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Article

Incremental Growth through Professional Learning Communities of Math Teachers Engaged in Action Research Projects

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Abstract: This study investigates the experiences of a professional learning community (PLC) composed of six secondary math teachers enrolled in a graduate math methods course. Through the discussion of educational texts and collaborative inquiry, the teachers identified classroom challenges they aimed to address through individual action research projects. The PLC provided a supportive environment for teachers to share their processes, receive peer feedback, and collectively reflect. This study underscores the value of action research and PLCs in driving educational improvement. By engaging in structured inquiry within a collaborative setting, teachers gained insights into pedagogical issues, developed targeted incremental interventions, and contributed to the broader discourse on math education pedagogy. The collaborative PLC model facilitated reflective practice, challenged assumptions, and empowered teachers as agents of change. Implications for teacher professional development, instructional practices, and future research directions are discussed.

Keywords: professional learning community; action research; mathematics education

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1. Introduction

Continuous improvement is a hallmark of effective teaching, and engaging in action research allows teachers to critically examine their practices, identify areas for growth, and implement targeted incremental interventions. In this study, I, a mathematics teacher educator, explore the experiences of a professional learning community (PLC) composed of six secondary math teachers enrolled in a graduate-level online math methods course that I taught. Through collaborative inquiry and the discussion of educational texts, the teachers selected classroom challenges they aimed to address through action research projects. The PLC provided a supportive environment for the teachers to share their processes, receive feedback from peers, and collectively reflect on their findings.

For the first eight weeks of the course, teachers read and discussed four books. These works introduced methods for fostering equity in math classrooms [1], encouraging iterative mathematical thinking [2], orchestrating productive mathematics discussions [3,4], and cultivating environments that promote student thinking [5]. I wanted teachers to be exposed to the math pedagogies in all the books, but I knew assigning four books would not be realistic. Therefore, each teacher chose one book to read (with two books being chosen by two teachers). Each teacher was responsible for providing a weekly summary of the book they were reading, and all teachers were responsible for reading their peers' weekly summaries.

I used Project Zero's Connect, Extend, Challenge routine to promote teachers' reflections and discussions about the readings [6]. The goals of the discussions were to help teachers link the new methods that they were learning about in the books to their existing knowledge and prompt them to reflect on how their thinking had evolved through their learning and experiences. I posed the following prompts in a weekly online discussion board to initiate the discussions:

1. How are the ideas and information connected to what you already know?

2. What new ideas did you get that broadened your thinking or extended it in different directions?
3. What challenges or puzzles emerge for you?

Every week, and after each teacher participated, I created a post aimed at synthesizing the discussion. I also interacted with each teacher using private comments in the grading page of the learning management system. My intention was to use inviting, suggesting, explaining, describing, and evaluating discursive moves to assess and advance teachers' knowledge of the methods presented in the texts [7].

Next, each teacher identified a specific problem of the practice they were currently encountering in their classroom that they thought a method that they learned about in the text(s) could maybe help solve. I thought this teacher-driven, bottom-up approach could promote incremental improvements in teachers' practices [8]. I intentionally chose this approach with the goal of disrupting typical professional development approaches, which often fail to have a direct, long-term, or scalable impact [8]. I guided each teacher in their selection of a high-uptake practice [9]. According to practicality theory, attention to instrumentality, congruence, and cost can facilitate teachers' acceptance of change [10]. Instrumentality is accomplished when the teacher's actions are clearly articulated. Congruence involves alignment of the practice with the teacher's current instructional approach and context. The cost involves the expected benefit from implementing the practice compared to the effort and resources required to enact it. Teachers shared diverse problems of practice and chose unique teaching interventions for their action research projects. The diversity of teachers' projects underscores the multifaceted nature of effective math instruction. Additionally, given the range of topics that the teachers chose, I was glad that I did not attempt to prescriptively tell teachers what to focus on.

For the next eight weeks of the course, teachers engaged in a Plan-Do-Study-Act (PDSA) action research project cycle [11]. Working together as a PLC, the teachers reflected on and discussed each stage of their PDSA cycles in online discussion boards. Through this collaborative process, the PLC aimed to generate insights that could inform the teachers' future teaching practices and contribute to the broader discourse on math education pedagogy.

