices, thus, informing the necessary conditions for an effective inquiry-based professional development.

Keywords: informal teaching, inquiry-based professional development, inquiry learning, instructional practices, in-service teachers, pre-service teachers, snacks, STEM education

1. Introduction

1.1 Project Modeling Inquiry Science Education (MISE)

1.1.1 Background of Project MISE

Inquiry-based instruction allows the teacher to make informed data-driven decisions (Windschitl, 2002). Improving a teacher's ability to think critically and teaching teachers how to teach children to think critically represents a shift in the academic focus from stimulus-response to facilitation, which helps students develop inquiry-based critical thinking skills (Cary, 2002). Similar to the need to change the educational program for students, there is a need to change the way teachers are taught to foster higher-order thinking skills. If teachers are not prepared to teach students, they cannot teach in a quality manner. To address this concern, the Laser Interferometer Gravitational Wave Observatory (LIGO) Local Educational Outreach Partnership, now known as the Laser Interferometer Gravitational Wave Observatory (LIGO) Science Education Center (SEC) Partnership was formed.

The LIGO SEC Partnership evolved as one of the educational outreach components of the ongoing research at the two LIGO observatories. The observatories are located in Hanford, Washington and the other is in Livingston, Louisiana. LIGO is operated by Massachusetts Institute of Technology and California Institute of Technology and is supported by the National Science Foundation. LIGO seeks to find gravitational waves produced in space by super-massive objects undergoing violent accelerations (Katzman, 2011).

The initial partners of the LIGO SEC partnership included the LIGO SEC, the College of Education and the Departments of Physics, Mathematics, and Science and Mathematics Education Doctoral Program at Southern University and A&M College, the Louisiana Systemic Initiatives Program (LaSIP)/Louisiana Gaining Early

Awareness and Readiness for Undergraduate Programs (LA GEAR UP), under the LA Board of Regents, and the San Francisco Exploratorium. The combined efforts of a cutting-edge research laboratory, a historically black college/university, a state education reform agency, and a leading museum that specializes in informal science education have resulted in an influential center for teacher training and student science education. This partnership has had a significant and growing effect on teaching and learning in Louisiana and beyond.

Southern University and A&M College (SUBR) is a significant component of the LIGO SEC partnership and the only university participating in the partnership. A vital goal of the SUBR LIGO project is to immerse pre-service and in-service teachers and STEM undergraduates in inquiry-based teaching and learning experiences focusing on LIGO science concepts using exhibits and "snacks." Ongoing experiences and activities relevant to this immersion comprised the SUBR LIGO Docent Training Program, SUBR LIGO Inquiry Laboratory, science and mathematics education doctoral research, and LIGO science summer and academic year inquiry institutes for pre-service teachers and in-service teachers, Project Modeling Inquiry Science Education (MISE). Project MISE is the focus of this research study. The following research question will be addressed: How did an inquiry-based professional development inform the instructional practices of science teachers?

1.1.2 Rationale of Project MISE

Project Modeling Inquiry Science Education (MISE) is an inquiry-based teacher professional development that began in the summer of 2005 (Meyinsse & Young, 2009). One of the major challenges in Louisiana is student performance in science and mathematics (LDOE, 2019). Project MISE dynamically addressed this challenge by immersing science and mathematics teachers in inquiry-based teaching and learning focusing on LIGO science concepts using interactive exhibits and "snacks" developed by the San Francisco Exploratorium, and the use of technology to ensure that participants are familiar with the content knowledge taught in pertinent grade levels.

The overarching goals of Project MISE are to (1) strengthen the physics/physical science content knowledge of teachers along a learning continuum toward a deeper understanding of science concepts and practices and (2) model effective inquiry-based learning practices that illustrate best inquiry practices. The professional development focuses on science (wave properties, light, color, and sound) and mathematics (measurement and number sense) concepts. The targeted school districts are in Louisiana. Each district consists of at least two participants. Additionally, up to five selected SUBR College of Education pre-service teachers to participate in the Professional Development Institute (PDI) and six follow-up days during the academic year. The workshops are primarily conducted at SUBR and LIGO SEC.

An essential component of Project MISE is its academic year follow-up of teachers. A full-time site coordinator, who plans and implements all activities of Project MISE, visits each participant up to three times during the academic year to assist with the implementation of the professional development into the classroom. These visits ensure that teachers are using "snacks" in their lessons and their students can attend LIGO, where they can interact with the actual exhibits that they model in their classrooms. After the one-year institute, the teachers, through collaboration, are expected to use the information gained from the project to develop mathematics and science activities with other teachers in their district to increase student achievement.

