Six Weeks with ROSE: Teacher Perspectives on Computer Science Professional Development

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***Abstract*—This innovative practice full paper describes a novel twofold approach to analyze the data collected during a six-week research-based summer professional development workshop for middle and high school STEM teachers in Southwest Missouri. In the fast-evolving field of Computer Science (CS), particularly within the Internet of Things (IoT) domain, the demand for a skilled workforce is increasing. To meet this demand, it is crucial to provide K-12 students with education in computing, computational thinking, and other broader Science, Technology, Engineering, and Mathematics (STEM) disciplines. The existing STEM curriculum could be enhanced to develop skills such as research-based problem-solving more effectively, aiming for a more comprehensive skill set among students. Therefore, empowering STEM teachers with a solid foundation of research-based problem-solving skills can significantly boost their readiness for the classroom, thus enriching their students' educational experiences. The Research Opportunity for Smart Environments (ROSE) program, a three-year initiative funded by the National Science Foundation (NSF), aims to prepare middle and high school STEM teachers to effectively introduce CS concepts through innovative IoT applications in Smart Environments, including Smart Homes and Smart Classrooms. To support STEM education in rural and other underrepresented areas, a cohort of in-service teachers from rural Southwest Missouri was selected for the inaugural ROSE summer workshop. Our data collection approach included open-ended questions and effective formative assessment techniques to gather the teachers' perspectives during the initial summer session. We adopted a twofold data analysis strategy, using the qualitative coding tool MAXQDA and sentiment analysis tools Valence Aware Dictionary and sEntiment Reasoner (VADER) and TextBlob, to analyze the teachers' responses. The research questions explored the impact of the ROSE program on educators and how their experiences and outlooks influenced their engagement and professional development within the program. The findings indicate that the ROSE program has positively influenced the teachers' personal and professional growth. The teachers experienced increased confidence and knowledge in research and teaching CS concepts, despite facing various challenges, which acted as motivation for learning. Their reflections also indicated that the mentorship and resources provided by the ROSE program have promoted the development of innovative teaching methods and a shift towards a student-centered approach, showcasing the program's success in fostering the personal and professional development of teachers for the advancement of future CS and STEM professionals.**

***Index Terms*—K-12 Education; Qualitative Analysis; Research Experience for Teachers; Sentiment Analysis; Smart Environments**

I. Introduction

The Internet of Things (IoT) is a network of interconnected devices, with its influence extending from everyday households to a variety of industries, such as Smart Homes, Smart Cities, Healthcare, and Energy Management [1]. In 2023, the global IoT market reached a size of $419.5 billion, and forecasts predict that it will grow to $1751.8 billion by 2029 [2]. As discussed in [3], IoT is anticipated to play a crucial role in higher education, such as the implementation of Smart Classrooms to enhance student learning, and the integration of Digital Campus System to promote operational efficiency. Therefore, there is an increasing demand for educating the new generation of students to become professionals equipped with IoT skills, irrespective of their academic focus [4]. However, K-12 schools in Southwest Missouri face two major challenges. Firstly, rural schools have limited Science, Technology, Engineering, and Mathematics (STEM) education resources and exposure, especially in innovative technology, potentially hindering STEM education quality and students' pursuit of STEM careers [5]. Secondly, teachers in rural schools struggle with professional development due to scarce opportunities and resources, impacting their abilities to develop innovative pedagogy and curriculum [6].

The Research Experience for Teachers (RET) program [7], funded by the National Science Foundation (NSF) [8], promotes STEM education by empowering K-12 educators through professional development. It equips teachers with the knowledge, skills, and hands-on experience needed for scientific research, promoting research-based learning and familiarity with advanced technology. Consequently, the impact of the program extends beyond individual participants as teachers foster innovation and inspire students to pursue STEM careers. In response to this vision, the Research Opportunity for Smart Environments (ROSE) program was initiated by the College of Natural and Applied Sciences (CNAS) and the College of Education (COE) at Missouri State University (MSU) [9]. The novel objectives of ROSE stem from its mission to prepare educators and students for the dynamic field of IoT and Smart Environments, inspiring them to develop their critical and computational thinking abilities through problem-solving activities. The innovation of ROSE lies in its emphasis on hands-on experience and experiential learning, offering research projects that cover Computer Science (CS) related topics, including Artificial Intelligence, Machine Learning, and Cybersecurity. By bridging the gap between theory and practice, ROSE facilitates the essential skills for adapting to complex real-world challenges. Moreover, ROSE addresses the disparities in STEM education within school districts in Southwest Missouri, highlighting the need for equitable access to technology and resources.

