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Addressing transition issues in mathematics and physics through practitioner inquiry

Tandeep Kaur[a], Eilish McLoughlin[b] and Paul Grimes[a]

[a] Centre for the Advancement of STEM Teaching and Learning and School of STEM Education, Innovation and Global Studies, DCU Institute of Education, Dublin City University
[b] Centre for the Advancement of STEM Teaching and Learning and School of Physical Sciences, Faculty of Science and Health, Dublin City University

ABSTRACT

This study reports on the implementation of a teacher professional learning programme designed to develop teachers' competencies in designing rich tasks that support student learning across transitions in mathematics and physics. Primary and secondary teachers were supported to conduct their own Practitioner Inquiry (PI) and design and implement rich tasks in their classrooms. This study reflects on the experiences of four teachers of mathematics and physics who collaborated as part of a professional learning community over a nine-month period. The findings of this study were identified from analysing teachers' reflections on their experiences of designing and implementing rich tasks in their classrooms and examining the impact of these tasks on their students' learning through practitioner inquiry. Examples of rich tasks prepared by teachers will be discussed along with the challenges identified by teachers in carrying out practitioner inquiry and designing appropriate rich tasks.

KEYWORDS

Practitioner Inquiry, Teacher professional learning, Transitions, Mathematics and Physics learning

CONTACT: Tandeep Kaur, tandeep.kaur3@mail.dcu.ie

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Introduction

Between the ages of 10 and 16, students face a range of educational transitions such as transitions across school systems (e.g. primary level to second level), transitions between different teachers, transitions across subjects (for example from general/broad science curriculum to a specialised physics curriculum and transitions across mathematics and physics) and several other social transitions. These transitions present several challenges for both students and teachers, as from the ages of 10 upwards, students experience new curricula and specialist teachers in these subjects. The implications of difficult transitions are associated with decline in academic performance, negative attitudes towards learning and students' wellbeing (Kaur et al., 2022). These challenges are particularly prevalent in mathematics and physics where students' negative experiences act as barriers to their learning and result in disengagement and disinterest for these subjects. Findings from a recent systematic review on mathematics and science transitions suggest the important role of learning environment and teachers' instructional practices in shaping students' experiences of these transitions as well as their interest and identity in subjects of physics and mathematics (Kaur et al., 2022). Therefore, student engagement in authentic learning opportunities is crucial for developing their conceptual understanding and improved learning (Stein et al. 2008; Sullivan et al., 2016).

Rich tasks have been identified as a valuable approach for designing differentiated activities that address students' learning needs and interests (Bobis et al., 2021). Rich tasks, a term more widely used in the context of mathematics, refer to authentic learning opportunities that are accessible to a range of students, promote productive struggle and are characterised by real-life applications of learning (Piggott, 2011; Sheffield, 2003). Several characteristics and learner outcomes of rich tasks have been identified, e.g. Rich tasks have a focus on inquiry, improve questioning, promote reasoning and problem solving, encourage collaboration and provide opportunities for critical thinking (NRICH). Such tasks can provide a useful scaffolding tool to enhance student learning in cognitive, behavioural and affective domains. However, for a sustained impact, teachers must be supported in both designing and implementing rich tasks and investigating how these tasks impact student learning in their own classrooms.

Practitioner Inquiry (PI) is a model of teacher professional learning defined as the "systematic, intentional study of one's own professional practice" (Dana & Yendol-Hoppey, 2014, p.12). By systematic engagement in enactment and reflection, the purpose of PI is to improve classroom practices with a focus on student centred learning. It provides educators with the tools to problematize their own teaching practices, and critically reflect on their beliefs and assumptions (Cochran-Smith & Lytle, 2009; Dana & Yendol-Hoppey, 2014, 2020). Many studies have established the powerful impact of PI on teachers' professional growth as well as on student learning experiences (Ermeling, 2010; Nichols & Cormack, 2017). Interchangeably referred to as 'teacher research', 'teacher inquiry' or 'action research', PI has emerged as a research tradition that 'highlights the role classroom teachers play as knowledge generators' (Dana & Yendol-Hoppey, 2020, p.5). Practitioners ask questions or wonderings, gather data to explore their wonderings, analyze data and make changes in their practice based on the knowledge they construct and share findings with others (ibid). By developing an inquiry stance, teachers become aware and responsive of their students' needs, and take evidence-based decisions to bring meaningful change in their classroom practices. A valuable context where teachers can engage in PI in a supportive and collegial environment, is a professional learning community (PLC) of teachers. While PI has a focus on a teacher's own practices, PLC as a professional learning approach provides opportunities for teachers to collaborate, share ideas and learn from the practice of other teachers. Through exchange of ideas and professional dialogue, effective PLCs promote a culture of inquiry among teachers and are characterised by a shared vision and curiosity about student learning (Cochran-Smith & Lytle, 2009).

