IT'S ALL ABOUT THE MIDDLE: PLACING A PEDAGOGICAL FRAMEWORK AT THE CENTER OF PRACTICE IN STEM EDUCATION

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Abstract

The Organisation for Economic Co-operation and Development (OECD) suggests that education reform initiatives in Science, Technology, Engineering and Mathematics (STEM) will require substantive changes in how these disciplines are taught at school and in teacher education institutions. In this paper I take up these challenges by examining how a longitudinal research study in six Australian primary schools supported changes to middle leaders' classroom practices in teaching and learning. The findings demonstrate how a pedagogical framework positioned alongside professional development and working with an academic partner in a process of action research is effective for teacher professional learning in STEM.

Introduction

The lack of focus on STEM education continues to be discussed in tertiary and school education circles and in the mainstream media in Australia and globally (Thibaut et al., 2018). Education jurisdictions are charged with raising national productivity using measures like GDP in their countries because of a perceived 'STEM drain' and declining standardized test scores in PISA and TIMSS[1]. It often seems that every person in the business world, in politics, and on social media has an opinion about and a solution for STEM education (Berry, 2018).

Both the National Research Council (2012) in the United States and the OECD (2012) suggest that reform initiatives focusing on STEM will require substantial changes in how the four disciplines are taught not only in schools but also in preservice teacher education courses in universities (Timms, Moyle, Weldon, & Mitchell, 2018). Multidisciplinary, interdisciplinary and transdisciplinary approaches to STEM when combined with technology-enhanced learning provide rich support to students at school, and may lead to increasing the numbers of graduates in the four disciplines in post-school education (National Academy of Engineering and National Research Council, 2014).

In this paper I take up these challenges by examining how a longitudinal research study in six Australian primary schools supports changes to middle leaders' practices in STEM teaching and learning using action research as an approach to professional learning at two professional development Sharing Days. The study uses a pedagogical framework for technology enhanced learning known as HPC or *High Possibility Classrooms* (Hunter 2013; 2015). This pedagogical framework for teaching and learning was developed from research into exemplary teachers' knowledge of technology integration in classrooms in Australian schools and builds on the work of TPACK (Mishra & Koehler, 2006). Table 1 shows the five conceptions and 22 underpinning themes of the HPC framework.

Table 1
The five conceptions and 22 underpinning themes of the HPC framework

Theory driven technology practice	**Creativity for learning through technology**	**Public learning through technology**	**Life preparation using technology**	**Contextual accommodations using technology**
Technology drives the construction of learning	Technology boosts creativity	Technology scaffolds performance	Technology operationalizes the real world	Technology remains personal and professional
Technology enhances purposeful teaching	Technology creates opportunities for production	Technology enhances outcomes	Technology gives voice	Technology changes time
Technology focuses planning	Technology unleashes playful moments		Technology means ownership and possibility	Technology nurtures community
Technology enriches subject matter	Technology supports values		Technology reveals effectiveness	Technology defines the game
Technology promotes reflective learning	Technology differentiates learning			
Technology shifts conversations and thinking				
Technology engages students in authentic ways				
Note. Copyright Jane Hunter (2015)				

Definition of Terms

Google + community is a collection of online PD resources teachers use as a central tool for discussion with colleagues.

Hardware and software: Technology hardware and software at each research site included laptops, interactive whiteboards, voice recorders, Arduino sets, Makey Makey kits, technology tools such as digital thermometers, digital water-testing supplies, and software applications like Wix and Seesaw.

Middle leaders (ML) in the study were identified by their school principals – they conformed to what Stoll, Taylor, Spence-Thomas, & Brown (2018) define as: "teachers who have a formal role, with responsibilities for a subject, cross-curricular aspect of teaching and learning, social development of students, or for a stage or phase of schooling" (p. 4).

Participant training: Participant training focused on ICT associated with STEM curriculum content. A workshop in the first stage of the study concentrated on the technology integration processes and strategies of the HPC framework

Professional Development (PD) describes structured learning activities for teachers, sometimes one-off but preferably ongoing and well resourced.

Professional Learning (PL) refers to the processes and experiences teachers' engage with in order to develop their practice.