While designing the summer professional development program, the ROSE team applied the Technological Pedagogical Content Knowledge (TPACK) framework as outlined by Mishra and Koehler in 2006 [10]. This framework integrates three primary knowledge areas, Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK), to enhance teaching with technology. It identifies intersections between these domains, leading to four additional knowledge areas - Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and the overarching Technological Pedagogical Content Knowledge (TPACK). For the initial six-week workshop covered in this study, the focus was on Technological Content Knowledge (TCK), with full application of TPACK planned post-implementation of the summer training lessons during the school year. Consequently, in this study, we focus on two research questions:

RQ-1) To what extent does participation in the ROSE summer program influence teachers' attitudes, knowledge, and confidence in research and teaching Smart Environments and other CS-related topics?

RQ-2) How do participants' experiences, including their positive outlooks and negative setbacks, collectively shape their engagement and professional development within the ROSE summer program?

Our data collection was in the form of formative assessments that featured open-ended questions, gathering the teachers' reflections during the six-week summer workshop. We adopted a twofold data analysis approach, qualitative analysis using coding tool MAXQDA, a common research approach in Education, and sentiment analysis using tools Valence Aware Dictionary and sEntiment Reasoner (VADER) and TextBlob, a notable branch from Natural Language Processing (NLP) in CS, to analyze the teachers' experiences and perspectives. The results highlight the valuable outcomes of teachers' participation in ROSE - how their engagement positively shaped their perspectives and knowledge, empowering them to create innovative pedagogical approaches and research-driven curricula, ultimately enhancing the quality of their teaching and enriching the learning experience of their students. Additionally, the analysis reveals how the teachers' experiences collectively contribute to their learning journey, such as their acquisition of knowledge, new ideas or discoveries, and encountered technical challenges.

II. Methods

A. Program Setting

During the first week of the summer workshop, the participants were introduced to the program through a series of orientation sessions. Since most of the participants had no prior experience in CS, the sessions focused on building a foundation in programming basics, starting with block-programming in Scratch and then transitioning into Python, one of the high-level programming languages. These sessions were structured with hands-on activities and informative presentations, introducing IoT and Smart Environments, Network Security, Artificial Intelligence, and Machine Learning concepts. Considering the importance of evaluation and data collection procedures in measuring the outcome of the program, participants were also introduced to these aspects during the orientation week. Additionally, in compliance with requirements from NSF, the MSU Title IX Office gave presentations covering topics like sexual harassment and workplace conduct.

At the beginning of Week 2, the faculty mentors presented lectures on Research Methods to familiarize the teacher participants with exploring new topics for in-depth research in later phases. The faculty mentors then introduced several research projects, and the teacher participants chose from three options: Emotion Detection from Short Audio, Multi-agent Control, and IoT Network Security. Following that, they collaboratively worked on their selected projects with teammates who had made the same choices. From Week 2 to Week 6, the daily activities included literature reviews, independent investigations, data collection and analysis, team discussions, and relevant lesson plan development for curriculum integration, which offered a balanced approach to experiential learning. The faculty mentors and graduate assistants were always accessible to provide assistance or critique on the projects. Several effective learning tools were utilized to help the participants have a better understanding of the content, including presentations with visuals, lecture notes, hands-on activities, powerful Integrated Development Environments (IDE), and supplemental online tutorials. Every Friday, the workshop featured morning roundtable discussions among all participants and mentors to review the week's activities and experiences in order to identify the best practices. In the afternoon, each participant gave a brief presentation on their accomplishments and progress. These activities fostered a collaborative environment that provided a platform for reflection and feedback. On the last day of the ROSE summer workshop, participants presented their final research project findings as well as the curriculum integration plans at the Annual RET Symposium at Missouri State University [11].

B. Participant Information

Given the late notification of the NSF's approval of the ROSE grant fund in March 2023, we faced time constraints in the recruitment process. Regardless, we issued invitations through posters and an online portal to teachers in the relevant school districts to submit their CVs and letters of interest. We then compiled a ranked list of qualified candidates, adhering to the guidelines from the Missouri Department of Elementary and Secondary Education (DESE) [12] focusing on the following criteria: 25% for teachers from schools with a high percentage of underrepresented students, 25% for teachers from underrepresented groups, 25% for research interest and teaching experience, 15% for computer knowledge, and 10% for other aspects. Exceptional candidates were shortlisted for interviews. Through a careful selection process, we ultimately recruited seven teachers, although our goal was ten. Our decision was influenced by the candidates' motivation and availability throughout the academic year.

To support STEM education in underrepresented areas, the participating teachers were all from rural Southwest Missouri. Six out of seven teachers were native speakers, and gender balance was achieved with three female and four male educators. The teachers spanned grades six through twelve, covering conventional STEM subjects like Math, Chemistry, and Engineering, as well as disciplines outside STEM such as Leadership, adding an interdisciplinary dimension to the program. The recruited teachers had diverse educational backgrounds (Fig. 1) and varying levels of experience (Fig. 2). This diversity in education and experience enriched the learning environment, allowing them to exchange and learn from different teaching methods. This collaborative environment went beyond the mere exchange of professional insights as it also fostered meaningful connections among the teachers and created a supportive community for them. The teachers with more experience brought valuable insights and offered mentorship, while the ones in their earlier stages of careers infused the group with fresh and novel perspectives.

