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Scaling professional learning and development: preparing professional learning and development providers to lead power of data teacher workshops

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ABSTRACT

This design-based research study examined the first two cycles of development, enactment, analysis, and redesign of the Power of Data (POD) Facilitation Academy. Professional Learning and Development (PLD) providers' geospatial technology (GST) skills, understanding of programme principles, preparation, and stages of concern for implementing POD Teacher Workshops were investigated. The POD Team analysed previous POD PLD models. Using these results, the POD Academy and Guide were developed, enacted, and revised. Two cohorts ($n = 28$) participated in the POD FA designed to prepare PLD providers to implement POD Teacher Workshops and to support teachers in learning to enhance an existing lesson via the integration of GST and Geospatial Inquiry. Data sources included surveys, daily debriefs, observations, performance assessments, and interviews. The qualitative data were analysed using inductive analysis conducted by two coders to reach agreement on codes and emerging themes. Quantitative data were analysed using descriptive statistics. Analyses informed the redesign and modification of the POD Academy and Teacher Workshops. Findings provide deeper insight into the needs and concerns of PLD providers in implementing PLD for science teachers. Furthermore, this investigation sheds more light on the selection and preparation of PLD providers as programmes seek to scale PLD.

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Introduction

A multitude of literature investigates the characteristics of effective professional development (PD) (e.g. Desimone, 2009; Guskey, 2002; Kennedy, 2016; Luft & Hewson, 2014). Research in this area identifies active engagement, content-focus, coherency, collaboration, and duration as design features of PD with the ability to impact teacher change of beliefs, attitudes, and/or practices (e.g. Whitworth & Chiu, 2015; Desimone, 2009; Kennedy, 2016). Furthermore, existing literature indicates that when these characteristics of effective PD are present, student achievement can be improved (e.g. Wallace, 2009). The

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terms PD and professional learning (PL) are often used interchangeably (Campbell et al., 2017). PD which is active, collaborative, and engages teachers as professionals in reflective practice results in professional learning (PL). Fullan and Hargreaves (2016), advocate for the more comprehensive concept of 'professional learning and development' (PLD). They argue PD involves learning something new that is considered useful, and that PL requires development to enable the application of the useful knowledge. They define PLD as 'deliberately learning something new, developing and growing personally and professionally, and doing this individually and with others' (Fullan & Hargreaves, 2016, p. 21). POD Teacher Workshops aspire to this model to both provide teachers new knowledge and opportunities to develop this knowledge, so we utilise the term PLD throughout the paper. Regardless of terminology, as Kennedy (2016) points out in a recent review of the literature on teacher development,

> There is little discussion in the literature about the nature of professional development expertise, how professional development providers are selected, how they are prepared for their work, or how their efficacy is assessed. These topics need to become part of our discussion as we generate and test our professional development theories of action. (p. 973)

As we are still not preparing enough students and teachers in the areas of science, technology, engineering, and mathematics (STEM) (Kuenzi, 2008; Means, Confrey, House, & Bhanot, 2008; National Research Council, 2011), funders and institutions are calling for and developing STEM-focused programmes that advocate for the meaningful integration of many disciplines in order to reach all students. More teacher PLD in science and STEM fields is needed to prepare teachers to implement these programmes. Scaling STEM PLD that has previously been effective to new locations and contexts is one strategy for expanding the number of teachers who are effectively prepared.

In order to provide high-quality STEM PLD for teachers, there is a need to understand the specialised skills STEM-focused PLD providers require to effectively engage and prepare teachers in STEM areas and fields. The current study focuses on the design, implementation, and analysis of a programme which prepares PLD providers to help STEM teachers effectively teach with technology and it provides deeper insight into their needs and concerns. The Power of Data (POD) Project was designed to support educators to provide STEM PLD to teachers by scaling up a previously developed POD Teacher Workshop (TW). The POD team first designed the TW, based on previous work. The POD Facilitation Academy and Facilitation Guide was then developed to enable PLD providers to implement POD TWs to teachers across the country with integrity to the original POD model. This current study focuses on the design, implementation and analysis of PLD in STEM and preparing providers to implement effective STEM PLD. This has particular implications as we strive to scale effective PLD and prepare providers to replicate these programmes.

Professional learning and development providers

As suggested above, there is little research investigating the work and practice of PLD providers (Kennedy, 2016; Perry & Boylan, 2018; van Driel et al., 2012). To serve effectively as a provider it is necessary to not only have expertise in teaching but to also be able to demonstrate that expertise through PLD activities (Byington & Tannock, 2011;

O'Dwyer & Atlı, 2015). In addition, PLD providers need to be able to effectively model good teaching (Margolis & Doring, 2013), make tacit aspects of the teaching practice explicit for participants (Borko, Koellner, & Jacobs, 2014), have a wealth of examples to draw upon, and be able to take on and know when to take on different roles of a facilitator like listener, coach, expert, mentor, critical friend, teacher, and leader (Krell & Dana, 2012; O'Dwyer & Atlı, 2015). Furthermore, PLD providers need to understand how teachers learn, how teachers are influenced by their own beliefs, experiences, and contexts, and the elements of effective PLD (Perry & Boylan, 2018).

Perry and Boylan (2018) suggest three categories of learning needs for PLD providers: teaching knowledge and skills, facilitation knowledge and skills, and knowledge of PLD. In the current study, we focus on the development of PLD providers' facilitation knowledge and skills and how the POD FA could support providers in developing the specific facilitation knowledge and skills required to lead a POD TW. Thus, this design-based research study examined the first two cycles of development, enactment, analysis, and redesign of the POD FAs. The current study examines how PLD providers were selected for participation as POD providers and investigates to what extent they were prepared for implementing POD TWs. Research questions included:

(1) Do providers have the technology skills needed to implement POD Teacher Workshops?
(2) Do providers understand the principles of POD? What of these POD principles do they understand and what is still unclear?
(3) To what extent do providers feel prepared to implement the POD PLD model? To what extent do providers develop an understanding for how to help teachers create Geospatial Inquiry lessons?
(4) What are providers' stages of concern for facilitating POD TWs?

POD professional learning and development model

Since 2009 the POD team has provided PLD to a diverse group of secondary teachers in rural and high-need schools with a focus on project-based learning (PBL) using geospatial technology (GST). Participants in our projects increased their technological and pedagogical skills, confidence teaching with PBL and GST, and implemented lessons which provided opportunities for students to analyse data and make claims based on evidence. The programme utilised PBL materials developed by the Buck Institute which define PBL as: 'a systematic teaching method that engages students in learning knowledge and skills through an extended inquiry process structured around complex, authentic questions and carefully designed products and tasks' (Markham, Larmer, & Ravitz, 2003). POD projects resulted in both teacher and student improvement in content knowledge, spatial skills, and scientific reasoning skills (Rubino-Hare et al., 2013). Based on this work, we discovered more effective approaches to POD workshop delivery, follow-up activities, and mentoring that improved learning experiences for teachers and students.

