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'They couldn't wait, every day they would say are they coming today?' Stakeholder perceptions of School–University partnership approaches to science teacher education

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Abstract

Initial teacher education programs have been criticised for their failure to deliver classroom-ready graduates. Problems of concern for preservice teachers (PSTs) identified in the literature are insufficient time in the classroom, lack of confidence, inadequate pedagogical knowledge and a theory practice divide. This research examines a school–university partnership approach to science teacher education from the perspective of PSTs, school students, teachers and teacher educators where university tutorials were conducted in a school environment. This research is underpinned by practice architectures theory, it follows collaborative participatory action research methodology using mixed methods of data collection including surveys, interviews and focus groups. The research findings revealed how the program built on PSTs' pedagogical knowledge and confidence and connected theory with practice. Teachers observed high level student engagement and students building on their prior science knowledge in innovative science lessons. The research provides rich data that illuminate aspects in this school–university partnership approach from a range of perspectives.

Keywords Science · School–university partnership · Teacher education

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Introduction and Context

Motivating, influencing and inspiring preservice teachers (PSTs) to make a difference to the children and communities where they work is touted as a central tenet of teacher education. However, it is plausible to argue that that this goal remains elusive, such that the recent Australian Government Quality Initial Teacher Education review called for further evidence-based initial teacher education (ITE) models to provide 'confident, effective, classroom-ready graduates' (Paul et al., 2021, p. 48). Squarely, lack of adequate time in the classroom or failure to be able to connect theory presented at university into practice in the classroom are two common problems associated with ITE in Australia and internationally (Kamenier et al., 2017; Korthagen et al., 2006; Teacher Education Ministerial Advisory Group [TEMAG], 2014). In addition, ITE programs are not necessarily preparing PST with the 'content knowledge', teaching strategies or skills for the classroom (TEMAG, 2014, p. ix). Problems such as these are particularly pertinent in science education where primary PSTs often claim to feel underprepared, and lack confidence to facilitate science in the primary classroom (Fitzgerald, 2020; Herbet & Hobbs, 2018).

In a four-year degree program in Australia, PSTs are currently required to undertake 80 'professional experience' days (or 60 days for Graduate Students) minimum (Australian Institute of School Leadership [AITSL], 2022, p. 10). How can PSTs learn to be responsive to the changing needs of students and the school environment (Buchanan et al., 2013) in such a short period? The solution is not necessarily requiring more professional experience placement days, but rather research informed, collaborative partnerships between teacher education faculties (universities) and the schools and communities they work with where the perspectives of all participants are bought into the decision-making processes (Zeichner et al., 2015). Furthermore, ITE has been criticised for decades for failing to bridge the theory practice nexus (Daza et al., 2021; Korthagen, 2018). Achieving a balance between theory and practice is an ongoing problem facing ITE programs (Darling-Hammond, 2017). This goal for more authentic alignment of theory and practice indeed forms the focus of the research project outlined in this paper. The research focuses specifically upon partnerships between universities and school communities in primary science education.

Revelations from the Literature

Despite four decades of extensive educational research, and ITE reform, teacher education programs both in Australia and internationally continue to be criticised for their inability to adequately prepare teachers (Allen et al., 2002; Cochran-Smith et al., 2018). Academics are seen by PSTs to be 'boring' and living 'in an academic bubble' whereas school teachers are the 'real ones'… 'real people at work' (Sjølie & Østern, 2021, p. 273). Traditionally ITE courses include lecture style approaches where PSTs are 'taught' about teaching and are expected to apply the ideas gleaned while at university into their practical teaching experiences (Cutter-Mackenzie & Fulton, 2012; Korthagen, et al., 2006). There have been rapid societal changes taking place in the twenty-first century, which influence teaching/learning environments and student behaviour; therefore, it is vital that teacher educators are open to embrace new and innovative approaches to teaching and learning in this changing environment (Fitzgerald, 2020).

One way to embrace change and bridge the theory–practice divide and in turn provide the opportunity for the school community to become more aware of the role that universities play is to explore a range of approaches to school–university partnerships (Yeigh & Lynch, 2017; Daza et al., 2021; TEMAG, 2022; TEMAG, 2014). The concept of school–university partnerships was defined by John Goodlad in 1991, as 'a planned effort to establish a formal, mutually beneficial interinstitutional relationship' (Goodlad, 1991, p. 59). The TEMAG (2018) report identified school–university partnerships as a 'pivotal role in all ITE' (TEMAG, 2018, p. 4). While there are numerous models of partnerships in ITE (Darling-Hammond, 2017) including community partnerships such as service learning (Lasen et al., 2015; Tinkler & Tinkler, 2020), it must be acknowledged that the facilitation of effective partnerships is complex and brings with it many challenges (Martin et al., 2011). The COVID19 pandemic has certainly created complexity surrounding ITE and has generated openings for the strengthening of partnership programs between schools and universities to share professional expertise in addressing educational challenges (Darling-Hammond & Hyler, 2020).