2. Theoretical Framework

The theoretical foundation for this study is grounded in the principles of action research projects and PLCs. PLCs provide a supportive environment for teachers to engage in collaborative inquiry, share knowledge and experiences, and offer constructive feedback [12,13]. Whether virtual or in-person [13], referred to as pods [14], pacts [15], or communities of practice [13], effective PLCs share common features.

These communities have a common purpose, shared goals, and a commitment to student success. Teachers work collaboratively to examine student data and instructional practices, deciding on strategies to enhance teaching and learning [16]. PLCs are evidence-based, focusing on ongoing growth and learning, and they continuously experiment to improve practices. They foster cooperation, emotional support, personal growth, and synergy of efforts.

Deliberative leadership, safe working environments, and essential practices contribute to the success of PLCs [17]. By collaborating, sharing knowledge, and learning together, teachers create a culture of continuous improvement. The collective efforts within PLCs lead to better outcomes for students [16,17].

Creating a productive PLC involves aligning these features, fostering collaboration, and valuing professional growth. By promoting a sense of collective responsibility and a shared commitment to student success, PLCs can positively impact instructional practices and drive continuous improvement [16].

Action research, as defined by Mertler, is a cyclical process where teachers identify an area of focus, implement interventions, collect and analyze data, and reflect on the outcomes, all aimed at improving their practice and enhancing student learning [18]. This

iterative process allows teachers to continuously refine their practices based on evidence and reflection.

Action research PLCs involve educators working collaboratively to refine their practices, with teachers acting as integral members of the research process, making it both collaborative and participative. In these PLCs, teachers work together to identify areas for improvement, design and implement interventions, collect and analyze data from their classrooms, and engage in critical reflection on the outcomes.

Action research can provide teachers with practical and relevant insights about how incremental changes can lead to improvements in their practices. Since teachers actively participate in all aspects of the research, the values and voices of the affected communities are genuinely incorporated, and deficit perspectives can be challenged [19]. This approach ensures that the research is grounded in the realities of the classroom and the lived experiences of teachers and students, rather than imposing external perspectives or assumptions.

Through action research projects, teachers can inquire about and critically reflect on their practices in a systematic and rigorous manner. This process of inquiry and reflection can help teachers develop a deeper understanding of their teaching strategies, classroom dynamics, and student learning needs. Action research can empower teachers to become reflective practitioners and active agents in their professional growth [20].

By engaging in action research PLCs, teachers can collaborate with their colleagues, share their findings, and learn from one another's experiences. This collaborative approach fosters a culture of continuous learning and improvement, where teachers can support and challenge each other in a safe and supportive environment. Collectively, teachers can identify and address common challenges, explore innovative pedagogical approaches, and contribute to the broader knowledge base of effective teaching practices.

Overall, action research PLCs provide a powerful framework for teachers to engage in ongoing professional development, enhance their teaching practices, and ultimately improve student learning outcomes. Through a cyclical process of inquiry, intervention, data collection, and reflection, teachers can become researchers of their own practice, empowering them to make informed decisions and drive positive change in their classrooms and schools.

The synergy between action research and PLCs has the potential to catalyze incremental improvements [21–23]. The collaborative nature of PLCs can enhance the rigor and validity of action research. When teachers work together, they can draw upon diverse perspectives, challenge assumptions, and refine their interventions, ultimately leading to more robust and meaningful findings.

Research supports the potential efficacy of PLC-supported action research projects with teacher-selected foci and incremental goals. Otten et al. found that bottom-up approaches can lead to significant improvements in teaching practices [8]. Additionally, de Araujo et al. emphasized the importance of high-uptake practices [9]. Moreover, as described in the Introduction, Doyle and Ponder highlighted the role of practicality theory in facilitating teacher acceptance of change [10].

3. Methods

This qualitative study employed a case study approach to examine six secondary math teachers' perceptions of the impact of their PLC-supported action research projects. The goal of the investigation was to understand teachers' perceptions of the outcomes of their PLC-supported action research projects, which had teacher-selected foci and incremental goals. This case study spanned sixteen weeks. The data included teachers' action research project final papers. In this section, I discuss the research setting and participants, data, and the analytic approach that guided this study.