In order for student learning gains to continue following teachers' participation in PLD, changes to pedagogical practices must persist (Desimone, 2009). To assess the persistence of pedagogical practices and the overall effectiveness of the PLD, POD teacher skills, knowledge, school support, and student learning were measured pre- and post-PLD (Rubino-

Hare et al., 2013). Results indicated that when there was a high level of implementation of PBL integrating GST, teachers and students improved their performance, increased their use of GST, and used the technology as a tool to collect data, analyse data, and to communicate ideas. Prior to the POD workshops, a majority of teachers (75%) had essentially no GST skills. By the end, a majority of teachers (78%) were able to score at the highest two levels of GST proficiency. Student achievement also significantly improved with a moderate effect size, a finding that likely cannot be explained by maturation alone. In addition, an affective survey was administered to 84 students. A dependent-samples *t*-test was conducted to evaluate whether students' self-efficacy or attitude towards science or technology differed significantly. The results indicated students' average self-efficacy towards technology was significantly higher on the post-test (Claesgens et al., 2013).

POD PLD has been developed to meet high national standards for quality and impact and embody the most current research and expertise of what works in STEM learning. In order to scale the PLD, the POD Team ($n = 5$), consisting of geologists, GST experts, and science educators, analysed previous POD PLD using a learner- and outcome-focused approach consistent with design-based research (The Design-Based Research Collective, 2003) to identify the programme's core principles, to develop the POD Teacher Workshop (TW), and to develop the POD FA and Guide for the current study.

POD professional learning and development design principles

POD TWs are designed to help teachers integrate Geospatial Inquiry into existing courses. Geospatial Inquiry is defined as: asking and answering a question through the analysis and communication of data that are linked to a geographic location on, above, or near Earth (Rubino-Hare, Evans, Manone, Palmer, & Sample, 2016). These data are often represented visually via maps. Prior to this study, POD TWs had only been delivered by the POD Team. To take the programme to scale, it was necessary to impart deeply embedded PLD knowledge to providers who did not have familiarity with the programme. We engaged in an examination of prior work, an extensive literature review of best practices in science education, in teaching with GST, and in PLD for science teachers to craft the POD Design Principles:

(1) Geospatial Inquiry requires purpose: answering a question, solving a problem, or explaining a phenomenon.
(2) Geospatial Inquiry employs geospatial technologies as tools which enhance the ability to make sense of relationships and patterns in geospatial data and to create visual evidence to support written arguments.
(3) Geospatial Inquiry promotes cross-disciplinary practices and twenty-first-century skills such as collaborating with peers to ask questions, creatively selecting and displaying appropriate geospatial data, critically analysing and interpreting geospatial data, and engaging in an argument using geospatial data as evidence to communicate ideas to diverse audiences.
(4) Geospatial Inquiry is iterative, sequenced over time, and employs technological and communication scaffolds to promote conceptual understanding of big disciplinary ideas.
(5) Geospatial Inquiry is socially constructed. It provides opportunities to collaborate, compare ideas, and receive feedback on those ideas through productive, equitable and respectful discourse.

(6) Geospatial Inquiry involves reflective practice. It starts from prior knowledge and experience and requires metacognition to support conceptual understanding.
(7) Engaging in Geospatial Inquiry and seeing how Geospatial Inquiry is used by professionals provides inspiration to enter STEM careers. (Rubino-Hare et al., 2016, XX)

Once established, the Principles were used to design a more formalised TW with six components (engaging Geospatial Inquiry as a learner, implications for teaching with Geospatial Inquiry, pedagogical moves to support Geospatial Inquiry, career spotlights, designing a Geospatial Inquiry lesson, metacognition, and homework) and an accompanying Teacher Guide. We hoped to develop the capacity of teachers by providing support and resources in order to ultimately see student gains (Figure 1). We then developed a Facilitation Academy and accompanying Facilitation Guide to enable PLD providers to effectively implement the formalised POD TWs. The Academy is described in more detail in the Context.

Characteristics of effective science and technology professional learning and development

PLD is a critical component of successfully developing practices for teachers that lead to the effective integration of geography, science, and technology. Teachers often struggle with implementing GST in their classrooms and integrating it in their lessons (Rubino-Hare et al., 2016; MaKinster & Trautmann, 2014). Some professional learning standards suggest coherence and emphasise the integration of learning theory (Learning Forward, 2011). However, there are PLD standards unique to the practice of science teaching. For example, PLD in science should get teachers actively involved in investigating phenomena, interpreting results, and sense-making practices (Jeanpierre, Oberhauser, & Freeman, 2005). With this in mind, it is essential to first immerse teachers in authentic problems as learners. When participants experience the natural phenomenon and have the opportunity to grapple with data to resolve a problem, they are able to relate to the same experiences as their students. In addition, learners must have multiple opportunities to process new information and construct meaning for themselves. By becoming a learner, participants broaden their own understanding and knowledge of the content they are

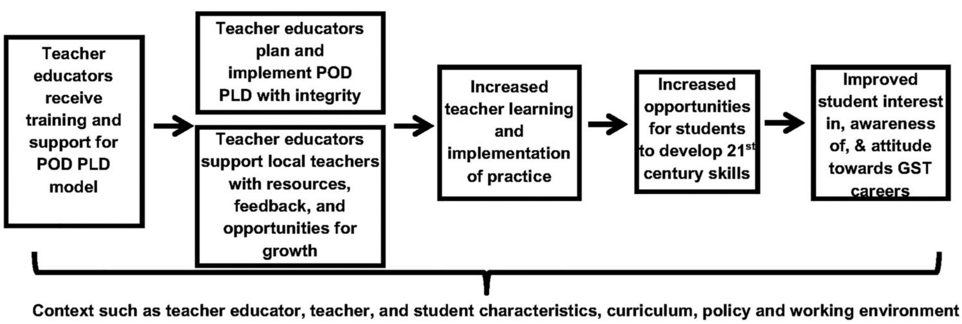

Figure 1. Proposed model for investigating the links between PLD providers and student interest and attitudes in GST careers.

addressing with their students (Loucks-Horsley, Love, Stiles, Mundry, & Hewson, 2003). There are specialised recommendations for PLD for teaching science with GST. These include helping teachers adapt existing lessons to incorporate geospatial analyses as opposed to creating lessons and emphasising how to use GST to teach content versus learning the technology in isolation (MaKinster & Trautmann, 2014).

Unfortunately, there is not as much research on what is best for the design of PLD for providers of science and technology-integrated PLD, so when designing the POD Facilitation Academy, we relied on and built upon best practices for PLD for science teachers and incorporated best practices for PLD providers, generally, as described previously. For example, it was important for the providers to experience an abbreviated POD TW, but the Academy also incorporated time for them to plan and customise TWs while keeping core ideas consistent. Additionally, effective instruction should be sequenced over an appropriate amount of time and situated in a larger context to build conceptual understanding (Desimone, 2009). Thus, PLD providers were given time to consider common teacher concerns and ways to help teachers successfully implement projects in classrooms.