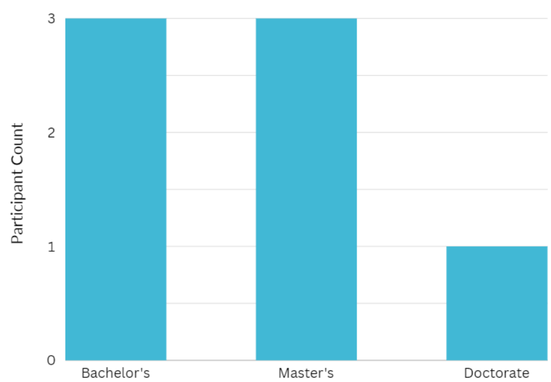

Fig. 1. Level of Education

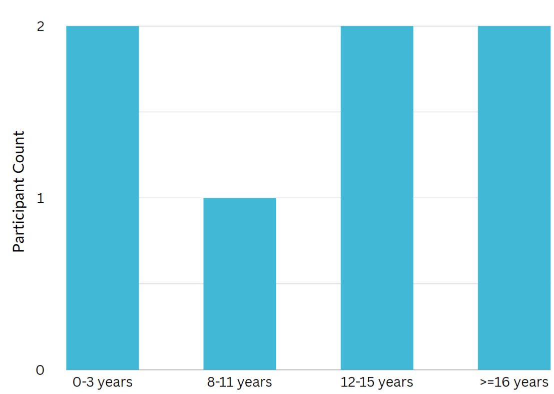

Fig. 2. Years of Experience in Teaching

C. Formative Assessment

Over the course of the six-week summer workshop, we collected data from the participating teachers through formative assessments on a daily basis. These assessments included various open-ended questions resulting in a total of 453 responses. According to [13], the inclusion of formative assessment in the learning process promotes positive learning attitudes and enhanced academic performance. The emphasis on reflection and inquiry stimulates curiosity and a positive attitude toward learning. By actively involving the participants in the reflection process, they were encouraged to reflect on their learning of the day, which helped them consolidate their knowledge and understanding of the materials. Additionally, the assessments served as a channel of communication and feedback between the participants and mentors.

The formative assessments administered primarily consisted of open-ended prompts and were designed using established techniques. Considering the different program agendas between Week 1 and Week 2 to Week 6, we adjusted our assessment techniques accordingly. In Week 1, our questions incorporated the 3-2-1 Strategy [14], and Exit Card Reflections [15]. The 3-2-1 questions included: "Three things I learned today", "Two things I want to learn more about", and "One question that I have". This technique effectively encouraged the participants to articulate important concepts and related inquiries. The Exit Card Reflections questions included: "Insights I have about what helped me learn, process, and/or fully participate", "Suggestions I have based on today's activities", "Unique needs of my students that ROSE-RET team must know based on today's activities", "Ideas I have gained for curriculum integration". Such questions promoted reflection and constructive feedback from participants, allowing for continuous improvement for both the participants and mentors.

For Week 2 to Week 6, our questions focused on Daily Reflection and Planning: "What did you accomplish today", "What is your plan for next day", "Specific curriculum modules/lesson plans/activities developed", and "Comments and feedback". These questions were designed to prompt the participants to assess their daily achievements and overall progress. Additionally, the questions encouraged planning for the following day, thereby fostering continuous improvement.

D. Qualitative Analysis

To analyze the responses to the open-ended questions, we first employed the qualitative coding method, which is frequently used in disciplines such as Social Science, Education, and Humanities. Different from coding in CS, which is designing algorithms and writing instructions in a programming language, qualitative coding is the analytical process of manually interpreting and categorizing data to identify patterns and themes [16].

For the qualitative coding process, we utilized MAXQDA [17]. We applied a hybrid approach, combining both deductive and inductive coding methods. We initially started with a small set of predefined codes based on our research questions. As our analysis progressed, we derived additional codes from the data. Via multiple iterative rounds of coding, we refined our codebook with definitions of each code and supplemented each definition with a sample coded entry, facilitating the identification of recurring themes within the entry dataset. For instance, the statement "I need to catch up on programming and learn a new programming language to proceed" was under the code "Technical Challenges", with a description of "Participants encountered technical difficulties or expressed a need for more technical knowledge or training (particularly in terms of coding experience)". We discuss more about this codebook in Section III.