If teacher educators are to initiate change in teaching practice rather than being objects of reform (Cochran-Smith et al., 2018), the contention is that they need to have a depth of understanding concerning their own practices and importantly be open to sharing ideas and experiences relating to their own reflections on their practices (Edwards et al., 2010; Russell & Loughran, 2007). Reflective practice improves both teaching practices and students' achievements (Day et al., 2022). In a school–university partnership, it is possible for teacher educators, PSTs, and practising teachers to reflect collaboratively on their practices and address their own hidden assumptions in contrast to the 'top down' approach of the traditional teacher education, where educators are often 'saying one thing and doing another' (Russell & Loughran, 2007, p. 8). The point is that educators need to think outside of the square to develop new ways of thinking and embrace change, in addition to encouraging students to do likewise (Russell & Loughran, 2007). Furthermore, research revealed that when PSTs are provided with opportunities to reflect on their practical experiences in ITE they make connections between these experiences and theory presented at university (Day et al., 2022).

It is very important for school students to experience a solid grounding in science as it plays a crucial role in the twenty-first century. Citizens are presented with scientific evidence to support change and are at the same time presented with sometimes conflicting information that could be politically, economically, or socially motivated, surrounding contemporary issues (Bybee, et al., 2009, p. 867) such as climate change or COVID-19 (Pietrocola et al., 2021). In fact, most aspects of present-day life in minority countries have been influenced by scientific knowledge, and it is therefore important that students acquire scientific literacy skills (Ainley & Ainley, 2011, pp. 51–52). Moreover, attitudes to science are an important component of a person's interest in, attention to, and response towards, science and technology (Logan & Skamp, 2008, 2013; Bybee, et al., 2009, p. 869;) and attitudes to science impacts students' scientific literacy (Bybee & McCrae, 2011, p. 23). Also, enjoyment of school science is closely related to how students perform in science (Lau & Ho, 2020). It is, therefore, essential for all teachers to have high self-efficacy or confidence towards facilitating science education experiences in all areas of science (Brígido et al., 2013) that engage and interest their students and enhance their learning outcomes. PSTs often lack confidence in the teaching of science and display anxiety towards teaching science in schools (McDonald et al., 2021). First-hand experiences in the classroom such as 'hands on' learning and extensive teaching experience can provide opportunities for PSTs to gain confidence and competence, particularly in subjects such as science (Fitzgerald, 2020, p. 304).

The research outlined in this paper builds on the research literature surrounding school-based approaches to science teacher education (Fitzgerald, 2020; Herbert & Hobbs, 2018) to investigate the impact of a school–university partnership model in ITE from the perspective of PSTs, school students, their teachers, and teacher educators with a practice architectures lens.

Theoretical framing

This research is underpinned by the theory of practice architectures (Kemmis et al., 2014a). Kemmis et al. (2014a) describe how the actions of educators and those who they educate have consequences and these consequences build and structure potentials for action. These potentials for action are in the form of practice architectures. Practice architectures examine how both the individual and collective practices of educators are enabled or constrained because of their practice architectures. Practice architectures take the form of three arrangements:

1. cultural-discursive,
2. material-economic, and
3. social-political (Kemmis et al., 2014a, p. 31).

These arrangements occur in particular sites and shape individual and collective practice's 'sayings, doings, and relatings' (p. 30). Kemmis et al. (2014a, p. 32) describe the three arrangements of practice architectures as follows: The cultural-discursive arrangement includes the specialist 'language and discourses' of the practice and 'enable and constrain the sayings' of the practice (p. 32), for example, the scientific language in the science classroom. The material-economic arrangements 'enable or constrain the doings of the practice' (p. 32), such as physical settings of the classrooms or outside areas within the school. The social-political arrangements 'enable or constrain the relatings of the practice' (p. 32) with a focus on the relationships and power structures within the setting. Sjølie and Østern (2021) found practice architectures theory valuable when examining the 'complexity' of the experiences of PSTs in ITE in Norway (p. 276). Practice architectures provided us with a lens to interrogate these complexities and experiences of PSTs looking closely at the three arrangements. In this study, we looked at how educational practices are shaped within school–university partnership sites relating to the uptake of content knowledge, the theory–practice gap, and confidence in the classroom. Viewing the cultural-discursive arrangements of actual science classrooms allowed us to explore the sayings of the stakeholders. Looking at the social-political and the material-economic arrangements of the school–university partnership model enabled us to investigate the 'relatings' and 'doings' of the stakeholders.