A criticism around PI is that it takes a considerable amount of time and space for teachers to delve deeper into practitioner inquiry, collect quality evidence and reflect critically on the practices undertaken (Ponte, 2002). However, despite this challenge, studies have shown that teachers who engaged in PI develop a higher confidence in the use of innovative classroom practices, consequently resulting in an improvement of pupils' learning and engagement (Ermeling, 2010; Nichols & Cormack, 2017).

Study context and aims

The aim of this study is to investigate teachers' experiences of carrying out a practitioner inquiry and examine the influence on their student learning in mathematics and physics. This research is carried out as part of a larger-scale programme that aims to support teacher professional learning to address transition issues in mathematics and physics with students aged 10-16 years (STAMPEd, n.d.). The programme facilitates teachers to inquire into their own practice, collaborate as a professional learning community (PLC) and design and implement rich tasks in their classrooms (Grimes & McLoughlin, 2021). The model adopted in this study to support teachers conducting a practitioner inquiry as part of a PLC has been described by Grimes and McLoughlin (2021), shown in Figure 1.

Figure 1. *Practitioner inquiry stages (source: Grimes & McLoughlin, 2021)*

This programme is developed using an Educational Design Research (EDR) approach (Lovatt, Grimes & McLoughlin, 2020), and data from this study was gathered as part of the EDR framework for the programme. This study examines four Irish teachers' experiences of conducting a practitioner inquiry as part of a PLC over a nine-month period and addresses the

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research question: ***What are teachers' experiences of using practitioner inquiry to address transition issues in mathematics and physics?***

Methodology

Four in-service teachers (one primary and three post-primary) formed a PLC and carried out a PI (referred to as Teacher 1 to Teacher 4). Seven PLC workshops, facilitated by STAMPEd project researchers, were facilitated as two-hour online workshops (due to Covid-19 pandemic) over a nine-month period, from September 2021 to May 2022. These workshops focused on developing teachers' understanding of practitioner inquiry and to support them to systematically inquire into their own practice.

Table 1. *Overview of PLC workshops*

Workshop (WS)	***Focus of workshop***
WS1 (Sep 2021)	Teachers identified and discussed transition issues. PLC established.
WS2 (Oct 2021)	Factors that influence transitions identified in literature mapped to factors identified by teachers. Teachers identified their own passions and were introduced to the concept of rich tasks.
WS3 (Nov 2021)	Introduction to PI. Teachers proposed a PI question.
WS4 (Dec 2021)	Features of rich tasks introduced
WS5 (Jan 2022)	Teachers engaged in co-designing rich tasks.
Between WS5 and WS6, one-to-one meetings were held between teachers and one researcher.	
WS6 (May 2022)	Understanding and interpreting PI data.
WS 7 (May 2022)	Teachers shared their PI and discussed experiences at the Showcase event.

In the first workshop, teachers were asked to discuss and reflect on the key issues and challenges of transitions in education and transitions across mathematics and physics. These discussions promoted sharing and exchanging of experiences between the teachers and supported the establishment of a PLC that had a shared goal of supporting students across mathematics and physics transitions. The second workshop facilitated teachers to identify their passions and introduced them to the concept of rich tasks. Teachers reflected on their own practice through the lens of eight passions conceptualised by Dana and Yendol-Hoppey (2020) (Figure 2). Using these passions as inspiration, teachers identified their own passions in education and delved deeper into their passion to come to a personal question about their practice. This is the first step towards a researchable PI question. For example, a strong inclination of Teacher 1 towards advocating equity and social justice led them to inquire into how language could be made more accessible to students across mathematics and physics transitions.