E. Sentiment Analysis

To further enrich our understanding of the teachers' experiences and attitudes expressed in their daily reflections, we performed sentiment analysis on these responses, which differed from the qualitative analysis mentioned above. Sentiment analysis is automated and efficiently provides an overview of the sentiment trends. We employed two sentiment analysis tools, VADER [18] and the textblob.sentiments module from TextBlob [19]. Compared to building custom machine learning models which require extensive training data and effort, the two chosen tools are open-source, computationally lightweight, and easier to implement.

VADER is a lexicon and rule-based sentiment analysis model that assigns sentiment scores to pre-built lexicons to evaluate the sentiments in entries. Trained on social media data, VADER excels in analyzing short and informal texts, such as the reflection data we analyzed. For each entry, it calculates a compound score based on the sentiment score of each word of the entry, along with percentages of positive, neutral, and negative sentiments. For instance, the sentence "I have learned so much and I feel like my kids will love the flappy bird stuff" was rated as 0.0% negative, 69.1% neutral, and 30.9% positive, with a compound score of 0.7717, indicating an overall positive sentiment.

TextBlob is a Python library that provides a natural language processing (NLP) Application Programming Interface (API). Sentiments are assessed through the textblob.sentiments module, which uses a rule-based approach to analyzing sentiments based on sentiment scores assigned to a library of pre-defined lexicons. It returns a polarity float between -1 and 1, where -1 indicates negative sentiment, 0 indicates neutral sentiment, and 1 indicates positive sentiment. For the same sentence that we used for VADER, TextBlob also defined it as having a positive sentiment, with a sentiment polarity of 0.35.

Before conducting sentiment analysis, no preprocessing steps were implemented on the textual data. These steps typically involve tokenization, lemmatization, lowercasing, normalization, and the removal of stop words and special characters. As discussed in [20], such preprocessing steps might affect the sentiment analysis results by altering the context and sentiment conveyed in the text. By performing sentiment analysis on the data, we were able to identify the sentiment trends from the teachers' reflections. Additionally, as discussed in [21], due to the limitation in the accuracy of such sentiment analysis tools, the incorporation of two distinct tools enabled us to mitigate potential inaccuracies associated with each tool.

III. RESULTS

In this section, we present the findings and observations which are based on the outcomes of the qualitative analysis and sentiment analysis.

TABLE I
QUALITATIVE ANALYSIS CODEBOOK

Theme	Code	Description of Code
Student-Centered Approach	1: Barriers and Challenges for Students	Participants identified obstacles or difficulties that their students may face in their learning journey.
	2: Empowering Students as Future Researchers/STEM Professionals	Participants shared their thoughts on equipping their students with independent research skills, computational thinking abilities, as well as other skills necessary to become a STEM professional.
	3: Curriculum Development	Participants expressed their interest in incorporating various elements into the curriculum.
	4: Impact of Technologies on K-12 Education	Participants discussed the influence of new technologies on K-12 education, which reflected their interest in the progress of education.
Confidence and Growth	5: Acquisition of Knowledge	Participants acknowledged the acquisition of new knowledge or skills, indicating progress and personal growth.
	6: New Ideas or Discoveries	Participants shared ideas or discoveries in their learning or research, which showed how ROSE inspired them in their research/learning journey.
	7: Inspiring Subjects	Participants expressed enthusiasm for topics in the field of CS, which reflected their dedication to learning.
	8: Effective Learning Tools	Participants gave positive comments about tools and methods that enhanced their learning experience and progress.
	9: Interactions and Collaborations	Participants discussed how the collaborations and interactions with other participants, faculty mentors, or graduate assistants contributed to their learning/research outcome.
Challenges and Struggles	10: Technical Challenges	Participants encountered technical difficulties or expressed a need for technical training.
	11: Lack of Motivation	Participants expressed a lack of motivation, or a feeling of stress and burnout due to the heavy workload.
	12: Uncertainty in Research Direction	Participants faced difficulty defining research direction due to their limited knowledge of the subject matter.

A. Qualitative Analysis

Our qualitative analysis identified twelve relevant codes, which were abstracted into three major themes: "Student-Centered Approach", "Confidence and Growth", and "Challenges and Struggles" (see Table I). As described in detail below, these themes provide valuable insights into the impact of the ROSE workshop on the teachers' attitudes, knowledge, and confidence in research and teaching Smart Environments and other CS-related topics, as well as the factors influencing their learning and engagement within the program.

1) Student-Centered Approach: As shown in Table I and Fig. 3, our qualitative analysis of participants' reflections demonstrated their emphasis on a student-centered approach in teaching. Participants expressed a commitment to empowering their students as future researchers, integrating innovative technology and teaching practices to enhance their students' learning experience and outcomes.

Participants conveyed an understanding of the barriers and challenges for their students in the learning process, which led to developing a more empathetic and inclusive approach to teaching (Code 1). For instance, one participant stated in Week 1, "There is a big achievement gap in classrooms. A handful of students will be self-motivated, then there are other students that will need a lot of guidance to participate".