Research aim

The aim of the research project was to examine the outcomes for PSTs, school students, their teachers and teacher educators, by taking part in ITE school–university partnership programs.

The measurable outcomes of this project are:

(1) Establish a school–university partnership model in science teacher education that leads to improved knowledge of PSTs and their students;
(2) Connect theory and practice in science teacher education; and,
(3) Build PSTs' confidence in the facilitation of science in the classroom.

Methodology

The collaborative participatory action research methodology complemented the practice architectures theoretical underpinnings of the study that takes a site-based approach to examine the outcomes of stakeholders (Sjølie & Østern, 2021). According to Kemmis and et al., (2014b, p. 19) 'critical participatory action research is directed towards studying, reframing, and reconstructing social practices'. Critical participatory action research involves the investigation of 'real' practices of people in actual situations and is a collaborative approach involving all participants (Kemmis et al., 2014b, p. 20). In these school–university partnership programs that took place in the school settings, the research involved reflection with all participants (PSTs, teachers, school students, and teacher educators). The critical action research findings were analysed through the lens of practice architectures, and this allowed the educators to reflect on the three arrangements from the perspective of all stakeholders. The cultural-discursive arrangements of the settings (focussing on the sayings, in particular the language), and the material-economic and social-political arrangements of the settings (focussing on the doings [actions] and relatings of the PSTs and their students).

Project context

This research project explored a school–university partnership model for primary science curriculum and pedagogy in the 3rd or 4th year of a bachelor or master's degree in ITE at a regional university in Australia. This program was in addition to the professional experience placements that the preservice teachers carry out in schools each year as part of their ITE. Prior to attending tutorials, all PSTs were required to engage individually in weekly online recordings and readings relating to theory and practice. The first two or three weeks were undertaken at the university where the PSTs were given support and guidance from university educators to plan and prepare science lessons using Bybee's (1997) 5E teaching model. The key aspects of this model that took place in schools over five or six weeks are as follows:

- PSTs met in schools during their scheduled tutorial time for science pedagogy and curriculum development and attended preparation tutorials with their university teacher educator in school classrooms (without children) prior to applying the ideas and theories with the children in the classroom;
- PSTs worked in pairs to plan, implement and evaluate lessons with small groups of 5–10 school students;
- School teachers observed their students working in small groups interacting with the PSTs providing guidance and support for the PSTs where necessary (no formal reports);
- Assessment of school students' skills and knowledge was carried out by the PSTs throughout the five lessons;
- Short group debriefing and reflection sessions followed the lessons where support was provided by teacher educators for subsequent lessons; and,
- PSTs completed two assignments in the program, the lesson plan (completed in pairs) with justification, and an individual critical evidence-based reflective report on the teaching experience. PSTs were not formally assessed while teaching the lessons.

The program involved, PSTs, teachers, school students and teacher educators garnering ideas from each other to enhance the educational experience of all involved (Russell & Loughran, 2007, p. 8). Strong social constructivist theory underpins the program's approach to learning and this learning is "situated" where the learner and social environment are entwined (Skamp & Preston, 2018, pp. 35,36). PSTs were provided with a safe environment where they trialled their own fresh innovative ideas to venture out of their comfort zone and reflect on their own teaching and learning journeys and to investigate how they influenced the learning outcomes of the school students (Hattie, 2012). The PSTs, school students, teachers and teacher educators provided feedback about the program. The educators reflected on the outcomes to reframe the model in response to the outcomes and feedback from stakeholders.

Method

The research for this paper focussed on the programs in 2013 and 2016 (note the program is under study in 2023). The research in 2013 including focus groups, pre-surveys and post-surveys was conducted with funding from an internal university grant providing the opportunity for a broad research program and the employment of a research assistant to carry out the research and analysis. The findings were utilised to support the introduction of the program across campuses. The 2016 research consisted of an online research study into the partnership approach built on elements of the 2013 research and introduced the perspective of the school students. In the 2016 study, teachers and students were included in the post-surveys (Table 1).

Internal university funds were secured for a research assistant to carry out statistical analysis of the post-survey in 2016 but there were insufficient funds to include focus groups in the research and there were no pre-surveys conducted.

First the 2013 program is outlined and then the associated research in 2013 is documented. These are followed by an outline of the 2016 program and the documentation of the 2016 research (See Table 1).

