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Linking cutting-edge scientific content and educator professional development: A collaborative approach to supporting science teachers

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ABSTRACT

Effective professional development plays a crucial role in teacher growth, retention, and mitigating factors leading to teacher burnout. This paper explores the impact of a professional development opportunity that resulted from a cross-disciplinary collaboration between school districts and two entities at a western university in the USA. The professional development opportunity outlined in this paper connected middle and school science teachers to a local and timely scientific concept, engaged them with interactive workshops, and provided them with all the necessary resources (e.g., lesson plans and related instructional materials) needed to implement content and pedagogy in teachers' classrooms. Program evaluation results indicated a high level of satisfaction from participants regarding course content, activities, and resources.

Keywords: professional development, secondary in-service teachers, science

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INTRODUCTION

Professional development is a process designed to support teachers' work with the goal of improving student learning and creating opportunities for professional advancement (Guskey, 1994). Effective professional development opportunities relate to content expertise (Van Driel & Berry, 2012), a combination of pedagogical knowledge and content expertise (Avalos, 2011), self-growth, and mindfulness (Roeser et al., 2012). These experiences are designed to support teachers' daily work by building professional growth, extending learning, collaborating with other teachers, and prioritizing reflection.

In addition to improving daily practice, professional development has been linked to teacher retention (Croft et al., 2018). Specifically, the rate of teacher burnout and related retention challenges have prompted education stakeholders to examine the merits of robust support systems for teachers at all levels. According to Maslach et al. (2001), burnout is a general emotional and mental exhaustion resulting from exposure to stress. This stress can be related to overburdening courses, not having appropriate support for lesson plans or instructional materials, and having lack of support from administration, among many other factors. The short-term and long-term impacts of burnout include withdrawal from work, absenteeism, low productivity, and deterioration in interpersonal commitments and communication (Swider & Zimmerman, 2010).

This paper features the collaboration between a college of education, an energy and geoscience institute, and science teachers from school districts. As a collaborative team, the stakeholders developed a professional development opportunity within the discipline of geoscience for middle and high school in-service science teachers.

This professional development opportunity was not only designed to share content on geothermal energy but also to provide supportive learning experience to the science teachers. This experience assisted middle and high school science teachers in learning content and exploring teaching resources in support of the cutting-edge science content. The learning supports (lesson plans and related instructional materials) provided teachers with the pedagogical approaches and activities they could implement in their classrooms. Additionally, this experience encouraged science teachers to reflect on their own teaching practices and understanding of the current scientific content.

LITERATURE REVIEW

Professional Development in Education

Researchers have described professional development as experiences that include multiple variables contributing to the effectiveness of the professional development opportunity offered. Some of these variables include active learning processes, strong

content focus, coherent topics, experiences offered for a significant duration, and collective participation among teachers thereby creating resources and experiences designed to assist science teachers in their work. Desimone (2009), Birman et al. (2000), Garet et al. (2001), and Kennedy (1999) stress the need for a strong content focus in a professional development opportunity. This is true for teachers looking to advance their knowledge of the content as mentioned by Van Driel and Berry (2012). Birman et al. (2000) stress the need for topic coherence as a crucial component to be addressed in the professional development opportunity. The benefit of topic coherence is that it allows for significant learning on the part of the teacher looking to improve classroom practice. Ottoson (1997) poses that coherence in topics should be aligned with national, state, and district standards and policies. Taken together, these factors will inform effective professional development in ways that support science teachers' work.

Desimone (2009) suggests that effective professional development may result in teacher learning and shifts in attitudes and beliefs that lead to change in teaching practices. Darling-Hammond (1999) and Hattie (2008) take this idea a step further and suggest a relationship between professional development and teacher change. Teacher change is defined as a shift in teacher beliefs, understandings, and/or instructional strategies with the goal of impacting practice (Ottoson, 1997; Whitworth & Chiu, 2015).