Additionally, there was a notable emphasis on empowering students as future researchers and STEM professionals (Code 2). One participant pondered upon the best practice for fostering independent research skills in students, stating in the Week 1 reflection, "I wondered how much I could implement making my students effective researchers instead of everything coming from me".

Furthermore, participants expressed enthusiasm for curriculum development (Code 3), discussing different ideas to integrate novel topics into their teaching practices to enhance students' learning experience. One participant reflected in Week 1, "I think the idea of adding files of data and being able to remove particular data can be incorporated into my science class for plotting line graphs or scatter plots. We could use Python applications, and my students could practice using codes in order to discuss the cause and effect of environmental impacts on Earth".

Moreover, participants discussed their ideas about the impact of technologies on K-12 education and strategies to implement such technologies for enhanced learning (Code 4). One participant shared in Week 3, "Today, I wrote a couple of paragraphs of introduction for my research document. My focus in the introduction is on the following: Importance of tech in K-12 schools, overview of IoT, K-12 IoT devices (academic and facilities focus), benefits and challenges of IoT devices. I also continued to research other thoughts and ideas that would relate to cybersecurity and discovered that there are actually K-12 cybersecurity standards".

2) Confidence and Growth: As we discuss the theme "Confidence and Growth" from the participants' reflections in detail, we refer to Table I and Fig. 4. The participants' reflections on "Acquisition of Knowledge" (Code 5) showed a consistent

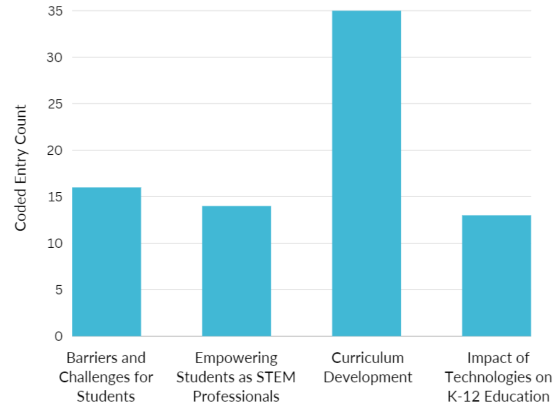

Fig. 3. Theme 1: Student-Centered Approach

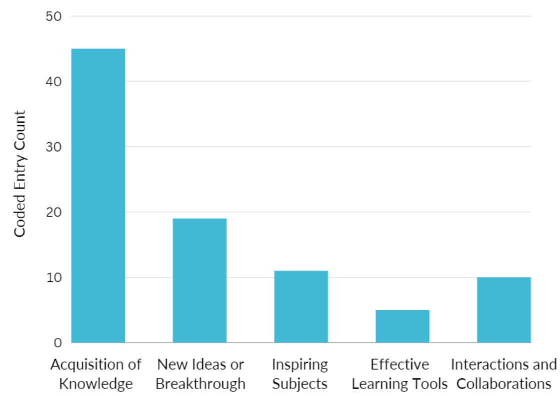

Fig. 4. Theme 2: Confidence and Growth

presence throughout the program, continuously acknowledging their learning progress and personal growth. By exploring the materials in greater depth, the participants developed a stronger understanding of the concepts and techniques, which led to a sense of fulfillment that would further inspire them in their learning and research journey. One participant expressed in Week 2, "I learned more today than the entire rest of this class combined". This reflection showcased the immediate impact of the ROSE program on participants' learning experiences and emphasized their increasing confidence and knowledge of the subject matter.

"New Ideas or Discoveries" (Code 6) encompassed the participants' reflections discussing new ideas or discoveries in their learning journey or research project, inspired by various aspects of ROSE, including research activities, materials, and technologies. One participant expressed the excitement of learning about a development platform in Week 3, "Today was really cool and I know my kids would think that it was amazing. I feel like Unity has opened up a world for me that I can make my own models for my classes". The participant perceived Unity as a gateway to new possibilities, illustrating how ROSE fostered creativity and innovation among participants by exposing them to novel technologies.