Following the Academy, PLD providers were supported through online professional communities of practice for continued improvement (Learning Forward, 2011). The POD Team provided three to four opportunities for PLD providers to meet online through videoconferencing software each year. PLD providers also had access to a website with resources such as planning templates, sample teacher applications, memoranda of understanding, and a discussion board where they could post questions, successes, and/or issues that arose as they taught. Individuals also reached out to the POD Team and one another throughout the year to receive support as needed.

Scaling professional learning and development

Identifying methods to scale effective innovations and programmes to benefit a larger number of teachers and students, while still holding to the core principles of the original innovation is important if we view PLD as critical to educational reform (Heck, Plumley, Stylianou, Smith, & Moffett, 2019). Scaling PLD or innovations is necessary in order to maximise the impact of an innovation; thus, considering the approaches taken and the lessons learned from other researchers is necessary for success. To scale an educational innovation that works in one setting to other contexts, programme developers must understand and maintain the sources of effectiveness while making changes that enable it to thrive in different conditions (Dede & Rockman, 2007). In designing the POD PLD model, we tried to anticipate how the successful POD TWs might change in the hands of others and what that might mean for modifying the innovation.

In developing the POD TWs for scaling, we utilised the five dimensions of Dede and Rockman's (2007) framework: *Depth*, *Spread*, *Shift*, *Sustainability* and *Evolution* (Dede & Rockman, 2007; Dede & Knox, 2010; Dede, 2013) to determine what elements were critical for success and what could be changed in order to reach a larger audience. We also relied on advisors who scaled similar programmes and provided guidance. Future POD TWs might be less powerful than those we delivered ourselves but reaching more teachers would be worth the compromise. For example, with the availability of online GST tools, we scaled back expectations for technological competency and focused instead on the basic skills teachers would need in order to effectively engage students in simple but powerful, data analyses and visualisations for the purpose of understanding and explaining natural phenomena. However, PLD providers would need a much higher level of technological competency to troubleshoot problems and support teachers attending POD TWs.

Similarly, we reduced expectations for teachers to learn PBL, and concentrated instead on helping teachers enhance an existing lesson with a geospatial perspective for a specific purpose (Rubino-Hare, Bloom, & Whitworth, 2019; Whitworth, Rubino-Hare, & Bloom, forthcoming). It was, therefore, necessary to provide experiences that would allow teachers to engage in meaningful discourse around pedagogy and to provide templates to support the enhancement of existing lessons. PLD providers required guidance to provide useful feedback and address common problems teachers might encounter as teachers developed their lessons. Earlier, we addressed how we began by identifying the core principles of POD. These principles were useful when we developed the Academy and Facilitation Guide for PLD providers. For each activity of a POD TW in the Guide, we referenced one specific principle that was highlighted or emphasised as well as listing specific goals for teacher participants. Additionally, during the Academy, PLD providers were tasked with identifying specific components of the POD TW that exemplified certain principles.

Methods

A multiple methods design-based research approach (The Design-Based Research Collective, 2003) was employed to design, enact, analyse, and redesign the POD FA. Quality design-based research incorporates the following elements:

- Continuous cycles of design, enactment, analysis, and redesign during the development;
- Documents and connects the enactment processes to outcomes of interest;
- Details how designs function in authentic settings and focuses on interactions that refine our understanding of the learning issues involved; and,
- Results in sharable theories that help communicate relevant implications to practitioners and other educational designers (The Design-Based Research Collective, 2003, p. 5).

Pre- and Post-Academy surveys, Daily Debrief Forms from PLD providers and the POD Team, Post-Academy interviews, observations of the implementation of the POD FA, and artefacts were collected to answer the research questions. Qualitative and descriptive analysis of these data informed the redesign and modification of the POD FA.

Selection of professional learning and development providers

To enter a POD FA, potential PLD providers completed an online application. The application included a survey, a GST proficiency survey, and two letters of recommendation. The application included questions about applicants' experience as a PLD provider, experience with GST, their background in education, and demographics. The GST proficiency survey asked applicants to (1) identify when they had last used specific ArcGIS Online skills; (2) provide examples of geospatial analyses and when these might be appropriate for different spatial questions, (3) provide examples of data, applications,

Table 1. POD Facilitation Academy participant demographics.

Characteristic		Cohort 1	Cohort 2
Gender	Female	9 (60%)	9 (69%)
	Male	6 (40%)	4 (31%)
Highest Degree	B.A. or B.S.	0	2 (15%)
	M.Ed. or M.S.	10 (67%)	8 (62%)
	Ed.D. or Ph.D. in progress	1 (5%)	0
	Ed.D. or Ph.D.	4 (27%)	3 (23%)
Current Position	Science Lead Teacher	3 (20%)	3 (23%)
	Higher Education Instructor	7 (47%)	4 (31%)
	Other[a]	5 (33%)	6 (46%)

[a]Education Programmes Coordinator, Research Scientist, Wildlife Education Coordinator, Geospatial Data Specialist, Research Assistant.

and maps they had created, and (4) to identify skills for which they needed the most and least review. The POD team independently reviewed applications and scored them using a rubric assessing these criteria. Preferred criteria included: experience with PBL, experience teaching and learning GST, applying with a colleague, having a background in science, and experience participating with respected GST PLD. Each applicant was scored by at least two members of the POD team. The scores for each applicant were then compared by members of the POD team before coming to a consensus and scoring by a third POD team member if necessary. GST proficiency surveys and recommendations were also examined, with preference given to high GST knowledge and skills and strong recommendations. The top 15 applicants were selected as Cohort 1.

A few changes were made for the selection process for the second academy. Like the first FA, for the second academy two members of the POD team scored each application. However, if scores had less than 90% agreement, they were reevaluated by the entire POD team instead of just one additional team member. If scores had 90% agreement or greater, applicant scores were averaged. In the first FA, the top 15 applicants were selected; however, in the second FA a cutoff score of 45 out of 60 was established to ensure the quality of applicants accepted. Part of the reason for this change in cutoff score was to ensure the required GST skills were present. Only 13 applicants who scored above this cutoff score were selected as Cohort 2 for the second FA.

Participants

Participants ($n = 28$) of the POD FA were PLD specialists, district science coordinators, school STEM education specialists, and others whose primary goal was to support teachers (Table 1). Participants were recruited nationally and selected based on the criteria outlined above. There were 22 applications from which the final participants were selected for Cohort 1 ($n = 15$). There were 26 applications from which the final participants were selected for Cohort 2 ($n = 13$).