Professional Development in Science Education

Inquiry-based science teaching supports increases learning and retention of content among teachers (Anderson, 2002; Davis & Krajcik, 2005; Furtak et al., 2008; Hickey et al., 2003). These findings are noteworthy regarding the next generation science standards (NGSS). Richman et al. (2019) conducted professional development activities focusing on increasing teachers' content and pedagogical knowledge related to effectively implementing the NGSS with specific emphases on the science and engineering principles and cross-cutting concepts (e.g., modeling scientific practices like argumentation and inquiry, offering strategies for students as they use scientific practices). Findings indicated benefits for teachers to work collaboratively across grade levels.

According to Luft (2011), professional development should provide opportunities for teachers to be actively involved in investigating phenomena, interpreting results, and sense-making practices. The active learning component can be supported in a variety of ways including observing other teachers, being part of workshops and discussions as a participant or a lead, practicing what has been learned, engaging in effective reflection by means of reviewing and analyzing student work, and making necessary changes to the pedagogy (Birman et al., 2000).

In order for educators to benefit from the advantages of professional development, the experiences must create opportunities for sustained exposure, reflection, and align with quality standards. Professional development for in-service science teachers must reflect current standards and relevant information and must equip educators with the necessary skills and knowledge to address the evolving needs of students and the changing educational landscape (Suters, 2004). To reach this goal, effective professional development opportunities for science teachers should include content-specific courses that advance science teachers' understanding and being part of research experiences. If professional development opportunities are effective, they lead to teacher growth which is ensured when science teachers are actively involved in the learning process (Desimone, 2009; Guskey, 1997, 1999; Sparks, 1994, 1995).

Reflecting on their own understanding and practice is another crucial piece of learning for teachers (Heller et al., 2012). Hence, careful consideration of the design, relevance, support, and individual needs of teachers should be incorporated in professional development opportunities to ensure they are engaging, effective, and aligned with the improvement of teaching practices and student outcomes.

THE GEOTHERMAL PROJECT: A COLLABORATIVE APPROACH TO PROFESSIONAL DEVELOPMENT

Science Partners

In 2015, a federal government department sponsored the creation of the Geothermal Project *(a pseudonym)* as highlighted at the work at the Western University (*a pseudonym*). Operationally, the Geothermal Project operates out of an underground field laboratory with the aim of advancing the utilization of geothermal energy worldwide by developing, testing, and accelerating breakthroughs in enhanced geothermal system (EGS) technologies. The Geothermal Project conducts research on drilling tools and other EGS technologies to make such systems more economically viable and efficient. Creating EGSs that can be applied virtually anywhere in the world, thereby providing a clean and inexhaustible energy source, are the central goals of the Geothermal Project.

The Geothermal Project is housed within the energy and geothermal research institute specializing in sustainable energy and mineral production. Since its inception, the energy and geothermal institute has performed groundbreaking geoscience research around the world, exploring innovative geothermal technologies, and developing a portfolio of carbon dioxide sequestration projects. The Geothermal Project's position within the energy and geothermal institute invites a unique opportunity to pursue institutional collaboration.

Because non-renewable energy resources have largely supplied the world's primary energy requirements and have consequently led to global warming, a transition to renewable energies has become a necessity. However, the US geothermal industry lags behind its global counterparts in taking advantage of only a small percentage of its vast geothermal resources (Copley, 2013). Hence, the geothermal community sees an increasing need for an education campaign to encourage public support and better policymaking.

Education Partners

Beginning in 2019, Western University received funding through a federal government department that prompted discussions with the college of education faculty. Starting with the exploration of lesson plans related to geothermal energy, members of the energy and geothermal institute and school district representatives extended their early work to collaborate on information-sharing on improving geothermal literacy. All of these activities were related to the goals of the Geothermal Project. In the early meetings, the college of education's teacher education specialist and the principal investigator of the Geothermal Project agreed to capitalize on their team's mutual expertise

to share information on geothermal energy with the public, leading to developing resources for the science teachers as their first step.