Sharing Days (SD) are PD events for teachers.

STEAMpop is a 'hands on' PD experience that values the intersection between the Arts and STEM concepts.

STEMShare is a kit of digital learning resources that are available for schools to borrow. Each STEM Kit includes robotics, 3-D printing, coding, filmmaking, and virtual-reality equipment.

The Structure of the Paper

There are three sections to the rest of this paper. First, in the background section, I discuss some critical moments in recent years for STEM education in Australian schools and examine some of the claims and ideas for more contemporary approaches to teaching and learning with technology, noting that PL focused on middle leaders is one way to pedagogically prioritize this space. I also say more about how the HPC framework and action research informs effective middle leader development in STEM (Hunter, 2017). The second section details the study design, research question, the methods of analysis, and the results. In the third section, I conclude by discussing how agency can be fostered with a pedagogical framework like HPC to create potent STEM professional learning for teachers.

Background to the Study

Australian schools, like so many others in the world, are taking steps to outline what it takes "to make great teaching of Science, Technology and Mathematics the norm, and teaching a profession of choice" (Prinseley & Johnston, 2015, p. 1). Ways to do this must involve attracting high achievers in STEM to primary school teaching, boosting the rigor of preservice courses in teacher education in universities, and making time for principals and executive staff to focus on leading STEM in their schools (Bybee, 2018). This amplification of the what, where and when attention to STEM should commence is endorsed by the Australian government's 10-year *National STEM School Education Strategy 2016–2026* (Education Council, 2015), whose goals are "to ensure that all students finish school with strong foundational knowledge in STEM and related skills [and] are inspired to take on more challenging STEM subjects" (p. 5). Fulfilling such aims requires not only curriculum change and time for PD, but also funding (Ringland & Fuda, 2018). Keen to make its STEM priority known, the Australian government committed more than AUD 1.1 billion in its National and Innovation Science Agenda (2015).

In a comprehensive literature review of the barriers and supports to STEM commissioned by the Australian Department of Education, Tytler, Osborne, Williams, Tytler, & Cripps-Clark (2008) identified that Science and Mathematics in primary schools are either "not well taught or not taught often enough" (p. 133) and that a long-term strategy would be needed to support teachers of these subjects in Australian primary schools[2]. A key aspect identified in the review was the move away from "transmissive and inflexible pedagogies that dominate primary school teachers' practices" (p. 141). Moreover, Tytler et al. (2008) recommended that teachers would require government support to make the teaching transitions and develop the required skills and conceptual shifts.

As education bureaucracies measure more performative milestones (Comber & Nixon, 2011), it is highly accomplished teachers or middle leaders, frequently described as 'experts', who are responsible for shifting and changing classroom practices (Spillane, 2006). They are often a "buffer and a bridge" (Bennett, Wood, Wise & Newtown, 2007, p. 462) between the principal and other teaching staff. Central to their developing capacity and success at this level is support from the principal and appropriate PD (Edwards-Groves, Grootenboer, Hardy & Ronnerman, 2018). These were features of this study, which give voice to strengthening the role of ML through STEM PD in an academic partnership.

A Pedagogical Framework for Technology-Enhanced Learning and Action Research as Drivers for Teacher PL in Effective Middle Leader Development in STEM

The HPC framework backs an approach to integrating STEM that is project based and uses inquiry learning and design challenges[3]. Through its attention to five

conceptions that broaden understanding of innovative pedagogies, it involves the knowledge base for teaching the primary school curriculum. By planning and co-teaching, and the 'deprivatisation of practice', the ML in this study were able to flatten the power hierarchies of their schools to enhance collaboration and leadership at the middle level.

Action research is familiar to those acquainted with the professional learning activities of teachers (Groundwater-Smith, 1988). Kemmis (2011) makes it explicit that critical participatory action research is undertaken: "collectively by participants in social practice to achieve 'effective historical consciousness' … of their praxis as practice – that is a morally informed, committed action, oriented by tradition that responds wisely to the needs, circumstances and particulars of a practical situation" (p. 13).