Context

Participants attended a five-day POD FA to: (1) increase understanding of POD Principles, (2) increase understanding of how Geospatial Inquiry cycle embodies the POD Principles, (3) increase confidence and skills for facilitating POD Teacher Workshops, (4) collaborate with POD team to study and refine POD Facilitation Academy, POD

Teacher Workshop, and supporting guides, and (5) receive access to Facilitation Guide, data, and other online materials to support implementation of at least two POD TWs. The Academy included the following daily components: experiencing an abbreviated version of the POD TW, talking about facilitation moves, exploring resources, and reflecting upon POD Principles. The components are described in more detail below:

- Geospatial Inquiry – Engages participants in a model unit on natural hazards and risk designed at adult-level content. Develop GST skills while engaging in multiple cycles of Geospatial Inquiry. Progress from acquiring and examining data, to learning about natural hazards and ways to forecast them, to considering risks the hazards might pose to humans, and determining when and where they might become disasters based upon proximity to vulnerable populations and their ability to respond.
- Designing a Geospatial Inquiry – Enhance an existing lesson to incorporate Geospatial Inquiry. A template scaffolds the process of backwards lesson design toward a series of lessons that engage students in multiple cycles of Geospatial Inquiry to answer a question, solve a problem, or explain a phenomenon. Formative assessments and criteria for success are identified.
- Implications for Teaching with Geospatial Inquiry – Consider cases from teachers who have taught with Geospatial Inquiry, Consider the benefits, anticipate potential barriers and potential solutions. Collaboratively examine student work to enable discussions about assessments, criteria for success, and the importance of providing regular feedback to students.
- Pedagogical Moves to Support Geospatial Inquiry – Consider how to support students' academically productive discourse through effective planning and questioning.
- Career Spotlight – Introduces participants to a diverse group of GIS professionals who engage in Geospatial Inquiry across a wide array of careers.
- Metacognition – review science content and geospatial technology skills learned, reflect upon learning through Geospatial Inquiry. Includes prompts that bring explicit attention to the elements of the TW that reflect the POD Principles and how one might apply what they learned.
- POD Facilitation – Reflect on a daily POD Principle. Examine elements of POD TWs that exemplify specific POD Principles. Collaboratively explore responses to common POD TW scenarios. Collaboratively plan POD TWs.

Data collection

Because the focus of the study is on PLD providers' abilities and understandings to implement the POD model through attending a Facilitation Academy, individual PLD provider data (GST skills, understanding of POD Principles, and preparation for and stages of concern for implementing POD Teacher Workshops) were the primary focus of the investigation. Multiple methods were utilised to collect and triangulate findings, identify patterns, and develop a rich description of the patterns of implementation and preparation of PLD providers (Creswell, 2014). Data sources included: PLD provider surveys, academy observations, team member and PLD provider daily debrief protocols, a GST performance assessment for PLD providers, and interviews with PLD providers after the completion of the Academy.

Pre-FA survey

The Pre-FA survey included 26 questions and was completed prior to the start of the FA. The questions focused on collecting information about PLD provider demographics, geographic location, education, teaching experience, and experience leading PLD. If participants had experience in administrative, supervision, or in leading PLD, additional questions were asked about the length of time in those roles, the type of roles, the PLD audiences the provider had worked with, and the type of PLD implemented.

Post-FA survey

The Post-FA survey was completed by PLD providers after the Academy. It solicited PLD providers' perceptions of the Academy, future supports needed, modifications for the Facilitation Guide, and elicited their understandings of the POD principles through retrospective pre–post questions. Retrospective pre–post questions asked PLD providers to rate their understanding, confidence in their understanding, and confidence in helping teachers incorporate concepts and practices prior to the Academy and following the Academy. PLD providers also identified their feelings about the 'innovation', implementing POD TWs, using the 35-question Stages of Concern Questionnaire (George, Hall, & Stiegelbauer, 2006) as a retrospective pre–post questionnaire at the end of the Academy.

The Stages of Concern is a seven-level measure of participants' affective experiences when adopting an innovation, in this case, the POD FA (George et al., 2006). It diagnoses whether adopters of an innovation are self-, task-, or impact-related concerns. If adopters are focused on self-related concerns, then they are unlikely to be successful in adopting the innovation. The seven stages of concern are: 0 – unconcerned, 1 – information, 2 – personal, 3 – management, 4 – consequence, 5 – collaboration, and 6 – refocusing. Stages 1–2 are designated as personal concerns, stage 3 is designated as a task concern, and stages 4–6 as impact concerns.

A retrospective pre–post design was used to minimise response-shift bias (Mathison, 2005). Face and content validity for the survey was established through review by a team of science educators, GST educators, and evaluators (Haynes, Richard, & Kubany, 1995; Newman & McNeil, 1998). Revisions were made to the survey following each round of review. Two rounds of review were completed for the instrument.

Observations

Observations were made of the POD FA using a Modified Collaboratives for Excellence in Teacher Preparation core evaluation classroom observation protocol (CETP-COP), which was piloted, field-tested and refined to document the instruction of science and mathematics teachers by Lawrenz, Huffman, Appeldoorn, and Sun (2002). This protocol was modified to explore the how PLD providers utilised facilitation principles and incorporated POD principles. It is designed to examine how teachers interact with their students, how students interact with one another, and what types of class activities (e.g. lecture, small group discussion, whole group discussion) are taking place during a specific segment of the lesson. Codes are assigned every 5 min of the session for every category.

At least two observers completed the protocol daily during the Academy. Any discrepancies were resolved through discussion to reach 100% agreement. Observations served to describe participant engagement levels as well as to track adherence to academy schedule. Field notes were taken while observers also tracked whether the POD team was adhering to the FA programme design and guide.

Daily debrief

Both POD Team members and PLD providers completed a daily debrief protocol to provide feedback on the components experienced during the Session for the day. This feedback was analysed by the POD team at the end of each Session, allowing for adjustment of components of the Academy to meet the needs of the PLD providers. Protocols included feedback on Session components that supported the learning and feelings of preparedness of participants as well as feedback on components needing further development.

GST performance assessment

PLD providers completed a GST post-academy performance assessment, which included assessment of GST skills. Participants were asked to map, analyse, and interpret tornado data in relation to their school communities. PLD providers were able to use resources in their facilitation binder as well as online to complete the assessment. Constructs were derived by experts in the field to align with the minimum GST skills needed to facilitate a GST TW. A rubric was developed and used to score the assessment.

Interviews

For Cohort 1 a random sample of approximately 50% of the PLD providers ($n = 8$) were interviewed using a semi-structured interview protocol following the Academy. This interview followed the survey and characterised the barriers and supports encountered during the Academy, the understandings of POD Principles, and the plans for implementation of TWs. Examples of interview questions included:

(1) Briefly describe your experience with providing PLD to teachers.
(2) Which components of the Power of Data Teacher Educator Academy did you find to be the most valuable? Why?
(3) How were you explicitly exposed to the key definitions and practices of geospatial inquiry, integrating geospatial technologies, scientific practices, and elements of effective instruction?
(4) As a result of attending the Academy do you feel prepared to lead your own POD Teacher Workshop? Why or why not?

The interviews lasted approximately 45 min and were digitally recorded and transcribed for analysis. Analysis of the data gleaned from these interviews included thick and rich details about PLD provider experience at the POD Academy. Consequently, the research team implemented a design-based research change to allow for all participants from Cohort 2 to be included in the interview sample ($n = 13$).

Artefacts

Various artefacts including the Power of Data Facilitation Guide, collaborative projects (e.g. story maps created to answer questions), and posters from group discussions (e.g. charts of participants answers) were collected during the POD Facilitation Academies.