3.1. Research Setting and Participants

This study was conducted within a graduate math methods course at a large research institution in the southern United States. Table 1 provides information about the six secondary mathematics teachers. One of the six teachers obtained her teaching license through an undergraduate secondary mathematics education teacher preparation program. This teacher was in her fourth year of teaching secondary math. The five other teachers earned bachelor's degrees in kinesiology, information technology, physics, business administration, and meteorology. These five teachers had 1–2 years of teaching experience and had obtained their secondary mathematics teaching licenses through an alternate route graduate degree program. All six teachers were White, four were men, and two were women. While all taught at rural public schools, none taught at the same school.

Table 1. Secondary Mathematics Teacher Participants.

Pseudonym	Years of Experience	Age	Bachelor's Degree	Course
MC	4	27	Secondary Math Education	7th Grade
BB	1	25	Meteorology	Algebra II
AW	1	26	Kinesiology	8th Grade
CK	1	28	Physics	8th Grade
RH	2	34	Information Technology	6th Grade
AN	1	39	Business Administration	8th Grade

3.2. Data

Throughout the 16 weeks of this study, teachers participated in online discussions. During the initial eight-week period, teachers read and discussed four books. These literary works introduced methodologies for promoting equity within math classrooms [1], fostering iterative mathematical thinking [2], facilitating productive mathematical discourse [3,4], and cultivating environments conducive to student thinking [5]. I used the Connect, Extend, Challenge routine from Project Zero to stimulate reflective discussions about the readings [6]. After each teacher contributed, I created a weekly synthesis post, summarizing the discussions. Additionally, I used private comments to individually interact with the teachers. I purposefully used inviting, suggesting, explaining, describing, and evaluating discursive moves to assess and advance teachers' knowledge of the methods presented in the texts [7].

During the next eight weeks of the course, teachers discussed their PDSA action research projects [11]. The discussion board topics were selected based on the sections that teachers would need to include in their final action research project papers. The discussion topics included the following: Identify Your Problem, Write Research Question, Identify Connections to Each Book, Finalize Your Plan, Data You Collected, Data Analysis, Interpretation of Results, Limitations, Implications, Contributions to the Field, and Future Teaching and Research Directions. Each discussion functioned like a PLC, as teachers discussed their progress, challenges, and provided each other with constructive feedback aimed at helping each other refine their action research projects. The teachers' final reports summarized each stage of their action research projects. For this study, the data analysis focused on teachers' final reports, because the final reports represented a polished version of teachers' perceptions of the impacts of their PLC-supported action research projects.

3.3. Data Analysis

To assess teachers' perceptions of the impacts of the PLC-supported action research projects, I analyzed the six teachers' action research project final reports. I began by carefully examining each report to identify the specific problem of practice or challenge the teacher aimed to address through their action research project. Then, I analyzed the intervention chosen by the teacher as a potential solution, considering how it was justified

based on the course readings. I noted patterns and themes across the different problems and interventions. To assess the teachers' perceptions of the impacts of the PLC-supported action research projects, I closely read teachers' reflections on and evaluations of the impacts of their chosen interventions. I analyzed evidence such as data from student surveys, observations, and assessments to understand how teachers interpreted the intervention's successes, challenges, and outcomes in relation to their identified problems of practice.

I used thematic analysis to systematically code the reports and identify recurring themes related to problems, interventions, and perceptions [24]. I examined the language, tone, and underlying assumptions reflected in the teachers' writing. To develop a comprehensive understanding, I triangulated findings with teachers' discussion board posts and individual messages. Through synthesis across the six papers, I aimed to gauge teachers' perceptions of whether incremental improvements resulted from their PLC-supported action research projects.

3.4. Limitations

While this qualitative study offers valuable insights into PLC-supported action research projects through an in-depth analysis of teachers' reports, several limitations must be acknowledged. Firstly, the small sample size of only six reports restricts the generalizability of the findings to broader populations of teachers or educational contexts. Additionally, the teachers involved in this study were a convenience sample, which has more potential to be biased than if I had used random or systematically sampling methods to select teachers. Moreover, thematic analysis is inherently subjective, and my own biases and theoretical lenses could have influenced my interpretation of the data. Also, the action research reports themselves may not provide a comprehensive or nuanced account of the teachers' experiences, perceptions, and reflections. Since the data were self-reported by the teachers, it may have been subject to biases such as social desirability or selective memory. I could have conducted classroom observations and interviews to triangulate the data. These findings may also be context-specific, limiting their transferability to other grade levels, subject areas, or school settings. Finally, framing my analysis with PLC-supported action research lenses could potentially overlook alternative explanations or perspectives.