The districts chosen to participate in the PDI were lower-performing districts and High Needs Local Educational Agency's (LEA) with low standardized reference test scores in math and science. In addition to the abovementioned criteria, districts were evaluated to reveal if they needed improvement in science and mathematics content and inquiry-based practices for teachers. Project MISE aims to improve science and mathematics teaching and learning in each participating school district by immersing teachers in LIGO science teaching, learning, and research. Project MISE recruits new teachers each year through collaborative relationships that current Project MISE participants have with interested teachers.

1.1.3 Project MISE Design

The design of Project MISE consists of four major components:

1.1.3a Teachers Attend Summer Institute/Academic Year Workshops

The collaboration between SUBR and LIGO SEC integrates LIGO science concepts into the core of the summer institute and academic year workshops. This training enhances pre-service science teachers' informal teaching and learning preparation and contributes to in-service teachers' professional development (PD). The training is administrated by SUBR personnel who have a relevant understanding of how science concepts associated with LIGO SEC interactive exhibits and "snacks" can be used for instructional purposes and how they can be integrated into the classroom based on Louisiana's curriculum and accountability needs.

During the summer institute and academic year follow-up workshop, SUBR provides ongoing PD to Project MISE participants. The SUBR personnel has gained a great understanding of science concepts associated with the Exploratorium, prepared LIGO SEC exhibits, and collaborated closely with key Exploratorium and LIGO personnel. As a result, common knowledge is delivered to Project MISE participants.

1.1.3b Teachers Reform Science Instruction

The PD activities that the Project MISE participants are involved in allow teachers to implement inquiry-based teaching and learning using LIGO SEC exhibits and "snacks" in their classrooms. All materials used align with Louisiana's Student Standards for Science. SUBR personnel and the Site Coordinator employed by Project MISE visit and mentor teachers to implement curricular revisions.

1.1.3c Teachers Take Field Trips to LIGO

In collaboration with the LIGO-SEC outreach staff during the year, field trips are arranged for participants to engage in continued PD. Before field trips to LIGO, participants use LIGO science "snacks" to undertake in pre-investigations. While at LIGO, the participants tour the LIGO facility, visit the SEC, and participate in investigations about LIGO-related science concepts. After returning to their schools, they continue using LIGO-SEC "snacks" in their classrooms. Also, the teachers are able to take their students on a field trip to LIGO-SE during the school year.

1.1.3d Teachers Attend Follow-up Workshops and Conferences

During the year, teachers participate in other PD activities, including LIGO SEC sponsored workshops and conferences, which extend the PD initiative. These opportunities include the Share-A-Thon at LIGO SEC, the Louisiana Science Teacher America Association and Louisiana Association of Teachers of Mathematics conferences, and the associated national conferences.

2. Theoretical Framework

The theoretical framework defines the role of the researcher, forecasts the design for data collection, and grounds the study in a larger context (Creswell & Creswell, 2017). The theoretical perspective used for this study was based on symbolic interactionism. Symbolic interactionism is a framework of sociological theory (Blumer, 1969). Symbolic interactionism focuses on three primary assumptions: 1) human beings act toward things based on the meanings that things have for them; 2) the meanings of things are the product of social interaction; and 3) meanings change when self-reflective individuals symbolically interact with each other (Denzin, 1992). This approach, applied to the study of teaching and learning, defines teaching practice as a culture created by students and teachers as they interact.

It has been argued that much social science research is irrelevant to teaching since it fails to focus on the process of education (Bolster, 1993). Bolster also contends that one way to get at the teaching method and the meanings constructed by teachers is through symbolic interactionism. He suggests that a more effective research model on teaching relies on the assumption that people are both the creators and products of the social situations in which they live. They make meaning out of what happens around them and how they and others interact. In this study, symbolic interactionism provides the means for investigating the impact of inquiry-based professional development on science teachers.

It serves as an approach to discover and understand the meanings of events and how individuals define their realities resulting from those events. This perspective relies on the symbolic meaning that people develop and rely upon in social interaction. Teacher professional development in science education involves an organized group of teachers that socially interact, which deepens learning and provides meaningful communication that can improve the quality of teacher learning.

3. Methods

A qualitative research design was used for this study to collect data from ten Project MISE participants through focus group interviews and semi-structured, in-depth individual interviews. According to Patton, during the focus group interview, “participants get to hear each other’s responses and to make additional comments beyond their original responses as they hear what other people have to say” (Patton, 2002). The focus group interviews were selected to allow the science teachers to interact with each other and draw upon the experiences of each other as experiences are shared. Using semi-structured, in-depth individual interview techniques, these data were collected to provide in-depth, detailed, and deeper meaning on Project MISE’s impact on science teachers. In this type of interview, the researcher was able to ask some open-ended questions and some that were closed-ended. These data were analyzed using the constant comparative method (Glaser & Strauss, 1967; Lincoln & Guba, 1985).