These artefacts allowed space for PLD provider experience and participation to be documented for analysis. The artefacts served a data collection purpose while informing the integrity of practice for implementing the POD PLD. Collection of these artefacts allowed for the POD team to provide interventions where appropriate with the intention of strengthening the reliability of the research. Analysis of posters from group discussions and collaborative projects contributed to POD Project analysis. Additionally, collaborative projects also remain accessible to serve as resources for PLD providers.

Data analysis

A summary of the alignment between the research questions, data sources, and data analysis is provided in Table 2. Coding of observations, open-ended survey questions, GST performance assessments, and interviews were completed by at least two coders using inductive analysis (Creswell, 2014). Research team members began by working collaboratively to develop codes through the reading and re-reading of data sources and the consideration of the research questions and frameworks used. After developing codes through the reading and re-reading of observations, open-ended survey questions, and interviews, confirming and disconfirming evidence in the data were coded individually. After individual work was completed, research team members met to compare findings and reach an agreement. As appropriate codes were revised and refined as the agreement was reached. Inter-rater reliability was established and any disagreements were discussed to reach 100% agreement. Quantitative data were analysed using descriptive statistics. Confirming and disconfirming evidence found in the qualitative data to support the quantitative analysis was searched for and coded appropriately. These are reported together in the 'Findings' section below.

Table 2. Alignment between research questions, data sources, and data analysis.

Research question	Data sources	Data analysis
Do providers have the technology skills needed to implement POD Teacher Workshops?	• GST performance survey and GST performance assessment • Daily team debriefs	• Coded GST performance assessment for technological skill using GST • Confirmed technological skills through team observations during FA
Do providers understand the principles of POD? What of these POD principles do they understand and what is still unclear?	• Retrospective pre–post survey • Post -Academy interviews • FA observations • Analysis of posters • FA debrief forms • Researcher analytic memos	• Comparison of post-FA means with retrospective means on the survey using inferential statistics • Coded interview transcripts for evidence of understanding principles and struggles with principles • Confirmed principles taught through content analysis of FA using observation protocol • Coded posters for understanding of principles and lack of understanding of principles
To what extent do providers feel prepared to implement the POD PLD model? To what extent do providers develop an understanding for how to help teachers create Geospatial Inquiry lessons?	• Retrospective pre–post-FA survey • Interviews • Researcher analytic memos	• Statistical analysis of survey data • Coded interview transcripts for perception of preparation • Confirmed coding with researcher memos
What are providers' stages of concern for facilitating the POD TWs?	• Stages of Concern Questionnaire • Interviews	Scoring and interpreting Stages of Concern Questionnaire Data(George et al.,2006)

Potential threats to the validity of the design were addressed throughout the study (Creswell, 2014). During the data collection, qualitative and quantitative data were collected from the same population and contradictory results were explored. Multiple methods were utilised in the study as suggested by Erickson (1986), including: surveys, observations, interviews, and the collection of artefacts. Furthermore, unobtrusive data collection procedures were utilised and the analysis was consistently framed by guiding questions and the recognition of the researcher as an instrument for conducting the research.

Findings

The purpose of the current study was to investigate how PLD providers were prepared for implementing their own POD TWs. We present these findings by research question examining the PLD providers' GST performance skills, the effectiveness of the FAs in preparing POD PLD providers in understanding the POD principles, to teach Geospatial Inquiry to secondary teachers, feelings of preparedness to implement the POD PLD model, and concerns for facilitating their POD Teacher Workshops with integrity.

Geospatial technology performance skills

The GST Performance Assessment had two parts: GST skills and story maps. A story map is a visualisation that allows the author to combine maps with narrative text, images, and multimedia to utilise maps and geography to tell a story. In the POD FA, story maps were utilised to answer a question using data and maps. For the first cohort, the lowest score on the GST skills portion of the assessment was a 4 and the maximum score was 17 out of 17. The mean was 14.9 and the standard deviation was 3.4 (Table 3). Thirteen of the 15 PLD providers scored at least 80% (14 or higher) on this portion of the assessment. On the story map portion of the assessment, the lowest score was a 0 and the maximum score was a 12 out of 12. The mean was 9.9 and the standard deviation was 4.1. Twelve of the 15 PLD providers scored at least 80% (10 or higher) on the story map portion. Based on these scores, the majority of PLD providers appear to have the skills to successfully support teachers with GST skills during their workshops. Two PLD providers scored lower than 80% indicating they might struggle with the GST skills required to lead a POD TW. The POD team reached out to those PLD providers and offered them additional support to help improve their GST performance skills following the FA. The difficulties these PLD providers encountered led to a design-based research decision to increase the importance of GST experience in the assessment of Cohort 2 applications.

With Cohort 2, the lowest GST skills performance score was 14 and the maximum score was 17 out of 17. The mean was 16.2 and the standard deviation was 1.2. All of the 13 PLD providers scored at least 80% (14 or higher). On the story map portion of the assessment, the minimum score was 9 and the maximum score was 12 out of 12. The mean was 11.7 and the standard deviation was 0.9. All of the 13 PLD providers scored at least 80% (10 or higher).

Table 3. GST assessment scores by cohort.

GST assessment component	Cohort 1 ($n = 15$) M (s.d.)	Cohort 2 ($n = 13$) M (s.d.)
GST skills	14.9 (3.4)	16.2 (1.2)
GST story map	9.99 (4.1)	11.7 (0.9)

There were no significant differences between the two cohorts in regards to their GST Assessment scores. This is not unsurprising as we purposely chose PLD providers who reported they had these skills.

Observations of both cohorts during the FAs confirmed PLD providers have the GST skills required to support their teachers. For example, in the first FA, the POD team observed an improvement in PLD provider GST performance throughout the duration of the academy. One team member recorded that on Day 1 of the FA, 'PLD providers appear to have the GST skills need to implement the POD workshops. Some seem to need further development, but most seem comfortable with the work – those who are not comfortable are asking for help'. On Day 2, the same team member observed, 'PLD providers continued to demonstrate the performance skills needed to implement POD TWs … those who might be weak are working to make sure they understand the skills, asking questions. All seem to be able to solve issues'. On day 4 of the academy, the POD team compared their daily debriefs and summarised that 'PLD providers completed Geospatial Inquiry presentations today and the POD Team was very impressed with their products. PLD providers were very engaged in the process and had the skills needed to answer their own questions'.

The observation of improvement in GST performance skills during the course of the FA was echoed in the second academy. PLD providers were also aware of their GST skill improvement as a result of attending the FA. In her Post-Academy Interview, one PLD provider mentioned, 'I came in with a limited knowledge of GST, but I feel much better'. Overall, these results indicate PLD providers possessed the GST performance skills necessary to successfully implement a POD TW after completing the FA.

POD principles

Because POD principles reflect best practices in teaching and PLD, they were made explicit to PLD providers as part of the FA. Understanding these principles is critical to being able to effectively provide high-quality POD TWs and for teachers to ultimately design high-quality Geospatial Inquiry lessons for students. PLD providers were taught that the POD principles were the standard upon which their POD TW should be implemented with integrity. PLD provider understandings of POD principles were evaluated during and after the FAs to better prepare them to lead their own POD TW.