Additionally, "Inspiring Subjects" (Code 7) captured the

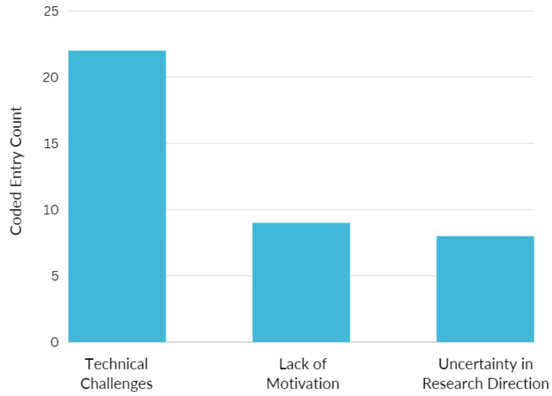

Fig. 5. Theme 3: Challenges and Struggles

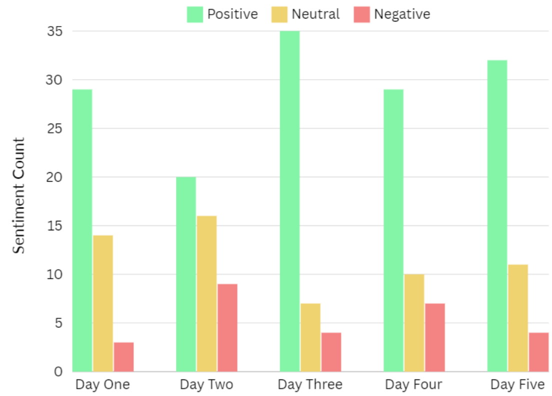

Fig. 6. Week 1 Sentiment Analysis Using VADER

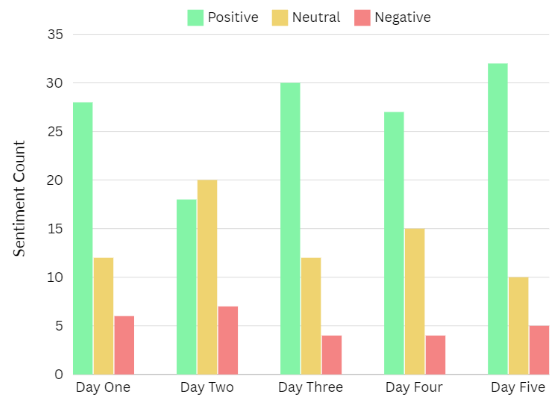

Fig. 7. Week 1 Sentiment Analysis Using TextBlob

participants' interest and enthusiasm to learn more about specific subjects within the field of CS so that they could implement those in a project or curriculum. This enthusiasm reflected their passion for learning and their curiosity to explore further based on the materials presented. One reflection in Week 4 showcased this participant's proactive engagement in the learning process and passion for exploring novel approaches, "I'm excited to learn more about scapy's capabilities, especially as they apply to other packet protocols like Bluetooth".

"Effective Learning Tools" (Code 8) reflected the participants' acknowledgment of the various learning tools provided at ROSE, which contributed to enhancing their understanding of the materials. One participant shared the importance of such resources in supporting their learning journey, "The notes and lecture slides really helped me learn today. I also liked the group discussion and the scratch practice we got online. I think another day of proactive activity would help me get a deeper understanding as well".

Moreover, "Interactions and Collaborations" (Code 9) showcased that the participants valued the support and feedback from peers, graduate assistants, and faculty mentors, as they recognized the importance of interactions in the learning environment for personal and professional growth. For instance, in Week 6, one participant expressed gratitude for the assistance and guidance received in the program "I had a great time and the faculties and GAs have been a blessing in this program".

3) Challenges and Struggles: We again refer to Table I and Fig. 5 to analyze the reflections under the theme "Challenges and Struggles". We see that alongside the enthusiasm and growth experienced by the participants, they also encountered various obstacles throughout their learning journey. "Technical Challenges" (Code 10) was a significant challenge, including limited coding experience and lack of knowledge in CS-related concepts. One participant shared in Week 1, "I need to catch up on programming and learn a new programming language to proceed". It is notable that such reflections also illustrated a willingness to overcome obstacles, serving as motivation for personal and professional development.

Moreover, "Lack of Motivation" (Code 11) emerged as another prevalent challenge experienced by the participants. Some participants expressed being overwhelmed or feelings of self-doubt. One participant remarked in Week 5, "I'm feeling a little out of my league". This lack of motivation could be attributed to the demanding workload associated with the project or the complexity of concepts, leading to feelings of stress, frustration, and burnout. Nonetheless, such reflections were part of the ongoing nature of learning and growth.

"Uncertainty in Research Direction" (Code 12) was another notable challenge for the participants. Some of them encountered difficulties in defining research direction or connecting newly acquired concepts into curriculum integration. For instance, one participant expressed in Week 2, "I don't know enough about what I'm learning about to start thinking about classroom integration. I am having a hard time thinking about how I would use these concepts in the classroom, but I'm sure it will become clear as my knowledge improves". However, despite these challenges, participants remained optimistic about their learning experiences and future progress.