Teacher Resources and Professional Development Opportunity

In order to disseminate information to the teachers, professional development workshops were conducted for middle and high school science teachers. Along with the workshops, lesson plans developed by a graduate student with a science background and other instructional materials were shared with the teachers. All of these resources were shared with the aim of supporting science teachers in their delivery of content to their students. This early work also set the stage for collaborators to expand beyond lesson plans to develop a series of initiatives to support teachers and to think about translating technical geothermal information into an accessible format to be used for teaching by middle and high school science teachers.

The instructional materials formed the basis for a comprehensive plan for professional development. This included housing the professional development opportunity within a Canvas site. This site was made available to teachers in 2023. Canvas is a web-based learning management system that is used widely by educators across school districts. Within the context of the Geothermal Project, collaborators were able to create this Canvas page as a teacher resource that would expand teachers' content knowledge and pedagogical knowledge on geothermal energy, provide advanced lesson planning, and share the curricula for professional development workshops.

Content Knowledge & Pedagogy

Partnership efforts included the development of a professional curriculum to enhance in-service science teachers' understanding of core concepts about geothermal energy and to equip them with pedagogical strategies that science teachers could incorporate in their classrooms. Incorporating geoscience resources into the school curriculum can support the teaching of rising generations to achieve the geothermal community's goals.

Collaborators aimed for professional development to bolster teachers' understanding of pedagogies that support strategic content delivery to middle and high school science students. Curricula of the professional development included Student-Sensemaking Shifts in 3D instruction, where middle and high school teachers would learn about classroom instruction that moves from *learning about* to *figuring out* content through interactive learning thereby enhancing student learning. The larger aim was to achieve the geothermal community's goal of disseminating the information about local geothermal resources to the school community.

Lesson Plans

The Canvas site facilitated sharing of lesson plans as the collaborators adapted the Geothermal Project lesson plans to better align with the instruction for teachers. Specifically, content was scaffolded to make information accessible and usable for middle and high school science teachers (grade 6 through grade 12).

The content of lesson plans was based on the uneven distribution of the earth's natural resources; transfer of thermal energy; explorations of varied renewable resources across the USA; designing, building, and refining a device that works within given constraints to convert one form of energy into another form of energy; and design a method to change the rate of heat transfer. Practical examples related to each of these topics were shared with teachers with the objective of being used in their classrooms. Specific examples included geoscience methods, the copper conundrum, hot springs, US energy distribution and engineering in Western State's energy needs.

Professional Development Workshops

Following the development of lesson plans and Canvas site resources, the professional development experience was offered through a two-day workshop. Workshop instructors made geothermal energy content and pedagogy along with lesson planning information available on the Canvas page the focus of professional development experience. Within the context of workshops, teachers were challenged to consider how they would offer support and guidance to students when identifying acceptable explanation/argument/evidence of data related to geothermal energy. As part of their professional development training, teachers were instructed on supportive pedagogical structures, including lab notebooks, small group learning experiences, opportunities to expose and discuss thinking related to curriculum, and iterative engagement/learning activities. Teacher participants submitted assignments, accessed lesson plans, and performed checks on their learning through the Canvas site.

METHODOLOGY

A key component to the professional development experience was providing middle and high school science teachers with the opportunity to provide feedback to the collaborative team. Determining teacher perspectives on the information and resources available through the Canvas site and the workshop experience has important implications for geoscience education and literacy, information-sharing related to the advancement of renewable technologies, and for the benefit of teachers.

Workshop Participants & Format

There were a total of two workshops and each workshop spanned two days. The first two-day long workshop was offered during February 2023 and then repeated for a new set of science teachers in November 2023. Workshop participants included middle and high school physics and earth science teachers, as well as other members of the scientific community. Since this opportunity was open to all middle and high school science teachers in the state, workshops were offered via Zoom (commonly used online platform) to allow for flexibility for the teachers.

Survey

A survey (executed through Qualtrics) was created to obtain feedback from middle and high school science teachers who participated in each workshop as a professional development opportunity. The goal of the feedback survey was to measure participants' level of satisfaction with the workshop experience (modality, topics covered in the workshop, etc.) and to understand whether the professional development opportunity was effective in enhancing teachers' content knowledge, their teaching practices, and the potential to impact student learning.