4. Findings

I begin with the set of problems and changes the teachers made. Then, I point out some of the themes and noteworthy phenomena from within the teachers' choices. Table 2 provides an overview of the incremental action research projects the teachers chose to carry out within the PLC. MC and BB both reported feeling overwhelmed by the quantity of questions their students asked during class time when they were supposed to be working independently or in small groups. MC and BB investigated the nature of the questions their students were asking but took different approaches. MC surveyed her 22 seventh-grade math students, and BB video recorded her 25 students during their Algebra II class to find out if their questions were stop thinking, proximity, or keep thinking questions [5]. MC found that most students self-reported asking stop thinking and proximity questions. BB watched one week of video recordings of her class and found that most stop thinking questions occurred after the lunch break in the middle of the class. Additionally, BB noticed some gender differences, with males asking the most stop thinking questions and females asking the most proximity questions. Both MC and BB talked with their students, and they developed a shared agreement that they would only answer keep thinking questions. Both MC and BB reported feeling that their incremental action research projects led to their students thinking more and both felt less overwhelmed.

Table 2. Secondary mathematics teachers' action research projects.

Pseudonym	Students in Sample	Problem	Intervention(s)	Instrumentation	Results
MC	22	many students asking many questions	only answer keep thinking questions	student survey	mostly proximity or stop thinking questions
BB	25	many students asking many questions	only answer keep thinking questions	observation (video recording)	most proximity or stop thinking questions
AW	100	students not enjoying math and not thinking	group work, non-curricular tasks	student survey	promoted enjoyment and thinking
CK	35	students not enjoying math and not thinking	incentivize test corrections	student survey	promoted enjoyment and thinking
RH	90	ineffective note-taking	write notes to future forgetful selves, open notes test	content test	improved test performance
AN	130	classroom management	co-construct norms	student survey	improved behavior

The problems that AW and CK aimed to address with their incremental action research projects were students not enjoying class and not thinking. To address the problem, AW tried two interventions with his 100 eighth-grade students, working in random groups of three, and using non-curricular tasks [5]. Inspired by Jansen, CK tried three different incentives to motivate student completion of test corrections, a daily grade, a prize, and an improved test grade [2]. Both AW and CK surveyed their students to uncover their self-reported enjoyment and thinking. On average, all of AW's students reported enjoying and thinking during both the group work and the non-curricular tasks. More specifically, on average, AW's students reported group work promoting the most thinking and the non-curricular tasks promoting the most enjoyment. AW stated that although he "found success with this research study, in the future I could improve on this study by adding more detailed questions in my student survey and trying out different activities." Similarly, on average, CK's students reported that the incentives motivated them to complete test corrections. However, on average, students associated low thinking and low enjoyment with the daily grade, high enjoyment and low thinking with the prize, and high thinking and low enjoyment with the improved test grade. CK created the graphs in Figure 1 to summarize his results. From left to right, students' ratings for the daily grade, prize, and increased test score incentives. Blue represents students' ratings for thinking or effort. Orange represents students' ratings for enjoyment. Likert scale ratings from 1 to 5 were used, with 1 representing "not at all" and 5 representing "very much."

RH's problem was that the notes his 90 sixth-grade students were mindlessly taking were meaningless notes during class. RH stated that his issue was "conveying all the information in a way that students can digest. What I find is students don't seem to translate what they learn to assessments". Instead of copying all of his notes throughout class, RH's incremental change involved having students write brief notes, in their own words, only at the end of class. RH also allowed students to use their notes on their test. RH found that, compared to their performance on previous tests, overall, students performed better on the test when they could use the notes they wrote to their future forgetful selves [5]. RH shared that he "learned that having students write brief notes in their own words at the end of class greatly improves their ability to recall and ultimately perform better on assessments".