B. Sentiment Analysis

In this subsection, we present the results of sentiment analysis performed using both VADER and TextBlob on the reflections collected from participants. The generated sentiment scores are analyzed in reference to the six-week

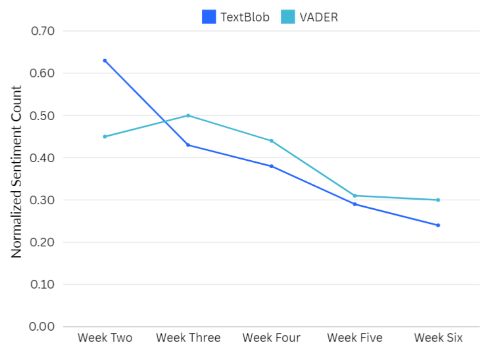

Fig. 8. Weeks 2-6 Positive Sentiment Trend

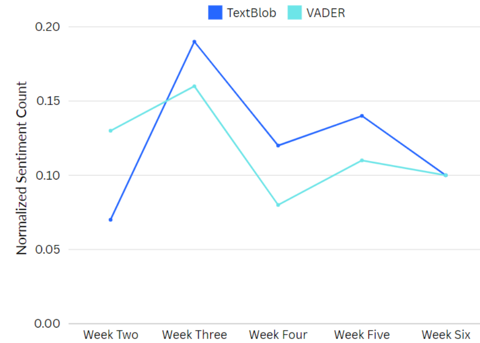

Fig. 10. Weeks 2-6 Negative Sentiment Trend

summer workshop agenda to explore the correlation between the expressed sentiments and the topics covered. As mentioned earlier in Section II, considering the different questions posed during Week 1, and Week 2 to Week 6, the analysis for these two time periods is separated accordingly to ensure a more focused examination of each week's sentiments.

For Week 1, our analysis shows a correlation between the sentiments expressed by participants and the topics covered that day (Fig. 6 and Fig. 7). Despite variations in the specific counts, both VADER and TextBlob consistently identified instances of particularly strong sentiment expressions. On both Day 3 and Day 5 of Week 1, participants expressed high levels of enthusiasm towards the lectures on Introduction to IoT and Smart Environments, Network Security Protocols and Tools, and Python Programming Basics. One positive comment from a participant on Day 3 and Day 5, respectively, was "Honestly, the networking and security stuff was so cool that I want to just keep learning more", and "I was able to get practice by myself today that really benefited my learning skills for the Python coding application". Notably, though participants had positive sentiments for the Python Programming Basics lecture on Day 5, the programming lecture on Day 2 had the most negative sentiments and least positive sentiments. This was likely because participants were first introduced to programming and feeling overwhelmed. One comment remarked, "I still find much of the code connections-loops and all to be very challenging to understand conceptually".

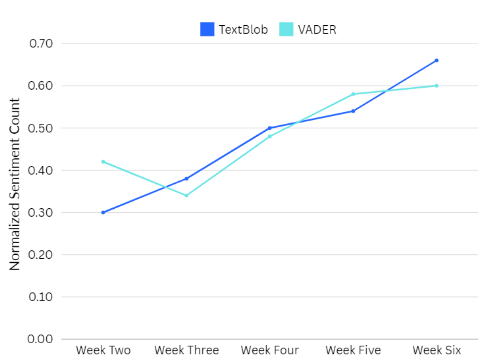

Fig. 9. Weeks 2-6 Neutral Sentiment Trend

From Week 2 to Week 6, the number of sentiments for each week was normalized to portray the overall sentiment trend. This reflected a notable emphasis on positive and neutral sentiments (Fig. 8 and Fig. 9), which aligned with our qualitative analysis findings of codes under the theme "Confidence and Growth". Additionally, as the program progressed, we observed a gradual shift in sentiment dynamics - the neutral sentiments steadily increased over the weeks. The negative sentiments (Fig. 10) correlated to the codes under the theme "Challenges and Struggles", and were consistently of a low intensity compared to the other sentiments within each week. In the following paragraphs, we analyze the sentiments in more detail by referencing the weekly agenda.

During Week 2, the participants experienced a peak in positive sentiments. At the beginning of the week, they focused on setting up the machines and environments, gradually shifting their focus toward conducting literature reviews as the week progressed. The notable positive sentiments could be attributed to the engaging and inspiring nature of their tasks, with a relatively low level of stress. The literature reviews were intellectually stimulating, inspiring different possibilities for research topics, as one participant expressed, "I enjoy how much exercise my brain is getting". While the majority of responses were positive, there were also negative sentiments expressing frustration, "Most difficult day mentally yet".

Beginning Week 3, the participants transitioned into working on their projects and curriculum development. This shift inevitably brought about feelings of overwhelm and stress, leading to a decrease in positive sentiments and an increase in negative ones. For instance, one participant expressed frustration with coding for the project, "Fix my coding mistakes from today is the plan. I know what the problem is, but I don't know how to fix it". On a more positive note, another participant shared a positive reflection regarding the progress of the day, "Today was the first day of machine learning. Specifically, we learned how to use KNN and measure accuracy using MFCCs and mels from TESS database. I feel confident in generalizing these with other databases, changing features with librosa, and experimenting with KNN accuracy by adjusting arguments".