The program in 2013 involved 81 PSTs from one campus of the university (3rd or 4th year of university); 10 teachers; 160 school students (kindergarten to year six); at three regional NSW primary schools; and two teacher educators (one being the lead researcher the other being a participant in the research). The participant schools included one small public rural primary school (five teachers) (all classes) and two regional catholic primary schools (designated classes). The schools were situated close to the university for convenience, and the designated classes were those where teachers volunteered to take part in the program.

The research in 2013 involved mixed methods. The quantitative aspects involved paper surveys for PSTs which consisted of pre-tests ($n=59$) and post-tests ($n=75$)

Table 1 Research detail in two data collection periods (2013 and 2016)

Year	Data type	Participants
2013	On site Pre-Surveys On site Post-Surveys Focus Groups Interviews Unit Feedback	59 PSTs 75 PSTs 8 PSTs and 10 Teachers (separate focus groups) 2 Teacher Educators PSTs online
2016	Online Post-Surveys Unit Feedback	35 PSTs, 22 Students, and 6 teachers PSTs online

Note 2013 Surveys, focus groups and interviews conducted by research assistant outside the program

Note 2016 Statistical Analysis conducted by a research assistant outside the program (see questions in Table 2). A research assistant who was not involved in the actual program conducted the focus groups and interviews. The qualitative components included one focus group for PSTs who volunteered ($n=8$), one focus group for teachers, conducted at each school ($n=10$) and one interview for each teacher educator ($n=2$). Anonymous standard Unit Evaluation Student Feedback data, administered by the university survey management team at the end of each semester, were utilised.

The program in 2016 involved 140 PSTs (3rd or 4th year of university) from three university campuses, 440 school students, 20 teachers from five state schools (four in NSW; one in Queensland) situated close to the university campuses for convenience of travel for the PSTs and three teacher educators (one the lead researcher).

The research in 2016 (Table 1) involved anonymous online surveys that were conducted following the program (with PSTs ($n=35$) (Table 3), school students ($n=22$) (Table 4) and teachers ($n=6$) (Table 5). The data did not include teacher educators in 2016. All online surveys included two open response questions. Responses from the PSTs' unit evaluation student feedback conducted by the university were also included.

The planning, observation and research surrounding the program in 2013 informed the subsequent delivery of the program in 2014, 2015 and 2016. This paper reports on the research findings of the 2013 and 2016 programs only. After analysis of the 2013 research, the program was reviewed, and subsequent programs were discussed with the teachers in the partner schools. The research does not report on the findings of 2014 and 2015 programs as there was no formal research carried out in these years only PST's online feedback and informal observations by teacher educators. The research studies from 2013 and 2016 are slightly different studies with some common survey questions. These data illuminate how the PSTs, teachers and teacher educators experienced the program in 2013 with rich qualitative and quantitative data and some detail of subsequent changes that were made to the program are provided. It was decided in the 2016 study to incorporate surveys by school students and teachers in addition to PSTs to provide evidence from the perspective of PSTs, teachers and the school students, as to how school students experienced the program and how they built on their science knowledge and understanding.

Analysis

The surveys in both studies (2013 for PSTs and 2016 for PSTs, students, and teachers) involved 5-point Likert scale questions ranging from strongly disagree to strongly agree. The mean and standard deviation for all surveys were calculated using SPSS software.

In 2013, there were four survey questions and two open response questions (Table 2) for PSTs. The 2013 surveys included pre-surveys before the PSTs undertook the program and post-surveys, after the PSTs undertook the program. The analysis included descriptive statistics of two open response questions. The interview and focus group data in 2013 were analysed and commonalities and differences between respondents and underlying patterns were revealed (Anfara

Table 2 Response to the school–university partnership approach to science and technology education in 2013 from PST participants (73% response rate pre-survey, 93% response rate post-survey)

Question (Likert Scale 1–5 1 strongly disagree, 5 strongly agree)	Mean Pre-survey ($N=59$)	SD	Mean Post-survey ($N=75$)	SD
1. I feel confident to carry out my science and technology curriculum studies in the classroom with the children	3.9	0.7	4.2	0.6
2. The 'school based' activities in this unit (will) have (help) helped me feel more confident about presenting science in the classroom in the future	4.6	0.5	4.7	0.6
3. The 'school based' activities as part of this unit (will) have (help) helped me gain some valuable knowledge and/or skills	4.4	0.7	4.5	0.6
4. I think participating in the 'school based' activities component of this unit (will) has (assist) assisted me to link the theory introduced in the unit with practice in the classroom	4.4	0.7	4.6	0.6