3.2 Participants

Qualitative research involves selecting people or sites to help the researcher best understand a phenomenon (Creswell & Creswell, 2017). The population for this study was composed of science teachers who participated in Project MISE from several cohorts to ensure consistency and validity. The sample for this study consisted of ten science teachers who participated in Project MISE (Table 1). To understand the impact that Project MISE had on science teachers, ten science teachers were selected using purposeful sampling that includes snowballing or chain sampling methods to recruit groups of science teachers as participants in this study. Participants were asked to provide an adjective that describes or defines that begins with either their first or last name to create a pseudonym. Pseudonyms were utilized to maintain the confidentiality of the participants.

4. Results

Before asking the participant interview questions about how Project MISE informed their instructional practices, the researcher asked the participants, “How do you define instructional practice?” This question was asked to determine how the participants defined instructional practice. The participants described the instructional practice in the following terms (Table 2).

Based on these responses, most participants understood instructional practice since their definition centered around their personal experiences, which gave the researcher grave insight.

The significant findings from the qualitative data collection are presented as themes supported by the participants’ voices. “The identification of themes provides the complexity of a story and adds depth to the insight about understanding an individual’s experiences” (Creswell, 2012). Five themes emerged showing how Project MISE significantly impacted their instructional practices. These broad themes are summarized (Table 3).

5. Discussion

The participants’ explanation of how Project MISE informed their instructional practice included five significant themes: hands-on teaching and learning (inquiry learning), the 5E instructional model, student-centeredness classrooms, changes in teaching style (innovative teaching methods), and formative assessment. The majority of the teachers in this study expressed how Project MISE introduced them to hands-on activities that they were able to transfer to their classrooms and colleagues. “Snacks” are the hands-on activity that Project MISE highlights. “Snacks” are miniature science exhibits that teachers can make using common, inexpensive, easily available materials (Exploratorium, 2013; Meyinsse & Young, 2009). The concept of hands-on teaching and learning that emerged in this study aligns with the Next Generation Science Standards, which supports science education reform through a commitment to enhancing science and learning (NGSS, 2013). NGSS (2013) promotes hands-on teaching and learning through inquiry learning. Additionally, all of the teachers in this study stated that the 5E instructional model was first formally introduced at Project MISE. Their involvement in Project MISE significantly enhanced their understanding of this instructional model. This enhancement supports literature on the effectiveness of the 5E instructional model as common practice for teachers utilizing strategies to enable students to take an active role in their learning or construction of knowledge (Bybee et al., 2006).

“Snacks” and the 5E instructional model led to students gaining control of their learning, thus the teacher serving as the facilitator. This transformation of students gaining control in the classroom is also known as student-centeredness. Historically, students have not been interested in science (NGSS, 2013). Still, after implementing Project MISE, which utilized a student-centered approach, increased student engagement and involvement have been observed in the classrooms of some of the teachers who participated in this study. "Less of me and more of the students" was a strong statement made by a teacher in this study when she expressed the increased student engagement that she witnessed. This new approach has positively impacted the mind frame of students of becoming more actively engaged and referring to learning science as being fun (Aguirre, 2014). Teachers within this study hold the concept of inquiry learning liable for this transformation in student learning.

Additionally, Project MISE has introduced teachers to innovative ideas on various instructional and evaluative methods/styles (Meyinsse & Young, 2009). For this study, teachers felt that this project channeled their inner-creativeness, allowing them to support student-centeredness. Having teachers become creative in their delivery methods promotes quality teachers and education (Barman, 2002). Teachers in this study expressed their openness and willingness to adapt. In addition, this specific inquiry-based professional development supported teachers in adapting to a new role as the classroom facilitator, facilitating student-centered learning. To adopt this new role, teachers had to fully embrace the implementation of Project MISE and immerse themselves in the professional development component of this project.

Further, teachers in this study felt that formative assessment was another innovative method of assessing and evaluating student-centered learning which included not formally grading student learning but using other strategies to assess the student understanding (e.g. exit/enter tickets"). This aligns with a study conducted by Ruiz-Primo and colleagues that found increased student learning and knowledge when teachers utilize non-traditional assessment methods (e.g., test, exams, essays) (Ruiz-Primo & Furtak, 2006).

6. Conclusion

The research question that was addressed for this qualitative study was: How did an inquiry-based professional development inform the instructional practices for science teachers? Based on the analysis of the participants' interview responses, the participants answered the research question positively, showing how Project MISE significantly impacted their instructional practices. As a result, Project MISE should continue to be a site for data collection to identify how the program helps teachers improve their STEM content knowledge and pedagogy and what barriers still exist to further improve in these areas. This further understanding will provide a basis for expanding and enhancing the existing Project MISE program and scaling the model (partnerships between an HBCU, research laboratory, and museum) to improve STEM education.