The survey contained 17 close-ended questions and 7 open-ended questions. Closed-ended questions used a 5-point Likert scale. The question topics included satisfaction with the workshop, content covered in the workshop, and the format in which the workshop was offered. Survey questions also asked teachers to share their perceptions

about the impact of the workshop on their content knowledge, applications to their future teaching, and the impact on student's understanding of geoscience and geothermal energy in the state.

The data collection period for the February workshop was from February 22 to March 3, 2023. The data collection period for the November workshop was held from November 17 to December 1, 2023. Teachers who attended both days of either the February workshop (n = 16) or the November workshop (n = 17) were invited to complete the survey. For each data collection period, the program evaluator sent two emails to teachers to remind them to complete the survey. The feedback survey from the first workshop generated 13 responses out of a possible 16 responses, yielding an 83% response rate. The feedback survey from the second workshop garnered 14 responses out of a possible 17 responses, yielding an 82% response rate.

DATA ANALYSIS

The survey results from the two workshop implementations in February and November were combined to measure the impact of the workshops on teachers according to the research questions outlined above. The closed-ended survey responses were analyzed using frequencies and descriptive statistics (Neuman, 2023). The open-ended survey questions were analyzed by comparing and contrasting responses, identifying patterns, and uniting themes (Miles et al., 2020).

FINDINGS

Teachers' Satisfaction with the Workshops

Most teachers (mean = 4.33 out of a 5-point Likert scale) indicated that they were satisfied with the workshops. Teachers offered many reasons for their high satisfaction levels, including the instruction (mean = 4.69 out of a 5-point scale), the teaching resources and materials, as well as being exposed to pedagogy that could immediately be implemented into their classroom. For example, one respondent said, "It was so helpful to receive local information and tons of practical teaching resources." Teachers also appreciated hearing from experts and learning about local geoscience from them.

While being satisfied with the workshops, teachers also suggested areas for improvement. They indicated that, in some cases, the workshop content was not applicable to their student group. For example, one teacher suggested that the information provided by the guest speakers was too detailed for the classroom. Along same lines, another teacher said, "Nearly all of the material is above my students' level." One teacher suggested that a model lesson would have been helpful while another teacher suggested that the workshop should be longer to be able to present all the information, such as when one teacher asked for greater detail during the physics lessons and geothermal plant data presentation.

Teachers were particularly satisfied with the Canvas page that was used to support instruction (mean = 4.69 out of a 5-point Likert scale). One teacher said, "The embedded pedagogy was wonderful. I really appreciated the fully built-out, student-ready Canvas course with comprehensive units. That truly was impressive." Teachers noted the usefulness of the Canvas site, but some said that they had a hard time navigating the Canvas site.

Perceptions of Workshop Impact on Content Knowledge

Overall, teachers agreed that the workshop content was helpful for other teachers (mean = 4.44 out of a 5-point Likert scale). Teachers emphasized that they learned about the concepts related to geothermal energy. Teachers were also satisfied with the topics that each workshop covered. Teachers were most satisfied with the topic "Copper conundrum and explaining the uneven distribution of the earth's natural resource" module (mean = 4.69). Though teachers were very satisfied with the content covering "inversions, renewable energy, US energy distribution, energy resources, and the Geothermal Project" module, this statement had the lowest mean score (mean = 4.11) out of all the other modules.

Perceptions of Workshop Impact on Teaching Practices

Although there were some who felt that the workshop didn't apply to the grade level curriculum they are currently teaching, many teacher participants mentioned a variety of ways in which they will apply the new knowledge acquired from the workshops to their teaching. Teachers were inclined to include renewable resources and hydrothermal energy contents in their lessons. Teachers also seemed open to applying the concepts learned in the workshop to other units that they were going to teach their students. Comments in this category included, "alternate energies unit," "use some of the documents for lessons in climate science," "to better explain hydrothermal energy to my students when we talk about power plants," and "maybe a field trip to the mine!"