et al., 2002). The multiple sources of data and integration of data increased triangulation (Anfara et al., 2002). Analysis of these data using a practice architectures lens drawing on the work of Sjølie and Østern (2021) in addition to Kemmis et al. (2014a) involved examination of the arrangements, cultural-discursive, material-economic and social-political that shaped the practices of the stakeholders within the school–university settings. In 2016, there were six online survey questions (an additional two questions added) (Table 3) for PSTs. As there were no pre-survey questions in 2016, a question, designed to retrospectively ascertain the PSTs' confidence prior to commencing the program, was included (Question 1, Table 3). Another question was included to assess how the PSTs perceived their students built on their science knowledge by taking part in the lessons (Question 6, Table 3). Questions relating to confidence and linking theory and practice with PSTs across the 2013 and 2016 iterations where the survey questions were the same were compared using a two tailed t test. It was not possible to carry out paired t tests for the pre- and post-surveys in 2013 as the sample size was unequal. There were two open-ended question responses for the PSTs, students and teachers in 2016.

The open responses from both 2013 and 2016 studies of PSTs, students and teachers were analysed and coded using a thematic analysis approach. The process to identify the themes (or categories) in the responses was conducted independent of any pre-existing framework for structuring the analysis. Categories were identified per open response and the lists of each category were ranked according to the count of each category and then assigned a percentage based on total respondents. Percentages for the open response categories in both 2013 and 2016 were incorporated into the results.

The authors were careful to be aware of research bias that might occur in a small study of this nature as the teacher educators (including the lead

Table 3 Response to the school–university partnership in science and technology education in 2016 from PST participants (25% response rate)

Questions (Likert Scale 1–5 1 strongly disagree, 5 strongly agree)	Mean ($N=35$)	SD
1. Before doing the school–university partnership program in science and technology education I felt confident to carry out my science and technology curriculum studies in the classroom with the children	2.9	1.1
2. The school-based delivery of science and technology education has helped me build my confidence to teach science in the classroom in the future	4.6	0.7
3. By doing the school-based delivery it has helped me build on my content knowledge in science education for my teaching	4.5	0.7
4. The school-based delivery has provided me with knowledge and skills relating to the pedagogy behind science teaching	4.5	0.7
5. Participating in the school-based activities this session has assisted me to link theory introduced in my university studies with practice in the classroom	4.6	0.6
6. The students in my group were able to build on their science knowledge as a result of taking part in the activities	4.6	0.5

researcher) in the program were involved in the research. Researchers outside the program administrated the surveys and conducted the interviews and focus groups (in 2013). Surveys were online in 2016 and outside researchers shared in the analysis and writing up of findings to provide independent administration and analysis.

Ethics approval was provided by the University Human Research Ethics Committee, the NSW State Education Research Application Process, Queensland Department of Education and Training and the Catholic Education Office.

Findings

Using a practice-architectures lens, these findings focus on three practice architecture's arrangements for the practices of the PSTs and their students. The cultural-discursive arrangement enabled the 'sayings' where PSTs applied the languages and culture surrounding the theory gleaned at university into the classroom setting. The material-economic arrangements enabled the PSTs' 'doings' in applying theory in an authentic school site in contrast to working with the constraints of the university tutorial room. The social-political arrangement enabled the 'relatings' of the PSTs with the students and to practise classroom management. The results from the analysis of the data have been documented addressing each outcome viewed through the practice-architectures lens.

Establish a school–university partnership model in science ITE that leads to improved knowledge of PSTs and their students

The PSTs in the program in 2013 and 2016 built on their knowledge in science education for their future teaching (2013, post-survey 4.6; 2016, 4.5) (Tables 2 and 3)

Table 4 Response to the school–university partnership approach to science and technology education in 2016 from school student participants (5% response rate)

Questions (Likert Scale 1–5—1 strongly disagree, 5 strongly agree—using smiley face icons)	Mean (*N* = 22)	SD
1. I liked doing the university science activities	4.7	0.5
2. When I was doing these, I learned new things about science	4.2	0.8
3. I would like to do the university science activities again one day	4.6	0.6

and built on their content knowledge in science education (4.5) (Tables 2 and 3). The post-survey results demonstrated PSTs believed they gained valuable knowledge and skills from program participation (4.5) (Tables 2 and 3).

A comparison was undertaken of two common questions in the PSTs' post-surveys comparing responses in 2013 and 2016. The first was between PSTs' perceptions of whether they were able to build on their knowledge and skills in 2013 and 2016, after taking part in the school-university program, and there were no significant differences between the years (Table 6). The second question (Table 7) that was compared between years relates to PSTs confidence and is reported below.