7. Implications

This research aimed to understand Project MISE's impact on the science teachers' instructional practices. The underlying goals of this study were to make suggestions and recommendations for improving the quality of inquiry-based professional development programs for science teachers based on the experiences of science teachers who participated in Project MISE. The knowledge gained about the effectiveness of Project MISE can better inform educational policy. Additionally, this study can guide further research in the evaluation of inquiry-based professional development programs for science teachers. These findings can also inform educational leaders and legislatives about needed improvements of inquiry-based professional development programs to better serve science teachers. These measures can potentially guide future development and delivery of science learning and identify strategies science teachers may incorporate in their classrooms.

Table 1. Demographics of Project MISE participants

Pseudonym	Ethnicity	Gender	Grade Level	Subject	# of years Teaching
Temper	Filipino	Male	10-12th	Physical Science Chemistry	12
Helpful	African-American	Female	9th and 10th	Physical Science Biology	9
Sincere	Caucasian	Female	6th	Physical Science	24
Smile	Asian	Female	11th and 12th	Chemistry Physics	19
Spontaneous	African-American	Female	5th	Science Social Studies	21

Vivacious	Caucasian	Female	6^{th} and 8^{th}	Physical Science Earth Science	16
Dedicated	Caucasian	Female	6^{th}-8^{th}	Physical Science Life Science Earth Science	6
Educator	African-American	Female	7^{th} and 8^{th}	Life Science Earth Science	12
Kreative	African-American	Female	10^{th}	Biology	14
Charismatic	African-American	Female	5^{th}-8^{th} Special Education	Science and Mathematics	12

Table 2. Participants Definition of Instructional Practice

Pseudonym	**Definition of Instructional Practice**
Temper	"A teacher must be well prepared. Not only just writing lesson plan but a teacher must well prepare the activities that he's going to do even before writing the lesson plan."
Helpful	"Instructional practice is; I would say what you do or how you convey the lessons or the other information that you are presenting to your students. Basically, the strategies, in which you used to involve your students, engage your students and get the message that you are trying to get across to them or the goal object that you are trying to convey at that time."
Sincere	"I don't know, I haven't really thought about that. Versus the teaching and the opportunity to teach and yet at the same time you are being trained as to how to teach."
Smile	"Any practice we use during the instruction."
Spontaneous	"Instructional practice is how you present your lesson, how do you present the material to the children, what strategy you use to present the lesson."
Vivacious	"Definitely taking what you learn and implementing it. Not just learning information and doing nothing with it. Having a total comprehension and being able to reach others."
Dedicated	"Instructional practice would be my personal way of teaching in the classroom."
Educator	"I think instructional practices deal with the methodology and the pedagogy as far as delivering concepts to a learning audience."
Kreative	"Instructional practices, how do I define it? I would say that there are methods for presenting to students a particular content, you know the method that you go about presenting that content to students."
Charismatic	"Instructional practice is basically is what, what a teacher does in the classroom and whatever methods or methodology he or she uses to teach content to the students."

Table 3. Five Emergent Themes

#	Emergent Themes	Particpant Quotes
1	Hands-on Teaching and Learning	Helpful: "Overall, I gained a plethora of knowledge in hands-on inquiry activities that I implemented in my classrooms. I also brought back to my some of my co-workers. It has actually brought my students' interest level in science where I wanted it to be because they did not really care about science and because the state does not push science as it does ELA and math, their attitude is that it doesn't matter. So it's helping them to be more investigative, be more interested in science.
2	The 5E Instructional Model	Dedicated: "They taught us the best way to teach math and science with the hands-on activities, the questioning, the inquiring, the five Es. So, that was the big thing. I learned the five Es during Project MISE. I never heard of that."
3	Formative Assessment	Educator: "I think Project MISE taught me other assessment methods versus standard test and quiz. I think I am more used to using rubrics now versus pen and paper test, just being open minded about how I grade the work that I grade and just being ensured to add comments to work that I grade for my students."
4	Changes in Teaching Style	Spontaneous: "I believe, I am more engaging, and I also believe that I am able to evaluate the children better, and my science has become more of a discovery type. I allow the kids to discover before I just get up and lecture."
5	Student-Centered Classrooms	Charismatic: "Project MISE allowed me to go back and reassess how I was teaching content and it actually brought in the method in which I, I was currently using. It's where I was able to do more hands-on and get the students more involved, you know. I don't really think I was doing much inquiry before I actually went to Project MISE."

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