Within action research, distinctions are made between its technical, practical and emancipatory intentions. It is significant that a commitment to improving practice underlines each of these distinctions and that teacher participation in AR involves feelings of vulnerability as a consequence of critical reflection and self-evaluation. Such reflexive practices align with the notion of 'insider knowledge' that is generated within the school context, in combination with 'outsider knowledge' from an academic partner or external colleague/s who might work together to support, progress, and sometimes challenge the classroom practices of a teacher. These actions together form influential teacher professional learning (Kirkby, 2015).

The Study

The Research Question

Several research questions related to middle level leadership for STEM in primary schools guided the study as a whole[4]. This paper focuses on one of them:
How does bespoke PD at two Sharing Days (SD) build middle leader (ML) capacity in STEM?

Design

The research was a 15-month mixed methods study with 22 ML whose teaching experience ranged from three to 30+ years at six primary schools in two regions in New South Wales, Australia. The sites are government schools with students ranging in age from five to12 years, there are high levels of parent involvement, and up to 61% of students come from language backgrounds other than English. Throughout the study, participants utilised a Google + community to share their learning and resources, ask questions and post student work samples.

Data were collected through a range of methods for the larger study (ML interviews, classroom observations, Stages of Concern Questionnaire as pre and

post intervention evaluations); those reported here involved 'exit ticket evaluations' from the two SD for the study participants held at the academic partner's university in the second and third stages of the research. The SD gave the ML an opportunity to engage in PD that facilitated sharing progress and practice.

Methods of Analysis

Data were analyzed in three steps: (1) notes were taken during the SD were coded into themes using NVivo 11 (2) these themes were triangulated against plans/policy/school documents; and (3) the SD evaluations (or 'exit tickets' accessed by the ML in Google forms). All participants (N = 22) completed online evaluations at the end of each day; 100% attendance on both days.

Results

The SD were held approximately four months apart. On both days, hands-on learning experiences from STEAMpop and the STEMShare programs were key features of the PD: STEAMpop on Sharing Day 1, and STEMShare on Sharing Day 2. There was also a tour of the university's data arena. Dominant themes in the data are presented in Tables 2 and 3, with relevant verbatim comments from the participants quoted.

Table 2
Findings from Sharing Day 1

Questions	Responses
1. What did listening to each other's presentations at the Sharing Day mean to you?	Dominant responses mentioned positive feelings of interest in what other schools were doing, the benefit of listening to colleagues, the support or validation it gave to the approaches adopted. Seeing more examples of HPC and STEM in action "really helped." HPC is a scaffold "that although it has teaching strategies that involve technology it gives us a way to talk about what we need to do in the content areas of STEM."
2. What was the most important part of the Sharing Day?	Finding out that "explicit teaching still needs to be embedded" and seeking ways to "declutter programming" was necessary. Direct instruction preferably takes place alongside group processes in, for example, a [problem-based learning] approach. Some teachers wanted whole school changes that required school executives to agree to "the adoption of whole school curriculum transformation."
3. How would you describe the session given by the Women in	88.3% of participants said it was informative.

Questions	Responses
Engineering and IT at the author's university?	
4. Would you like to contact STEM experts like Dr XX?	76% of participants said yes.
5. Would you like to hear from other STEM and HPC teachers, for example, YY from ZZ Public School?	78% said either excellent or very useful. They liked hearing about: "flexible programming"; the "*Masterclass* idea to teach specific concepts". Often it was about: "the scale of projects because they allowed students to integrate many outcomes", "community involvement beyond the classroom", doing "longer or shorter units of work (not always 10 weeks)" and "using a *Shark Tank* pedagogy for sharing and showcasing student work".
6. Was the STEAMpop workshop informative?	76.5% of participants said yes.
7. Was the Data Arena Tour useful?	76.5% thought the tour was either excellent or very good.

Table 3
Findings from Sharing Day 2

Questions	Responses
1. What did listening to each other's presentations at the Sharing Day mean to you?	Dominant responses mentioned very positive feelings towards the variety assessment types that could be used with STEM – in particular formative assessment strategies. It was an opportunity to gather "fresh ideas" to take back to their own school. For example: "I really understand HPC better now and that will move me from focusing on what I am doing to what the students are doing."
2. What was the most important part of the Sharing Day?	Finding out that "integrating multiple KLAs was possible," especially into literacy lessons, allowing for "failure in a safe place," not setting the agenda for "what product should be created, keeping projects small". Getting answers to questions about: "how to best support young people to become autonomous, to inquire, problem solve and cooperate with another" – all the while "pondering how to effectively assess the soft skills" and "the need for flexible dynamic programming with multiple entry points for learning and sharing knowledge."
3. How did you find the session with Little	64.7% of participants found it informative.