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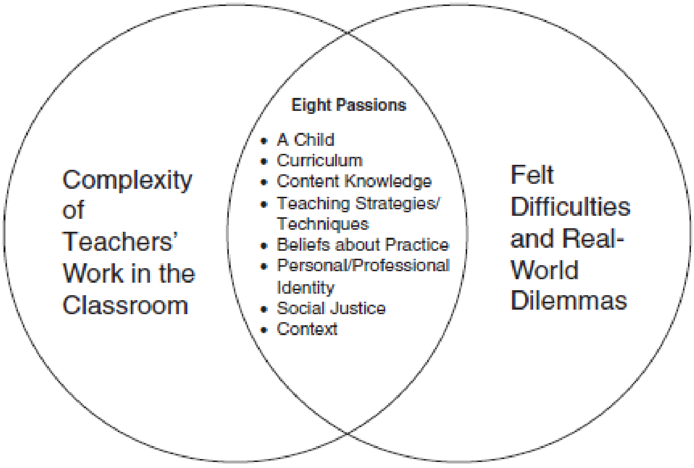
Figure 2. *Eight passions for developing practitioner inquiries (source: Dana & Yendol-Hoppey, 2020)*



The next two workshops (WS3 and WS4) introduced teachers to PI and features of rich tasks. In WS5, teachers engaged in codesigning rich tasks in mathematics and physics, using a structured approach. This supported teachers in designing rich tasks to implement with their students as part of their own PI. Throughout these workshops, teachers deepened their understanding of PI and how it can be used examine their students' learning. Students' learning experiences were evaluated by teachers in their own classrooms, using a variety of methods such as class observations, written feedback, student interactions, whole class discussions, assessment using rich tasks and students' views on the use of approaches used for their PI.

Findings

The teachers in this study conducted their PI in different physics and mathematics topics. Table 2 presents the passion related to teachers' PI question and the education level they focussed on.

Table 2. *Overview of teacher's practitioner inquiry questions*

Participant	*Education level**	*Teacher's Passion*	*Practitioner Inquiry Question*
Teacher 1	Senior cycle	Equity/Social Justice	How can I improve the physics classroom environment for my EAL students?
Teacher 2	Junior cycle	The curriculum	How does the use of visual strategies with student-generated questions impact student understanding in Speed/Distance/Time and Trigonometry?
Teacher 3	Junior cycle	Teaching strategies	How does Peer Feedback Effect Higher Academic Achieving Students in Maths?
Teacher 4	Upper Primary	Content knowledge	How can using visual strategies support students' learning and confidence in answering 6, 7, 8 and 9 multiplication facts?

*In Ireland, students attend primary school typically between the ages of 5 and 12, the junior cycle of secondary school between the ages of 12 and 15 and the senior cycle of secondary school between the ages of 15 and 18

A brief overview of each teacher's practitioner inquiry is provided below.

Teacher 1

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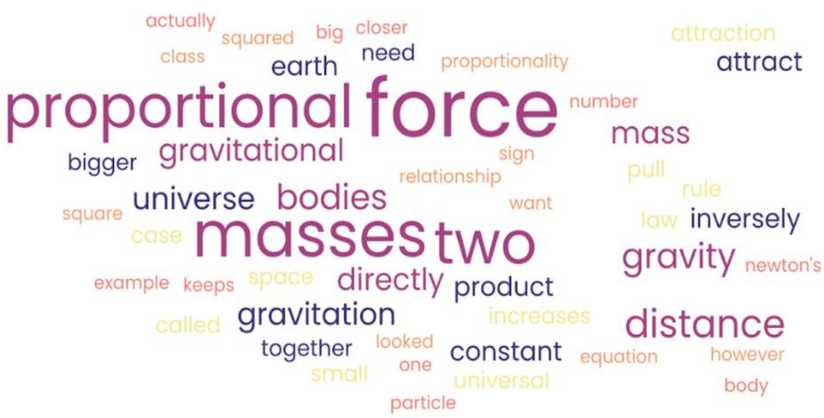
Grounded within the realm of social justice, and their passion for equity in the classroom, Teacher 1 engaged in PI with a focus on exploring how to make physics and mathematics more accessible for students for whom English was not their first language. Teacher 1 focused on creating the right learning environment in the classroom, collaborated with the EAL (English as an Additional Language) and MFL (Modern Foreign Language) teachers and paid special attention to students' identities. In creating a positive learning environment, they used a variety of strategies such as word banks, summarising exercises after each activity, comprehension, videos of experiments, infographics, visual presentations, and use of Google speakers in the classroom. Throughout the process, Teacher 1 ensured that students are well aware of the fact that the teacher is cognizant of their learning needs so that they can be more open in turn to ask for the support they need. The teacher identified a useful strategy to obtain feedback on students' learning was to summarise students' responses after every activity and put them in a word cloud to capture feedback on how that concept was understood by students. Figure 3 shows a word cloud generated by Teacher 1 to investigate students' understanding of the concept of 'Force'.