Related to the resources shared during workshops, teachers felt they could share the workshop resources with their students and use guiding questions in their teaching as well. Teachers found the maps to be extremely useful in their future teaching. Teachers' comments related to resources include "I will use a bunch of the maps. The visuals (or phenomena) are what get students engaged," and "I really enjoyed learning about this approach to presenting maps and geography to students."

Perceptions of Workshop Impact on Student Learning

Teachers said that they hoped their students could come to understand the presence and value of geothermal energy as a resource in the state, as well as the possibilities and potential geothermal energy provides for their locale. For instance, one teacher noted, "How all of the systems interact to form where we live, and what amazing opportunities and resources are provided by them." Another teacher wrote, "Geothermal energy is a potential base-load, low-carbon source of electricity that has a potentially wider range of application throughout [the state] and should be seriously considered as an investment to decarbonize [the state's] power generation."

DISCUSSION

The design of effective professional development is crucial for enhancing teacher performance and fostering continuous growth. According to Binkhorst et al. (2022), engaging teachers in collaborative environments like the one outlined in this paper, promotes shared knowledge and pedagogical content development. Hence, being part of professional development opportunities ultimately contributes to the enhancement of teaching quality and student success (Whitworth & Chiu, 2015). Addressing these goals requires careful consideration of

the design, relevance, support, and individual needs of teachers in professional development opportunities to ensure that they are engaging, effective, and aligned with the improvement of teaching practices.

The professional development work highlighted in this paper demonstrates the impact of an initiative taken by the college of education and Geothermal Project partners to provide support to classroom teachers. The relationship between the Geothermal Project partners capitalized on the experiences and expertise of content experts and those knowledgeable of teaching and learning. The format for delivery and the development of professional learning experience was timely and indicates the ways in which the relevant content and scientific expertise affected middle and high school science teachers who participated in the workshops.

Specifically, the professional development workshops provided opportunities for teachers to expand their content knowledge. Within the workshops, teachers were responsive to the knowledge shared by science experts who served as instructors for the workshops. Data from teachers mentioned that being part of this professional development opportunity will help them in expanding their curriculum and adding new activities to their teaching. This note from the teachers ties to the concept of teacher growth as elaborated by Ottoson (1997) and Whitworth and Chiu (2015). Teachers also felt that it would be useful for their students to learn about their local resources on geothermal energy.

Suggestions from teachers indicated ways to advance professional development opportunities by offering grade-level content and organizing the Canvas site such that it is easy for teachers to navigate. Overall, the project was successful at imparting professional development opportunities for the middle and high school science teachers that related to their interest and content as is mentioned by previous research.

CONCLUSION

The objective of this professional development opportunity was to provide middle and high school science teachers with the most recent content and instructional resources that they can use in their teaching practice. To accomplish this purpose, collaborators created a two-day workshop to provide teachers with the content and the resources to enhance their learning and teaching of geothermal energy. Findings highlight the benefits of providing teachers with exposure to a new area of study in ways that may apply to their teaching. This professional development opportunity also illustrates the power of working with others as part of an atypical collaboration. The partnership between the college of education and energy and geoscience institute led to providing teachers with enduring resources on a most recent topic along with creating awareness about a local resource on geothermal energy.

Limitations of the study include limited exposure to geothermal content using a workshop format. Further, while teachers viewed the experience positively, the long-term impact is unclear. That is, future research will need to consider how reflections from this professional development experience have influenced teaching practices. Finally, while general satisfaction may be an indicator of teachers' work that reduces their burnout, future research and data collection should address this area.

Professional development opportunities that capitalize on collaborative efforts that invite knowledge on new topics of study and the practical applications of content to teachers' daily work. The unique features of this opportunity included partnerships from unlikely stakeholders. Moving forward, future work should further examine the power of these collaborations in exploring topics designed to enhance the public's understanding of content than can only be enhanced through teaching in K-12 classrooms.

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