Questions	Responses
Scientists [a government program focused on early childhood experiences and STEM]?	
4. How would you describe the session with some social science /humanities experts from the university?	47.1% of participants said they would use the ideas presented with their own students.
5. Would you like to hear from other STEM and HPC teachers, for example, YY from ZZ Public School?	70.6% said this session was either excellent or very useful. Frequent comments included "surprise at how behaviour changes when [STEM] learning is motivating and engaging", usefulness of "quality picture books/literature in effective STEM", the need to "keep the focus short, i.e., smaller more doable projects", "being willing to trial n' error" and how STEM "re-energised" a personal sense of "professionalism and practice."
6. How would you describe the STEMShare workshop?	70.6% said this session was either excellent or very useful.
7. Final reflections.	Comments were very positive about the day; dominated by attention to how hearing from other teachers "was powerful"; "wanting more time to talk with teams from other schools"; "noting our growth in confidence"; "the Google+ community was useful to keep everyone connected", "it was a chance to understand what it means to teach in a sequence of learning", and "to boost tech skills even more".

Conclusion and Discussion

Results of the SD evaluations confirm how ML are able to learn from one another and from outside experts and then bring this experience to their work with coaches or mentees in classrooms. As is evident in Tables 2 and 3, learning with STEM experts and rehearsing hands-on activities like coding, using green screens, and making robotics kits were memorable activities. Significantly, professional readings and sharing in team meetings at school, the development of a shared language to talk about planning, and access to an online Google + community with colleagues and visits to 'buddy' schools are important. Contextualized PD highlights the importance of deepening collegial relationships and trust so that

ML can take risks with new and different teaching practices, especially when integrating content from several discipline areas (Day & Grice, 2019).

Teams at the six schools in this study plan to continue their work in STEM. As one ML said, "The research acted as a disruptor to many teachers' pedagogy and their perceptions of content knowledge in four and often five disciplines when it became STEAM." The value of a pedagogical approach to STEM using the HPC framework for technology-enhanced learning is strongly supported by the study's findings[5]. Teachers leading in the middle clearly want to work together in teams to solve the problems of practice, but they must be supported to audit existing content heavy units of work/programs and be given time to think and plan together in their stage teams and with 'buddy' schools'' if they are to continue to inspire the next generation of children to take their 'STEM steps' towards secondary schooling. Innovations often fail when educators "only focus on the surface features of the innovation rather than the underlying mechanism[s] that enable it to work" (Lewis, Perry, & Murata, 2006, p. 5).

A core part of this bespoke PD in the two SD was an academic partnership with the ML that focused on transforming their agency in STEM practice through self-reflective enquiry in action research cycles. When given the chance, through PD funded in a sustained experience over 15 months, these ML became highly enthusiastic about co-teaching large student groups and coaching and leading their colleagues. They were deeply committed to reflecting on their own learning and to refining and growing their teaching practices in STEM to be agents of change.

Notes

1. PISA is the Program for International Student Assessment in reading, mathematical and scientific literacy, and TIMSS is the Trends in International Mathematics and Science Study; both are international standardized tests that are the subject of considerable political controversy and debate in many countries. In Australia, primary schools cater for students aged 5 to 12 years of age.
2. Inquiry in this paper draws on Murdoch's (2015) ideas that teachers and children are at their "learning best [when] engaged in the powerful act of inquiry – be it challenging, playful, individual, collaborative, closely guided or independent" (p. 13).
3. The university ethics committee and the state education regulator approved the research; it was conducted in 2017–2019 (Approval No. ETH17-1467 and SERAP No. 2016182).
4. The main study limitations concern sustainability of what was found over time and understanding how leading from the middle impacts practice in the context of PD and a pedagogical approach to STEM education in the long term.

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