The PSTs in the 2013 focus group shared a belief that presenting science in the classroom setting made them accountable to engage in the content as they required the prior knowledge to be able to facilitate the lessons, 'made the lessons more meaningful', 'brought the content alive' and made the content 'sink in more'.

Both teacher educators thought that the program gave PSTs more incentive to engage with the scientific and theoretical content: 'it was my gut feeling that there were more PSTs engaging with the readings and materials than I had found in previous years when it was more tutorial based' (Interview, 2013). These educators also believed the program significantly developed PSTs' knowledge and understanding relating to teaching and learning science with a breadth of experiences including behaviour management, scaffolding, differentiating, questioning and fostering higher order thinking.

Assessment was conducted by the PSTs as part of their teaching program with their small group of students. From formative and summative assessment and general observations, the PSTs believed their students built on their science knowledge by participating in the program (2016, 4.6) (Table 3). A survey open response from a PST in 2016 demonstrates how their students built on their prior knowledge, by program participation:

> It was through summative assessment strategies I was able to observe the students conceptual understanding which was significantly improved. At the commencement of the lesson, they were not able to use meta-language for magnetic forces or explain more than they know that a fridge has magnets. Upon completion of the unit of work they discussed how their thinking had changed that magnets could be stronger and exert weaker forces on certain objects. They also discovered not all metals are magnetic after a self-discovery around

Table 5 Response to the school–university partnership approach to science and technology education in 2016 from school-teacher participants (30% response rate)

Questions	Mean ($N=6$)	SD
1. I believe the school–university partnership program for science and technology teacher education is a worthwhile program for the PSTs	4.7	0.5
2. I believe the school–university partnership program for science and technology teacher education is a worthwhile program for my students and the school community	4.5	0.5
3.By taking part in this university partnership program in science and technology my students built on their science understanding	4.3	0.8
4.My students were engaged with the science activities during the school–university partnership program	4.7	0.5
5.I used the opportunity to provide verbal feedback to support the PSTs	4.3	0.5
6.The PSTs used the time effectively to further their knowledge and understanding in science education	4.7	0.5

the school grounds testing different metals. It was fantastic to observe their enthusiasm and delight in learning.

Through a practice architectures lens, the cultural-discursive arrangements of the science classroom in the school sites enabled the 'sayings' of the PST and their students, illustrated by the comment above, to engage with the scientific metalanguage and from the perspective of PSTs, the students and their teachers built on their knowledge and understanding. These interview comments from the teacher educators followed by survey responses from the students and teachers illustrated the positive culture of the science classroom settings for both PST and their students elaborated in the following two paragraphs.

Most teacher participants in 2016 believed that both the PSTs (mean 4.7) (Table 5) and their students (mean 4.3) (Table 5) built on their science knowledge by participating in the program. In their open responses, teachers related how their students would demonstrate understanding of science knowledge that they had gleaned as result of taking part in the partnership program. The teachers described how students incorporated their new science knowledge into different contexts in their own science classrooms following the program. Teachers observed cultural aspects of language, thinking and discourse in student discussion and assessment: the students 'incorporated new knowledge into other lessons' and 'student assessment showed good take up of concepts'.

The school students described their experiences of the culture of the science classroom as 'fun' and stimulating illustrated by the following students' responses: 'They (the science lessons) were fun because we got to do the experiments and not watch people do it'; 'It was fun and I learnt so much about cemiclels and animals'; (spelling retained). Furthermore, the students believed that they learnt new things (4.2) (Table 4) by taking part in the program reinforced by the following comments: 'we learnt about how everything is a chemical'; 'I learnt that a life cycle keeps going round and round'.

Table 6 Comparison of PSTs' building on their knowledge and skills after taking part in the program of years 2013 and 2016

	Iteration	*N*	Mean	Std. deviation
Question 4	2016	35	4.5	0.7
	2013	75	4.6	0.6

The difference between the means was calculated using a two tailed t test, $p > 0.05$

Table 7 Comparison of years 2013 and 2016 PSTs' confidence to teach science and technology after taking part in the partnership program

	Iteration	*N*	Mean	Std. Deviation
Question 2	2016	35	4.5	0.7
	2013	75	4.6	0.6

The difference between the two means was calculated using a two tailed t test, $p > 0.05$

Connect theory and practice in science teacher education

Most PSTs believed by taking part in the program, they linked theory with practice. The majority of PSTs in the post-survey agreed or strongly agreed that the school-based delivery assisted them to link theory with practice (2013 post-survey, mean 4.6; 2016, mean 4.6) (Tables 2 and 3).