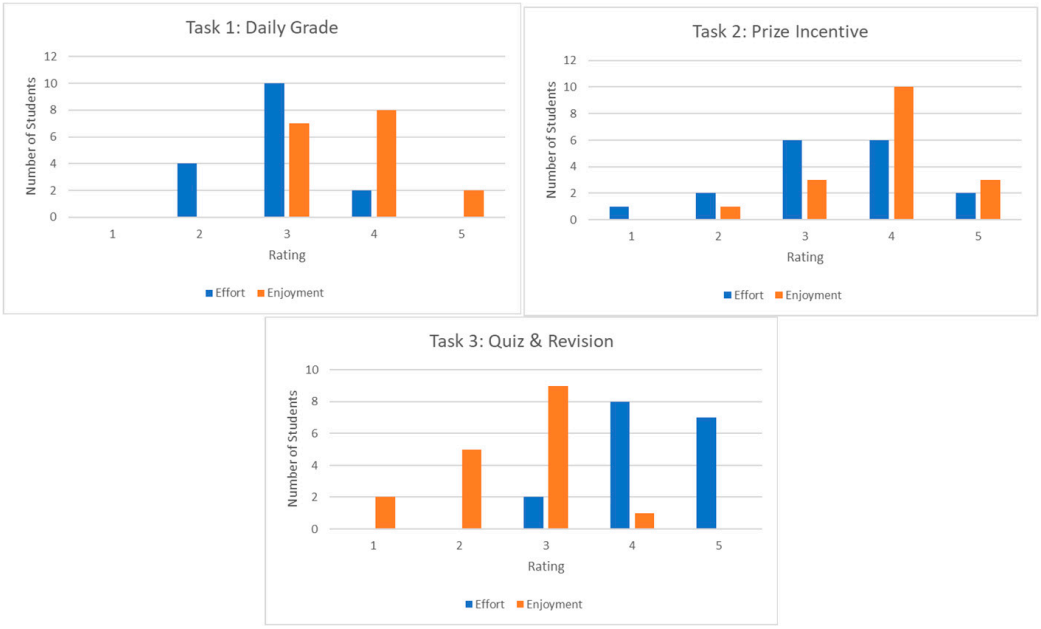

Figure 1. Results from CK's student survey.

Management of his classes of 130 eighth-grade students was the problem that AN aimed to address with his incremental action research project. Inspired by Jansen and Seda and Brown, AN co-constructed new class norms with his students [1,2]. During class, AN and his students brainstormed class norms. Then, AN surveyed his students about the rights and responsibilities they discussed [2]. Overall, students appreciated being included in the establishment of class norms. Although AN's former norms of being quiet, starting class when the bell rings, and not using their cell phones during class were not popular, students considered it important for the class to be conducive to learning. AN stated, "I was surprised at how much the students wanted structure. I think knowing the norms removed the anxiety caused by the former conditions of disorder. Once the norms were established I requested that the students sign a copy stating they agreed and understood. Common discipline issues declined so I felt very confident of my research".

The thematic analysis of the teachers' identified problems of practice revealed several overarching themes. The six teachers identified various classroom challenges. MC and BB were overwhelmed by the quantity of student questions during independent or small-group work. AW and CK faced issues with students not enjoying class and lacking cognitive engagement. RH noticed his sixth-grade students were taking meaningless notes. Finally, AN struggled with managing his classes and ensuring appropriate student behavior.

One common theme across the six action research projects was the teachers' use of participatory design. Through participatory approaches, historically marginalized communities, including students, are engaged as co-researchers and are empowered to design and implement a custom intervention. By taking a participatory design approach, the six teachers fostered collaborative decision making and mutual ownership of the research process [19]. MC surveyed her seventh-grade math students to categorize their questions, while BB used video recordings to analyze question types in her Algebra II class. MC stated that the survey results, which revealed that most questions were stop thinking or proximity questions, "were not surprising to me because I was expecting very similar results". On the other hand, BB was surprised by the "particularly a high concentration of questions following the mid-class lunch break and a gender disparity in the types of questions asked. The results suggest that the scheduled interruptions of the classroom significantly influence student engagement and questioning behavior. Moreover, the unexpected gender differences in questioning types highlighted potential areas for further investigation into socialization practices and gender-specific educational strategies". After sharing the results with their students, both MC and BB co-constructed agreements