In Week 4, both positive and negative sentiments experienced a decline, while neutral sentiments saw a steady increase. This trend corresponded with the peak of their research activities, indicating their heightened focus on their projects. The decrease in negative sentiments suggested that the participants had adapted to the pace of the program and developed stronger problem-solving skills to deal with the technical challenges. Most negative sentiments revolved around uncertainties associated with the project or curriculum integration. As one participant remarked, "Trying to figure out a way to integrate what we learned this week for the classroom. I think it's too difficult for my students to follow along so I need to think of another way to integrate". While the number of positive responses decreased due to intense concentration, there were still reflections expressing a sense of fulfillment, as one reflection stated, "Accomplished a lot today!".

In Week 5, as the participants focused on summarizing their research findings in the research papers, and creating materials for classroom integration, there was another rise in negative sentiments. This increase in negative responses could be attributed to several factors, including the participants feeling stress and burnout towards the end of the program, as well as experiencing difficulties in putting together presentations and posters. One participant's reflection explained this challenge, "My weaknesses in putting together presentations are really shining through". There were also positive sentiments expressing satisfaction with the progress, "I finished my curriculum integration poster! This entailed creating a poster, having a very challenging critique session, changing the poster, getting more feedback at the round table, then changing it again".

At the beginning of Week 6, the participants focused on summarizing their research projects into presentation posters for the upcoming symposium on the last day of the program. Therefore, neutral sentiments were the majority of the reflection sentiments, "I finished my poster describing my curriculum". Alongside the neutral sentiments, there were also positive reflections expressing a sense of accomplishment and growth, emphasizing the personal growth and professional development as a summary of the program, "I was thinking today that I felt pretty tech savvy six weeks ago but today? I know so much more. I love having a new angle of attack for learning that is so timely for today's digital citizens".

IV. Discussion and Conclusion

In this paper, we demonstrated a novel twofold approach to analyze the data collected during the six-week summer workshop within the ROSE grant program. The innovation of the ROSE program lies in applying IoT and relevant concepts as an effective and intuitive approach to train middle and high school teachers in computational thinking and research skills, thereby empowering future generations of students. By adopting TPACK, the program provided a structured approach to help teachers develop a comprehensive understanding of how to effectively combine their knowledge of content (CS and IoT concepts) and technology (programming, development platforms, and cutting-edge tools) to solve novel problems.

Conducting qualitative analysis on the formative assessment reflections helped us to reveal the immediate impact of ROSE on the teacher participants. Our findings showcase that the teachers gained knowledge of the fundamentals of CS and innovative technologies in Smart Environments. As a result, they reported increased confidence in conducting research and incorporating CS concepts in their daily teaching. Moreover, we discovered that along their learning journey, the teachers also faced various challenges and struggles, which acted as motivation for personal and professional growth. Moreover, the participants' reflections highlighted a shift towards a more student-centered approach to teaching, focusing on developing innovative and engaging curricula. Collectively, these findings demonstrate the effectiveness of ROSE in fostering personal and professional development of teachers, equipping them with the knowledge, skills, and confidence necessary to educate future generations of STEM professionals.

Additionally, the sentiment analysis enabled us to learn how the teachers' experiences shaped their learning journey within the TPACK framework. Positive sentiments peaked during the initial stages of content exposure and when the teachers explored various technologies, indicating their enthusiasm for developing CK and TK. As the program progressed, an increase in neutral sentiments coincided with more intense research activities, suggesting a greater emphasis on integrating components of TPACK. It also allowed us to identify any potential modifications for the subsequent years. For instance, the teacher participants faced challenges as they transitioned into research project activities. To address this issue, we propose extending the preparatory phase by offering additional training sessions focused on research methodologies, providing clearer guidance on defining research directions, and conducting one-on-one sessions to tackle the technical difficulties specific to each project. Similarly, as the participants experienced burnout and challenges in summarizing their findings into research papers and presentations, we suggest introducing stress-relieving activities and organizing a session focused on presentation skills. This will equip participants with the necessary tools and strategies to effectively convey their research findings. Lastly, we observed a shift to neutral sentiments and less detailed responses, suggesting that a less frequent reflection schedule might yield equally valuable insights without causing overwhelm. Therefore, we propose adjusting the frequency of reflective inquiries by reducing the number of questions asked in the reflections or changing the frequency from daily to weekly. Furthermore, in order to promote the sustainability of CS education and research, we encourage schools to have at least two teachers from the same school or district participate in the program together. This joint participation will foster a sense of collaboration and encourage continuous learning.

Overall, we are confident that the findings reported in this paper will enrich the future iterations of the ROSE grant program and inspire improvements in similar initiatives, collectively advancing STEM education for future generations.

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