Based on self-reported knowledge gains in the Post-FA Survey, PLD providers from both cohorts appeared to understand the principles of POD. PLD providers had a significantly higher knowledge of concepts and practices enacted in the POD design principles after the academy than before the academy ($p < .05$) except for *Geospatial Inquiry is used as inspiration to enter STEM careers* for Cohort 2 (Table 4). Cohort 2 reported an understanding of this concept both before ($M = 3.25$) and after ($M = 4.08$) the academy with no significant difference ($p = .10$).

Interviews with PLD providers after the first FA revealed those with little prior GST experience identified *Geospatial Inquiry promotes cross-disciplinary practices and twenty-first century skills* and *Geospatial Inquiry is socially constructed* as the POD principles they best understood. While other PLD providers expressed concern about their ability to use *GST as tools to promote Geospatial Inquiry*. For example, one PLD provider who expressed these concerns in his post-academy interview:

Table 4. PD provider knowledge of POD principles.

	Cohort 1 ($n = 15$)		Cohort 2 ($n = 13$)	
POD principle	Pre-FA *M* (s.d.)	Post-FA *M* (s.d.)	Pre-FA *M* (s.d.)	Post-FA *M* (s.d.)
Geospatial Inquiry requires a purpose	2.47 (0.990)	4.13 (0.516)*	3.00 (1.00)	4.00 (0.577)*
Geospatial Inquiry employs geospatial technologies as tools	2.87 (0.915)	3.87 (0.640)*	2.92 (0.760)	4.00 (0.408)*
Geospatial Inquiry promotes cross-disciplinary practices and twenty-first-century skills	3.20 (0.941)	3.93 (0.458)*	3.23 (0.832)	3.85 (0.555)*
Geospatial Inquiry is iterative, sequenced over time, and employs technological and communication scaffolds	2.27 (0.884)	4.00 (0.000)*	2.46 (1.05)	3.77 (0.725)*
Geospatial Inquiry is socially constructed	3.20 (0.775)	3.73 (0.458)*	2.54 (1.13)	3.69 (0.751)*
Geospatial Inquiry involves reflective practice	2.73 (0.704)	3.73 (0.458)*	2.08 (1.12)	3.23 (0.927)*
Engaging in Geospatial Inquiry and seeing how Geospatial Inquiry is used by professionals provides inspiration to enter STEM careers	2.73 (0.961)	3.87 (0.352)*	3.25 (1.05)	4.08 (0.289)

*Indicates significant difference from pre to post at $p < .05$.

> I feel like there's a lot that I need to still to become comfortable and to know, you know, when somebody runs into a problem how to troubleshoot it or how to identify better ways or easier ways to do what they're hoping they can do with the with the technology.

This individual, like two others, expressed a need to have a stronger understanding of how to utilise GST in order to lead a TW. These findings from the first cohort were part of the impetus to implement a cutoff score in the selection of PLD providers for the second FA.

Interviews with Cohort 2 PLD providers revealed that those with little prior science content knowledge focused on *Geospatial Inquiry is used for a purpose* and *Geospatial Inquiry promotes cross-disciplinary practices and twenty-first century skills* as most important in what they understood. Some were concerned about teachers having the GST skills. They also felt there were good examples for careers but would like more examples. PLD providers struggled most with *Geospatial Inquiry is a reflective practice* and *Geospatial Inquiry is socially constructed*. About half the PLD providers indicated they were the least comfortable with these two principles.

PLD providers wrote on posters during the FA about what they understood about the POD principles (e.g. how they defined it) and how they saw the principles enacted in FA. This activity served as a time of reflection and metacognition for the PLD providers at the end of the day and they participated in small groups. Early in the week, providers who responded on posters seemed to misunderstand *using GST for a purpose* as evidenced by comments in sessions 2 and 3. They saw it as a way to 'engage students through activity or involvement'. By session 4, PLD providers saw GST as a way to solve a problem and focused on relevancy of the problem to student lives, which is a more aligned understanding of *using GST for a purpose*. For example, one group wrote during session 4, 'Today in our geospatial inquiry we really got to do our own project for our own purpose which made it even more relevant, authentic and engaging'. Another group wrote that Geospatial Inquiry was a 'relevant, engaging, authentic experience process: answering questions, solving problems, explaining phenomenon'. It is evident understanding of this principle developed over time. Similar results were observed for Cohort 2.

Overall, PLD providers from both Academies felt prepared to support teachers in understanding the Design Principles and using or modifying the content to use as part of their workshops. In addition, both cohorts displayed an increase in their knowledge and understanding of the principles over the course of the FAs.

Table 5. PD provider preparedness to teach POD principles.

POD principle	Cohort 1 ($n = 15$) Pre-FA M (s.d.)	Cohort 1 ($n = 15$) Post-FA M (s.d.)	Cohort 2 ($n = 13$) Pre-FA M (s.d.)	Cohort 2 ($n = 13$) Post-FA M (s.d.)
Geospatial Inquiry requires a purpose	2.40 (0.828)	4.13 (0.352)*	2.92 (1.04)	4.00 (0.408)*
Geospatial Inquiry employs geospatial technologies as tools	2.73 (1.03)	4.00 (0.535)*	2.77 (0.927)	4.00 (0.408)*
Geospatial Inquiry promotes cross-disciplinary practices and twenty-first-century skills	3.13 (0.915)	4.07 (0.458)*	2.77 (1.24)	3.69 (0.751)*
Geospatial Inquiry is iterative, sequenced over time, and employs technological and communication scaffolds	2.33 (0.900)	3.87 (0.352)*	2.15 (1.14)	3.85 (0.801)*
Geospatial Inquiry is socially constructed	2.87 (0.915)	4.07 (0.458)*	2.08 (1.26)	3.54 (0.660)*
Geospatial Inquiry involves reflective practice	2.53 (0.834)	3.67 (0.617)*	2.15 (1.14)	3.54 (0.877)*
Engaging in Geospatial Inquiry and seeing how Geospatial Inquiry is used by professionals provides inspiration to enter STEM careers	2.73 (0.884)	4.00 (0.655)*	2.77 (1.09)	4.00 (0.577)*

*Indicates significant difference from pre to post at $p < .05$.

Preparation to provide POD professional learning and development

In general, PLD providers felt prepared to lead their POD Teacher Workshops. All PLD providers significantly increased their feelings of preparedness to implement the POD PLD components (Table 5). For both cohorts, PLD providers felt significantly prepared to teach all the POD principles after the FA when compared to how prepared they felt prior to the FA. Despite these increases in feelings of preparedness, many PLD providers indicated they still felt they needed more time to plan their TWs but were not overly concerned about their ability to do so prior to the start of their TW.

On the Post-Academy Survey, PLD providers also rated the effectiveness of Academy components in preparing them to plan and facilitate a TW (Table 6). PLD providers rated components from not at all effective (1) to very effective (5). Items on this survey were collapsed into composite scores around the following six components of the POD FA: Geospatial Inquiry, Pedagogy, Content, GST Skills, PLD Facilitation, and Social Interaction. To calculate composite scores, items were summed and averaged. Results suggest PLD providers felt the Academy was effective to very effective in their preparation as indicated by an average rating of 4 or higher for all Academy components. There were no significant differences between the two cohorts.