with their students. Because they were involved in the research, MC's and BB's students understood why it was important for their teachers to only answer their keep thinking questions. AW's and CK's students helped brainstorm possible interventions and shared how much they enjoyed and how deeply they thought as a result of each intervention. AW introduced group work in random groups and non-curricular tasks to his eighth-grade students, and CK used three incentives (a daily grade, a prize, and an improved test grade) to motivate students to complete test corrections. RH had a discussion with his students about their current note-taking predicament and what notes to future forgetful selves are [5]. Together, RH and his students agreed to postpone their note-taking until the end of class and to write brief notes that were in their own words. They also collaboratively decided that students would be allowed to use their notes on tests. Finally, AN co-constructed class norms with his eighth-grade students to improve behavior and classroom management.

The results shed light on teachers' perceptions of the impacts of their PLC-supported action research projects. Overall, all six teachers perceived incremental improvements from their interventions. MC and BB felt their interventions led to students asking less proximity and stop thinking questions, which led to MC and BB feeling less overwhelmed. AW and CK observed increased student enjoyment and cognitive engagement. AW's students reported that group work promoted more thinking, while non-curricular tasks were more enjoyable. CK's students found the incentives effective for completing test corrections, although each incentive had different impacts on enjoyment and thinking. RH's intervention of personalized notetaking resulted in better test performance, indicating that the notes were more meaningful and helpful for students. AN's co-construction of class norms led to improved behavior, even though students did not value all the norms.

5. Discussion

5.1. Incremental Instructional Changes and Teacher Success

The findings from this study demonstrate that improvements can result from incremental instructional changes made through PLC-supported action research projects. All six teachers perceived improvements in the conditions that inspired their action research projects. These results align with the theoretical foundations of continuous improvement and the principles of PLCs and action research, which emphasize collaborative inquiry, targeted interventions, and reflective practice [12,13]. Incremental improvements, as described by Otten et al., are critical in creating sustainable change in educational practices by promoting gradual, manageable adjustments that lead to significant long-term benefits [8]. I consider each component of the action research projects important, including the support of the PLC, the teacher-selected foci, and the incremental nature of the teachers' goals critical to the teachers' success. While I am unable to tease out the extent to which each component may have contributed to teachers' success, I conjecture that teachers may have been less likely to experience success if they had transformational goals, because such ambitious changes may have been overwhelming and difficult to achieve within the time constraints and support structures available.

5.2. Tailored Interventions and Diverse Classroom Challenges

The diversity of problems addressed by the teachers—ranging from managing student questions and engagement to improving note-taking and classroom behavior—highlights the multifaceted nature of effective math instruction. The PLC-supported action research projects were tailored to meet each teacher's needs because each teacher had the autonomy to identify a specific classroom challenge that they wanted to focus on and with the support of their peers, design and implement a custom intervention. The teachers exemplified the practical applicability of action research in fostering incremental instructional improvements. This reflects the notion that action research allows teachers to critically examine their practices, identify areas for growth, and implement targeted changes [18]. Moreover, this approach aligns with de Araujo et al. , who emphasize that high-uptake

practices are most effective when they are directly relevant to teachers' existing contexts and needs [9].

MC and BB's focus on managing student questions through categorizing and selectively answering keep thinking questions illustrates how targeted incremental instructional changes can promote deeper student thinking and help teachers feel less overwhelmed. Their strategy of developing an agreement with students to only answer keep thinking questions fostered an environment where students were encouraged to think critically and independently, leading to improved classroom dynamics and student engagement. This approach demonstrates the importance of aligning new methods with existing knowledge, a key aspect of effective professional development [16]. AW and CK tried a variety of incremental instructional changes. AW's students worked in random groups of three and completed non-curricular tasks [5]. In an attempt to foster a rough draft philosophy in his math class [2], CK incentivized completing test corrections with a daily grade, a prize, and an improved test score. On average, all of AW's students reported enjoying and thinking during both the group work and the non-curricular tasks. More specifically, AW's students felt that group work promoted the most thinking, while the non-curricular tasks were the most enjoyable. Similarly, CK's students indicated that incentives motivated them to complete test corrections. However, students generally associated the daily grade with low thinking and low enjoyment, the prize with high enjoyment but low thinking, and the improved test grade with high thinking but low enjoyment. The teachers' incremental changes underscore the role of innovative pedagogical strategies in addressing classroom challenges. Their findings suggest that different strategies can have varied impacts on student engagement and thinking, reinforcing the need for context-specific solutions that promote incremental progress [8].