Figure 3. *Word cloud generated from students' responses*



Another strategy that proved really beneficial was the use of Google speakers in the classroom which provided the required information about the topic and also described the source of information to students. Not only did this help students in understanding the related topic but also helped them in developing the skill of identifying a safe, and trustworthy source of information, and distinguishing between reliable and unreliable sources.

Teacher 1 made the following observations as they reflected on their practitioner inquiry

- *Everyday became a language day… every class was an opportunity to discuss and enjoy language*
- *Changing teacher practice leads quickly to a change in student interaction.*
- *Students began to request translations further examples images and context*
- *Students initiated conversations about language and words.*
- *In general students began to ask more questions and have independent discussions-students appear more confident.*

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Teacher 1 noted that students' awareness of their teachers' cognizance of the language challenges had a very positive impact on classroom learning. Such a mindful approach to students' identities noticeably improves students' confidence. Learning happened organically with these students and all students looked for opportunities to learn, discuss and share. The task, although conducted in physics, led to greater student interest in exploring language for other subjects and purposes too. They also noted that the use of a word cloud allowed them to reflect on their own focus during the lesson, and what concepts may need further attention; in this case, they were concerned by the low prominence of the word *particle* in the word cloud.

Teacher 2

Concerned by a significant drop in students' mathematics and physics performance as they transition to the second year of their secondary school, Teacher 2 engaged in PI with a drive to support student learning through real life contexts, using visual strategies.

Integrating mathematics and physics using visual strategies, Teacher 2 focused on the topics of Trigonometry and Speed-Distance-Time. The tasks involved a site visit (school playground) where students took pictures to look for shapes and variables that they could measure. From these pictures, students generated questions, solved them and then used these questions to teach and/or challenge their peers. Figure 4 shows an example of student generated questions using visual strategies.

Figure 4. *Student generated questions using visual strategies*

The task was perceived as enjoyable by all students. Teacher 2 noted that all students performed better using the visual strategies and student generated questions. A key challenge however emerged as the time taken to conduct the task. Teacher 2 shared that the initiative took approximately twice as long than usual time taken (with teacher-directed classroom teaching) to complete. This meant that the class in which these visual strategies were implemented, lagged behind other classes in content coverage with respect to the time specified in curricular specifications. Although all students enjoyed the activity, the high-achieving students did not want to repeat it and said that it took a long time - '*Quicker the old way. This took a long time.*'; *'I liked the activity but more work for an easy topic'.* Low-ability students preferred the tasks and found the questions easier than traditional text-book questions - *'I prefer the questions we made. They are easier than the book ones.'; 'Good fun and I understand it now.'*

Reflecting on their PI, Teacher 2 concluded that students who usually found these topics difficult to grasp, showed a clearer understanding of the concepts. Their performance scores were better after the task. Especially in the case of weaker students, they enjoyed the task and showed increased confidence. Thus, while the tasks proved beneficial for all student groups, gains in conceptual understanding and performance scores were reported to be higher for weaker students as compared to the high achieving students.

Teacher 3

Intrigued to explore the potential of a variety of teaching strategies, Teacher 3 chose to examine how peer feedback influences higher achieving students in mathematics. Guided by literature around peer feedback and discussions with the members of their PLC, Teacher 3 made the hypothesis- 'Students who are "underachieving" at Mathematics benefit greatly from feedback but find it difficult to give feedback to "over-achieving" students in Mathematics, hence limiting the over-achieving students benefits from Peer Feedback''.