PLD providers were also asked to rate the overall effectiveness of the Academy. They rated the overall effectiveness of the Academy in preparing them to plan and facilitate their POD TWs a mean of 4.53 (cohort 1, SD = 0.640) and 4.85 (cohort 2, SD = 0.376). Providers also rated the overall effectiveness of the Academy in helping them understand the POD PLD model as 4.60 (cohort 1, SD = 0.507) and 4.92 (cohort 2, SD = 0.277). There were no significant differences between the two cohorts.

Table 6. Effectiveness of POD FA components in supporting PD provider preparation.

POD FA component	Cohort 1 ($n = 15$) M (s.d.)	Cohort 2 ($n = 13$) M (s.d.)
Geospatial inquiry	4.33 (.511)	4.46 (.506)
Pedagogy	4.24 (.479)	4.51 (.538)
Content	4.13 (.640)	4.23 (.725)
Geospatial technology	4.27 (.704)	4.69 (.435)
PD facilitation	4.48 (.417)	4.65 (.376)
Social interaction	4.73 (.495)	4.81 (.384)

Note: Key: 1 = not at all; 3 = somewhat effective; 5 = very effective.

In both cohorts, Post-FA Interviews suggested PLD providers are still struggling with how to support the pedagogical aspects of implementing Geospatial Inquiry, particularly how to support teachers with scaffolding and sequencing the ideas to support conceptual understanding. After the third day of the academy, one PLD provider reported they really struggled with 'Pedagogical moves to promote Geospatial Inquiry. I need more examples to fully understand it'. In addition, many PLD providers seemed to lack a clear understanding of how to support teachers through the planning of the Geospatial Inquiry lesson and what pedagogy supports it.

Most PLD providers indicated they are prepared to support teachers with the GST skills, but some PLD providers expressed concern about helping teachers gain GST skills and the need to have more time to practice. For example, one PLD provider elaborated on her concerns about troubleshooting technical challenges during her TW in her interview:

> My biggest barrier, or my biggest support needed will be helping them to get up to speed and not be bogged down with the techie kind of pieces, you know, they can't get the mouse to work or can't seem to ever log in, that's a common one. We have people who have not remembered their password. You have to reset and reset. It's hard to get them in.

PLD providers note that teachers may struggle with the technology and that in TWs they may have to provide differentiated instruction in order to help teachers achieve the goals of the TW.

Almost all PLD providers indicated they just needed time to process and plan, as well as consider logistics (technical support, concerns with workshop facilities, recruiting workshop participants) in order to be prepared for the TW. This is not surprising, but it may help to consider how to make space for them to do more planning during the FA. From the interviews and daily debriefs, PLD providers feel time spent working with other PLD providers added to their feelings of preparedness, especially preparedness working through GST and incorporating Geospatial Inquiry in teacher lesson plans. In his interview one PLD provider said:

> … getting to talk to the other PD providers, especially the teachers who are doing this all the time, was kind of nice too because I could hear the types of things they were doing with their students.

PLD providers from both cohorts indicated their understanding of how to help teachers create Geospatial Inquiry lessons was aided by interactions with the POD Team and other PLD providers. PLD providers felt they had sufficient examples of lessons to provide teachers during a POD TW and would be able to model what these lessons look like and how these lessons might be enacted.

Observations and field notes from the first FA indicated concerns about the rushed nature of the first two days (Observation 1 and 2). Given this was the first time the POD team was implementing an FA, a need to adjust for time was not unexpected. However, concerns were raised about PLD providers' ability to lead a POD TW with integrity given the need to shorten and/or skip sections (Observation 2). Fortunately, by the fourth day of the FA, observers described the following:

> It seems as if PLD providers have a solid understanding of Geospatial Inquiry now and also feel they have the ability to facilitate the lessons based on the debrief surveys. This formative feedback has given us a lot of information to build on and use for refinement of the guide.

Interviews revealed that PLD providers in the first cohort feel most prepared to implement the following POD principles: GSTs are tools that support Geospatial Inquiry, Geospatial Inquiry promotes cross-disciplinary practices and twenty-first-century skills, Geospatial Inquiry is socially constructed, and Geospatial Inquiry is iterative and sequenced over time. Two participants did not feel prepared to implement POD principles: Geospatial Inquiry promotes cross-disciplinary practices and twenty-first-century skills and Geospatial Inquiry is socially constructed. These principles were addressed in a follow-up webinar with Cohort 1. PLD providers from the second cohort felt prepared to implement all seven POD principles as evidenced by interviews, surveys, and observations. Overall, both cohorts appeared to be well prepared to implement TWs based on the FAs they experienced.

Stages of concern

PLD providers completed a 35-question stages of concern (George et al., 2006) retrospective questionnaire as part of Post-FA survey in order to determine their perceptions of implementing the new innovation. Based on their responses, PLD providers' concerns changed over the course of the academy. At the beginning of the FA, the majority of Cohort 1 ($n = 8$) held concerns that were informational, and others had about collaboration ($n = 4$) or no concerns ($n = 4$). By the end of the FA the concerns of the majority of PLD providers were about collaboration ($n = 12$), others had no concerns ($n = 1$), management concerns ($n = 1$), or were refocusing ($n = 2$). Collaboration concerns indicate PLD Providers were interacting with others and beginning to see out how others were going to implement the FA. PLD providers in Cohort 1 moved from a focus on self (how change is affecting them) to a focus on impact (how change will affect others). At the end of the FA, they were more concerned about the outcome of the change and the effect it would have on teacher learning than the changes they would have to make or the resources needed for the change.

At the beginning of the second FA, the majority of Cohort 2 were concerned about management ($n = 4$), collaboration ($n = 4$), informational ($n = 2$), or had no concerns ($n = 3$). By the end of the academy, the concerns of the majority of PLD providers were about collaboration ($n = 6$), and others had no concerns ($n = 4$), management concerns ($n = 2$) or concerns of consequences ($n = 1$). Of those with concerns, Cohort 2 went from a split focus on self ($n = 2$), focus on task ($n = 4$) and impact ($n = 4$), to a focus on task ($n = 2$) and impact ($n = 7$). Similar to Cohort 1, they are more concerned about the outcome of the change and the effect it will have on teacher learning than the changes they will have to make or the resources needed for the change.

Discussion

Overall, the FAs were successful in preparing POD PLD providers to teach Geospatial Inquiry through the POD model to secondary teachers. It meant selecting PLD providers with GST performance skills necessary to lead TWs and preparing PLD providers by supplying resources and helping them develop an understanding of the POD principles. The FAs also addressed the concerns of PLD providers and increased their feelings of preparedness to teach their own POD TW with integrity. The findings above provide clear answers to the research questions. Here we discuss some of the implications of these findings.