RH's approach to notetaking, which involved students writing notes to their future forgetful selves [5] at the end of class, led to improved test performance. This intervention highlights the effectiveness of practical, student-centered strategies in enhancing meaningful learning. Allowing students to use their personalized notes on tests not only made the notes more relevant and useful but also encouraged students to engage more deeply with the material. This incremental change in note-taking practices resulted in significant improvements in student outcomes, supporting the idea that small, manageable adjustments can lead to substantial educational gains [8]. AN's co-construction of class norms with his students resulted in better classroom behavior, demonstrating the value of involving students in the creation of rights and responsibilities of members of the mathematics learning community [1,2]. This approach aligns with the principles of practicality theory, which emphasize the importance of instrumentality, congruence, and cost in facilitating teachers' acceptance of change [10]. By ensuring that the new norms were practical, aligned with existing practices, and perceived as beneficial by students, AN was able to foster a more positive and well-managed classroom environment.

5.3. The Role of Reflection, PLCs, and Enjoyment in Teacher Growth

The PLC-supported action research projects also led to shifts in teachers' ideologies regarding the root causes of the problems they were experiencing, the key principles of effective interventions, and the profound potential impact of incremental changes in their practices. Initially, the teachers framed the problems as inherent in their students, and therefore very difficult to solve. As a result of the discussions and reflections in the PLC, teachers began to realize the roles they played in the problems of practice they identified. BB shared that the PLC-supported action research project led her to "reassess my educational practices to ensure I am providing an environment that is conducive to increasing student engagement". Regarding the nature of their interventions, all teachers discovered the importance of taking a participatory design approach by involving their students in developing effective interventions [19]. Through their PLC-supported action research projects, teachers experienced and reflected on how incremental changes in their practices could solve the problems they were experiencing. The PLC-supported action

research projects empowered teachers to realize the profound impact they have in solving their own problems of practice.

The supportive environment provided by the PLC, characterized by collaborative inquiry, the sharing of knowledge and experiences, and constructive feedback, was instrumental in the success of the action research projects. The PLC facilitated the teachers' ability to reflect on their practices, receive peer feedback, and collectively refine their interventions, which is consistent with the evidence-based, continuous improvement focus of effective PLCs [16,17]. This collaborative effort not only enhanced the rigor and validity of the action research projects but also promoted a culture of continuous learning and incremental improvement, where teachers could draw on each other's strengths and insights to refine their practices [21].

Additionally, the structured reflection prompts (Connect, Extend, Challenge) used in the PLC discussions helped teachers link the new methods they learned about in the four books they collectively read to their existing knowledge, broaden their thinking, and address emerging challenges. This reflective practice is crucial for promoting deeper understanding and ongoing professional growth [6]. By engaging in these reflective activities, teachers were able to connect new pedagogical strategies to their classroom experiences, extend their thinking by exploring new ideas, and address any challenges that arose during the implementation of their action research projects. This iterative process of reflection and adjustment is key to achieving incremental improvements in teaching practices [8].

Teachers also reported enjoying conducting their PLC-supported action research projects. They liked trying different incremental changes, assessing their effectiveness, experiencing positive changes, and receiving feedback from the PLC. Moreover, teachers reported enjoying learning about each other' studies and providing feedback. AN stated, "I enjoyed keeping up with my classmates' research. I know this class improved my teaching skills. I came away with new ideas and established research". It seems the grain size of the incremental changes contributed to teachers' success and enjoyment. I joked with the teachers that they had been bitten by the research bug. Although the teachers' enjoyment was not the focus of this study, it is important because it increases the likelihood of the teachers seeing themselves as researchers and conducting more incremental action research in the future. The sustained cumulative impact of ongoing action research could be profound. The veteran of the group, MC stated, "I have been teaching for four years. However, I know that no matter how long I teach, there is always something new that I can learn".