Teacher 3 engaged in this inquiry with a class of second year ordinary level mathematics students. The class had no prior experience of peer feedback, and this was the first time they engaged in such activity. Students worked in groups to give feedback on their peers' work for the given tasks. The groups were formed in a way that each group had a similar mix of high achieving and under achieving students. Students were given a task and a feedback sheet to write their feedback to another person in their group. The activity was repeated with three different mathematics tasks on the topics of 'Financial mathematics' and 'Area'. After each task, Teacher 3 discussed the type and quality of peer feedback with the whole class. To examine the change in students' performance as a result of peer feedback, Teacher 3 collected students' performance scores in three tests each for pre-feedback and post-feedback. Teacher 3 analyzed the results of the pre- and post-feedback tests in the following way:

- The average result of each student over three tests pre-feedback.
- The average result of each student over three tests post-feedback.
- The overall class average pre-feedback and post-feedback.

Other than this data, Teacher 3 also made observations for students' engagement during peer-feedback activity and asked them to reflect on their experiences of engaging in peer-feedback. Reflecting on the results of their PI, Teacher 3 observed that students had started to feel comfortable in writing feedback for their peers and the quality of feedback gradually improved after each task. The results for the overall class average performance increased by 7.13% in the post-feedback tests.

However, as Teacher 3 analysed the data, they observed that analysis of average performance calculated for 'students who scored above 50%' and 'students who scored below 50%' in the pre-feedback tests results showed distinct differences. The average performance of students who scored above 50% in the pre-feedback tests decreased by 9.64%. On the other hand, the average performance of students who scored less than 50% in the pre-feedback tests improved by 7.13% in the post-feedback test results. This indicated that peer-feedback benefited low-achieving students more than the high-achieving students. Teacher 3 concluded that under-achieving students in mathematics did not possess a deep enough understanding of the topic to give feedback to those who did. This limited the benefits of peer feedback for high-achieving

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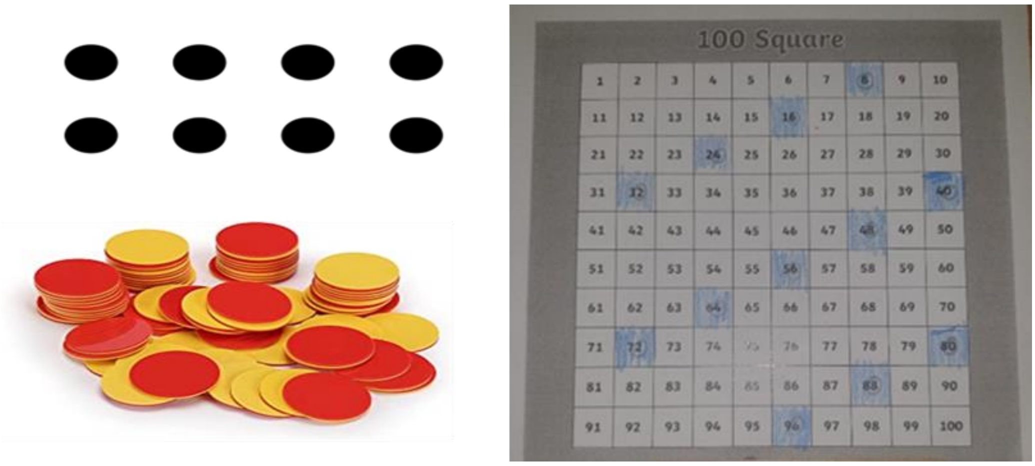
students in terms of improvement in their mathematics performance. This was reflected in the average results of the pre- and post-feedback tests.

Teacher 4

Focusing on content knowledge for transition to post-primary mathematics, Teacher 4 (a primary school teacher), used practitioner inquiry to investigate ways to alleviate maths anxiety and explored the role of visual strategies to support students' learning and confidence in answering 6, 7, 8 and 9 multiplication facts. Addressing this subject-specific transition, Teacher 4 used a variety of visual strategies (examples shown in figure 5).