Selection of professional learning and development providers

The Academy helped most PLD providers develop the GST performance skills needed to implement a POD TW. For two PLD providers who scored below the minimum, an intervention by the POD team improved their skills before implementing their TW. Both of these PLD providers struggled with the planning and implementation of TWs. One was eventually successful in implementing a TW, the other failed to be able to recruit a sufficient number of teachers to implement a TW. Therefore, one important consideration in developing PLD for PLD providers is the selection and application process. This process may be more important in selecting providers than it might be for selecting teacher participants and warrants further investigation.

These results are in line with Perry and Boylan (2018) who suggest the required knowledge needed to lead and facilitate effective PLD is much greater than is needed in a classroom. PLD providers need not only subject matter content knowledge, pedagogical content knowledge, curricular knowledge, and context knowledge, but also knowledge of how to model effective teaching, coaching, and facilitating PLD effectively (Perry & Boylan, 2018). In addition, PLD providers need to understand how teachers learn and develop and the content knowledge specific to the PLD itself (Kennedy, 2016; Loucks-Horsley et al., 2003). In the current study, it was necessary for PLD providers to have strong GST skills; thus, increasing the rigour of the application process and the cut-off score was one way to ensure the PLD could be implemented with integrity.

Depending on the design and content of the PLD, there may be a variety of areas teams may need to screen for in the application and selection process. In scaling PLD, this becomes a very important step in the process and one worth considering carefully, as the success in scaling the PLD is dependent on the PLD providers selected. In thinking about how the selection of PLD providers for participation may differ from that of teachers, it may be necessary for PLD providers to submit evidence of their facilitation (e.g. videos), skills or knowledge (e.g. tests, application tasks), ability to connect with participants (e.g. reference letters), and/or plans for future implementation of PLD. Ultimately, when scaling PLD the goal is to select high-quality candidates who can implement the PLD with integrity; carefully considering the selection process is one way to increase the probability of finding high-quality candidates.

Differentiating professional learning and development for PLD providers

As discussed above, even with the application and prescreening process for POD FA acceptance, differentiation was necessary to meet the Academy objectives. Additional training was needed for those PLD providers whose GST performance skills were below the minimum. Just as teachers differ in the skills and knowledge they bring to PLD (Grierson & Woloshyn, 2013), so do PLD providers. As another example, the level of support in pedagogical moves (e.g. eliciting answers from participants, leading whole group discussions, guiding participants to answers, etc.) needed by PLD providers varied by their experience in the K-12 classroom. PLD providers with more classroom experience wanted less time spent on pedagogical moves. Thus, one important consideration of those designing and developing PLD for PLD providers is the need to differentiate the PLD.

Grierson and Woloshyn's (2013) findings suggest the need to differentiate PLD in order to support teachers in changing their practice. Two implications of their work were the need to use collaborative, small group sessions to help teachers construct new understandings and the need for individualised coaching. In the same way, we found using small group follow-up sessions to support PLD providers in their implementation of POD TWs was useful in ensuring they were understanding the process and ideas from the Academy. In addition, we felt individualised coaching may benefit PLD providers who either did not have the technology skills or the pedagogical understanding.

Given the variety of skills and understandings PLD providers need to have in order to effectively lead PLD (Perry & Boylan, 2018), it is likely that most PLD will need to be differentiated to address all the needs PLD providers have in preparation for leading a PLD they are scaling. In this respect, it is critical for those scaling PLD to consider the variety of skills and understandings PLD providers need to effectively lead the scaled PLD and then develop a plan for differentiating that portion of the training if needed. It will also benefit those scaling PLD to consider how to assess for prior knowledge to see what needs their PLD providers may before starting training.

Scaling professional learning and development

When designing and providing the Academy, the POD Team recognised a need to not only have PLD providers experience the POD TW, but to also provide time for PLD providers to consider how they would implement their own POD TW. When scaling PLD, providers need to have a thorough understanding of the PLD being provided to teachers as well as opportunities to understand the philosophy behind the PLD, the ideas being taught, and build any facilitation skills needed to be effective (Dede & Rockman, 2007). In the POD FA, we found PLD providers also needed to time to consider the logistics and review the work they had done in order to make the next step in feeling prepared to lead a POD TW. As PLD designers consider how to design PLD for providers and to scale PLD, it may be necessary to build in extra time for the skills and planning required to lead PLD.

Some other important aspects to consider the supports PLD providers need in recruiting participants, in the midst of leading their own PLD, and in translating the model to their individual context. In doing so, it is helpful to determine if the PLD needs to have the fidelity of implementation or integrity of implementation. Reflecting on how rigidly PLD providers need to implement the PLD may change the supports needed and the design of the PLD. However, designers of PLD need to expect changes will be made and appropriately plan for and allow it (Dede & Rockman, 2007).

According to the literature, fidelity of implementation is defined as how closely PLD providers implement programmes as intended by the programme developers (Dusenbury, Brannigan, Falco, & Hansen, 2003), whereas integrity of implementation is defined as how closely a programme is implemented as planned (Gresham, Gansle, Noell, Cohen, & Rosenblum, 1993). These terms are often interchangeable in the literature; however, fidelity typically refers to 'accuracy in details, exactness' (Webster, 2019) with the goal being to exactly replicate a programme in its implementation. Integrity refers to a 'firm adherence to a code of especially moral or artistic values; incorruptibility' (Webster, 2019) and represents more of what we hoped PLD providers would do as they implement

POD TWs. We hoped PLD providers would adhere to the POD principles but implement within their contexts appropriately (Whitworth, Rubino-Hare, & Bloom, forthcoming). Whether a project is shooting for fidelity or integrity, will influence the amount and type of support that needs to be provided. For example, with POD, integrity of implementation was the goal for PLD providers; thus, PLD providers had more leeway in how they would deliver and implement POD TWs. Given this leeway, some PLD providers decided to deliver TWs as a hybrid workshop. Learning how PLD providers were planning to implement their TWs made the POD Team consider what aspects of the POD TW needed to be in person and what aspects could be delivered online. Those who chose to deliver online needed different types of support than those who delivered in person.

Conclusion

The current study focused on the design, implementation, and analysis of the POD Facilitation Academy and provided deeper insight into the needs and concerns of PLD providers in implementing PLD. Furthermore, this investigation shed more light on the selection and preparation of POD PLD providers as programmes seek to scale PLD in their own contexts. Future research should examine how the integrity of implementation vs. fidelity of implementation can impact the design and scaling of PLD. As suggested by Perry and Boylan (2018) it may also be beneficial to examine and measure the various outcomes of PLD for PLD providers. Thus, moving forward it is necessary for the POD Team to examine how PLD providers implemented their TWs and the effectiveness of that implementation.

As calls continue for increased production of highly qualified STEM students, it is critical we also produce highly qualified and effect STEM teachers (PCAST, 2015). In order to develop highly qualified and trained teachers, we must work to provide them the most effective PLD we can offer. Supporting PLD providers and examining how we scale PLD to more teachers effectively is an important aspect of providing the most effective PLD possible to science teachers. This study begins to provide insight into what may need to be considered as PLD developers create PLD models to be scaled and begin the process of selecting and training PLD providers to implement those models.

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