5.4. Implications for Teachers and Teacher Educators

Prior to engaging in their PLC-supported action research projects, half of the course was spent reading and discussing four books. Based on the discussions, teachers enjoyed and benefited from learning about the pedagogies in all of the books. However, looking across the action research studies, I noticed trends in which of the course readings teachers relied on. One trend I immediately noticed was that the practices from *Building Thinking Classrooms* resonated with the teachers and were the right grain size for their action research projects. MC's and BB's projects, which focused on incremental changes in the types of questions they answer, drew inspiration from *Building Thinking Classrooms.* AW's incremental changes in using random groups of three and non-curricular tasks were also guided by *Building Thinking Classrooms.* Moreover, *Building Thinking Classrooms* motivated RH's incremental change in having students make notes to their future forgetful selves. *Rough Draft Math* also inspired several teachers and offered incremental strategies. *Rough Draft Math* inspired CK to make an incremental change in his assessment policies by allowing and incentivizing test corrections. *Rough Draft Math* and *Choosing to See* motivated AN to co-construct norms with his students. I conjecture that although the teachers valued the practices shared in the *Five Practices in Practice*, they may not have considered it a feasible undertaking to learn to implement the five practices.

The findings from this study have several implications for math teachers, teacher educators, and researchers. The PLC model proved invaluable in supporting the action research process by offering a platform for teachers to share experiences, receive feedback, and engage in collective reflection. This collaborative environment fostered a sense of community, encouraged open dialogue, and facilitated the exchange of diverse perspectives, leading to more robust and well-informed interventions. By focusing on incremental changes, teachers can make manageable adjustments that lead to significant long-term improvements, ultimately benefiting both educators and students [8–10].

6. Conclusions

In conclusion, this article makes valuable contributions by sharing cases of how incremental approaches to professional development can integrate well with PLC-supported action research projects. Teachers were in the driver's seat, selecting the focus of their action research projects. However, these incremental changes were inspired by worthwhile ideas from math education scholars. Some may argue that the teachers did not implement the pedagogies with "full fidelity", and others may critique the teachers for not setting transformational goals. However, the cases underscore the significant potential of incremental instructional changes implemented through PLC-supported action research projects to improve teaching and learning. The collaborative and reflective nature of PLCs, combined with the iterative process of action research, provides a powerful framework for continuous professional development and effective teaching. Through structured inquiry within a supportive, collaborative environment, math teachers effectively identified and addressed pressing challenges in their classrooms, providing valuable insights into specific pedagogical issues and highlighting the interconnectedness of various factors that contribute to effective math instruction [8–10].

This study contributes to the broader discourse on math education pedagogy by demonstrating the practical benefits of integrating PLCs and action research in fostering ongoing improvement and innovation in teaching practices. By focusing on incremental changes, teachers can make manageable adjustments that lead to significant long-term improvements, ultimately benefiting both educators and students. This article provides important insights about the forms of support that can surround and promote the success of incremental improvements in teachers' practices. PLC discussions and reflections led to shifts in teachers' ideologies. Teachers realized the roles they played in causing the challenges that they were experiencing and therefore felt empowered to enact changes in their practices. Teachers also recognized the importance of taking a participatory approach by involving their students in developing interventions. The PLC model facilitated a culture of continuous learning, where teachers could draw upon the collective expertise of their peers, challenge assumptions, and refine their approaches based on evidence and their shared experiences.

Moving forward, it is crucial for educational institutions and policymakers to recognize the value of action research and PLCs as catalysts for pedagogical innovation and ongoing professional development. By providing structured support and dedicated time for collaborative inquiry, schools can empower teachers to become agents of change, continuously adapting and improving their practices to meet the evolving needs of their students. Future research could explore the long-term impact of sustained participation in PLCs on teacher efficacy, student outcomes, and school culture. Additionally, investigating the potential synergies between action research, PLCs, and other professional development approaches, such as coaching or mentoring programs, could yield valuable insights into creating comprehensive and holistic systems for teacher growth.

Ultimately, this study serves as a testament to the dedication and commitment of teachers to continually enhance their craft and create environments conducive to student success. By embracing a culture of inquiry, collaboration, and ongoing learning, educators can address immediate challenges and contribute to the broader advancement of math education pedagogy. The sustained, cumulative impact of ongoing action research and

PLC participation could be profound, leading to a continuous cycle of improvement that benefits both teachers and students alike.

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