Some PSTs included linking theory and practice, as a positive aspect in their survey open responses (2013, 15%; 2016, 18%). With a practice-architectures lens, it is the material-economic arrangements which enabled the PSTs 'doings' by applying theory within a genuine class setting. These cultural-discursive arrangements enabled language, thinking and discourse (of the science classroom) to be practised. The following comments in the unit evaluation student feedback illustrate the PSTs' appreciation of the 'doings' (the practice): 'I really love going into the schools, this is such a great learning experience putting theory to practice! Thank you for a great semester' (2013); and 'It was great to have a focus on science and put the technique into practice. I found all the theory became much clearer by being provided with this experimental hands-on approach to learning!' (2016). Additionally, the practical experiences of the classroom were included by many students as a positive aspect of the program in the survey open responses (2013, 44%; 2016, 29%).

A teacher in a 2013 focus group believed that without the practical aspect the theory is meaningless:

> You know it's all very well to have the theory but a huge part of it is managing the students and actually understanding how to manage a group, because if you can't manage a group, you may have the best theory in the world but it's not going to go anywhere.

In 2013 interviews, one teacher educator discussed how they observed PSTs applying the theory.

> If they can put it into practice straight away with practical experience and see what everyone else is doing, then it becomes this huge network of discovery and learning so it's pretty effective.

Another teacher educator described her pleasure in seeing the PSTs applying social constructivist theory (Interview 2013).

Build PSTs' confidence in the facilitation of science in the classroom

Most PSTs believed the 'doings' of the program in the culture of the classroom enhanced their confidence to teach science (2013, 4.7; 2016, 4.6) (Tables 2 and 3). Before undertaking the program in 2016, the PSTs were much less confident to teach science (2016, 2.9; compared with 4.6 after undertaking the program) (Table 3). There were no significant differences between the PSTs' responses in 2013 (post-survey data) and 2016 relating to confidence (Table 7).

The PSTs included increasing confidence as a helpful aspect of the program (2013, 13%; 2016, 7%).

The survey open responses (2013 and 2016) also confirmed the 'doings' of being in the classroom and 'relatings' with the students in the program increased PSTs' confidence: 'time in front of students in a classroom is building my teacher confidence and experience' (2013); and the experience provided 'an opportunity to work with a group of students exploring scientific concepts and misconceptions thus allowing us as preservice teachers to focus solely on and build up confidence in this KLA' (2016).

Other PST's comments highlighted PST's boost in confidence after undertaking the program: 'thank you for providing an in-school experience! ….. It provides an opportunity to practise the vital teaching skills without being watched or graded by people. The confidence gained from this experience has been amazing. I can't thank you enough!' (Unit Evaluation Student Feedback 2013). The social-political arrangements of the school–university partnership setting enabled practices within a relaxed environment for PSTs to build confidence without the constraints and power structures of being examined in formal professional placement settings.

Teacher educators in 2013 interviews also emphasised how the program increased PSTs' confidence to teach science:

> They get to put their ideas straight into practice right away and try out anything they might be finding difficult and build their confidence. I think that's a huge part of teaching science because if we lack confidence in something we tend to stay away from it. (Interview 2013)

The value of the program to stakeholders

In 2013, the program was only conducted in one campus (campus [a]). In the other two campuses, the PSTs carried out their curriculum development units in the university tutorial room. The PSTs' Unit Evaluation Student Feedback carried out at the end of the semester revealed the value of the school-based delivery as the unit satisfaction in campus (a) where the school-based approach was implemented was considerably higher compared with other campuses (b & c) where the school-based approach was not undertaken (4.47 [Campus (a) with the school–university partnership approach]; 3.94 and 2.78 [campus b & c without the school-based approach]; 3.91 [university mean]) (Table 8).

The value of the school–university partnership model for all stakeholders is highlighted by the following PST's comment in the Unit Evaluation Student Feedback in 2013:

> Thank you - what can I say - it was a real treat. A deep and meaningful learning experience where all stakeholders benefited. The kids at school said science was the highlight of their week ... that's a win for science, for kids, for teachers, for PSTs, … and (the university)! May there be more units like it. The unit has engaged my passion for science and made me curious again about the world around us, and our place, and relationships with other living beings, within it.

Comments from the 2016 Unit Evaluation Student Feedback also demonstrated the value of the 'doings' and 'relatings' of being in the school setting for PSTs: 'having the opportunity to work with the students at the school really enhanced my learning, and any practical experience is a bonus in my opinion' (2016).