Figure 5. *Examples of visuals used by Teacher 4*



After exploring multiple strategies, Teacher 4 realised that it was the connection to what students already know rather than the strategies used, that helped build students' confidence. Teacher 4 discovered that when students could see a problem that they are familiar with, it helped build students' confidence to attempt questions that were new to them and seemed difficult. This led Teacher 4 to structure their classes around students' prior knowledge so as to mitigate their anxiety in maths. Throughout the inquiry, the focus was not on right answers but on students' confidence to attempt new questions that they had not seen earlier.

Reflecting on the experiences of PI, Teacher 4 shared that initially one of the two students was reluctant to attempt any of the given questions but structuring tasks around students' prior knowledge instilled confidence in these students and they showed greater self-esteem in working out the steps of the given problems.

Reflecting on their experiences of practitioner inquiry, Teacher 4 made the following observations.

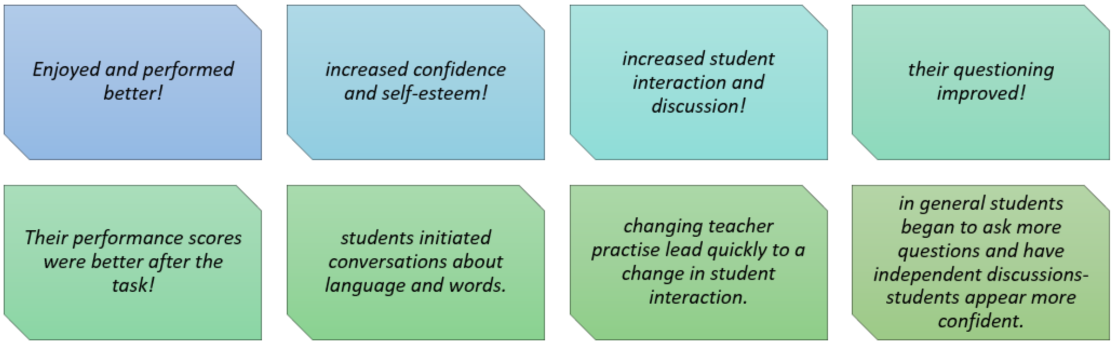
- *The intervention gave students strategies to have the confidence to attempt multiplication facts they previously didn't.*
- *When teaching multiplication facts in future, I will reuse steps 1, 4 and 5 most frequently in an effort to set future pupils up for success and reduce the anxiety around having to remember every fact.*

- *I will look at the students' summer Maths assessments to see if they were able to generalise these strategies to other Maths topics.*

Discussion and Conclusion

Overall, all teachers reported positive effects of PI on their own professional learning as well as on their students' learning. Their students enjoyed active participation in classroom learning and achieved better performance scores after the activity. Teachers reported increased student interactions and discussions and student questioning improved. Overall, students showed increased confidence and self-esteem towards learning. Some observations made by teacher inquirers are summarised in figure 6.

Figure 6. *Teachers' reflection of students' learning experiences*



At the end of the study, teachers shared the implications of their PI at a sharing event and reflected on their experiences of being part of the PLC over the 9 months. Their feedback provided insights into the value of PI for these teachers. 'Reflection' and 'Enactment' emerged as the two key aspects of the programme. Being cognizant of their students' identities, learning needs and their misconceptions, helped these teachers to reflect and modify their instruction as required at each stage. A key challenge noted by teachers is the time and space to engage in PI. Developing an inquiry stance needs time to delve deeper, observe, reflect, and modify which becomes challenging with time-bound curriculum (Dana & Yendol-Hoppey, 2020; Ponte, 2002). Despite these challenges, teachers in this study showed a willingness to engage and continually develop their skill of critical inquiry to improve students' learning experiences and for their professional growth.

In this study, teachers' engagement in the inquiry of their own practice provided them first-hand evidence of a positive impact of PI on students' learning and self-regulation skills. These teachers highlighted the importance of focussing their PI on addressing issues that negatively influence students' experiences of transitions in mathematics and physics, at primary, lower and upper second level. The findings presented in this study add to the existing body of literature around PI. Teachers appreciated the exchange of dialogue and feedback within their PLC and articulated this in the final sharing event. The use of PLC as a platform to develop inquiry stance amongst teachers, offers insights for other teacher professional learning programs, suggesting that PLCs can be a useful platform for developing an inquiry stance among teachers.

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