Teachers in the focus group (2013) believed the PSTs responded very positively and 'superbly' in the culture of the school setting: One teacher believed the program should be conducted more widely:

> I feel the model should be taken on board anywhere in Australia where teachers learn in the class, it is just so vital, and the research has proven that this is the approach …. this model gives students (PSTs) the opportunity to have a better understanding and actually practise their craft and I know it's a taster but it's quite valuable…

The value of the program for students was also evident in the Teachers focus groups (2013) data:

> 'They couldn't wait, every day they would say are they coming today are they coming today?'; and 'they (the school students) loved it and they were all highly engaged, really engaged'.

The teachers described how the parents responded to the program: 'we have had really good feedback from parents saying their child loves Tuesday because it's science' (Teacher response in Focus group 2013).

The teachers in 2016 perceived that the program 'opened up' new experiences for them as teachers and their students, highlighted by the following survey open response:

I think it is very valuable to be involved with the University as part of our extended learning community. It opens the children's minds to the idea of university as a possibility for their future education.

The school students perceived the science program to be a positive experience and most students, 'liked doing the university science activities' (4.7) (Table 4) and would like to do the activities again.

Fine tuning the programs in response to research findings

Analysis of the findings enabled the program to be refined in the subsequent delivery of the units in 2013 and beyond illustrated by a teacher,

The program was good in 2012 but it was even better in 2013, it was superbly organised in 2013, had strong links with the curriculum, and put science in a good light for the children. (focus group, 2013).

Some PSTs wanted future programs to remain the same (13% in 2013 and 15% in 2016). However, there were aspects of change that PSTs suggested in the open survey responses and these were taken into consideration for iteration of the program in subsequent years including incorporating more university workshops prior to the school-based component (2013, 29% requested more preparation time). One PST in 2013 discussed how they found the program overwhelming and thought the school visits could be reduced to every second week, other PSTs believed that there were too many activities (2013, 7%; 2016, 4%).

It was evident that the material-economic constraints surrounding the timing of the school site visits (Sjølie & Østern, 2021) needed to be addressed and aspects of the program were restructured and reframed in 2014, 2015 and 2016. The PSTs were given more time (three weeks instead of two) to plan and implement a sequence of lessons while in the university setting prior to going into schools.

The teachers generally believed the program should remain the same structure; however, there were suggestions that teachers offered that they thought would benefit the program. Two areas of the program highlighted by teachers in 2016 that they thought warranted improvement were as follows:

(1) 'More alignment with the class unit of work'; and
(2) More emphasis on 'differentiation'.

In 2016, the activities involved teaching topics outside the class curriculum. The PSTs facilitated the 5E lesson sequence over two lessons with limited time to cover each phase and assess knowledge and understanding. In response, in subsequent programs, the teachers were invited to choose the topic to align with their school curriculum, and the 5E sequence was implemented over five lessons. The teacher educators sought to ensure the social-political and cultural-discursive arrangements enhanced the 'sayings' and 'relatings' for both PSTs and their students. Strategies to achieve this included emphasising PST/student relationships and students' individual ways and rates of learning (differentiation), and

Table 8 For the Unit Evaluation Report: For Science and Technology Education 2013

Questions	Mean campus (a) (47% response rate)	Mean campus (b) (42% response rate)	Mean campus (c) (25% response rate)	Uni wide Mean
This unit helped me to develop some valuable skills/attributes	4.66	4.00	2.83	4.04
I am satisfied with the way this unit was taught/delivered	4.53	3.91	2.67	3.84
Overall, I am satisfied with this unit	4.47	3.94	2.78	3.91

Note Campus (a) was where the program was facilitated

supporting the PSTs with their diagnostic and formative assessment throughout the lesson sequence.

We endeavoured to improve the experiences for the PSTs, school students, teachers, and teacher educators, to enhance practices in the school–university partnerships, and research is underway to examine the program in 2023 in shortened semesters and a post covid culture.

Discussion

The research revealed that the school–university partnership program in science education both in 2013 and 2016 was generally perceived by most participants to be a positive and valuable experience for all. For the PSTs and teacher educators, it was the value of experiencing the classroom as part of the university curriculum and pedagogy unit coursework. For the teachers and students, the school–university partnership program was a 'valuable' and 'fun' link to university life in their school site. TEMAG (2018) believes strong School–University Partnerships are now integral not only to the professional experience element of courses but also in course design, assessment of readiness to teach and evaluation of impact (TEMAG, 2018, p. 4). The programs were seen by PSTs, students, teachers and teacher educators as achieving the project outcomes and in so doing addressing key problems identified in the education research literature relating to classroom readiness such as 1. lack of content knowledge in science, 2. lack of confidence to teach science and 3. failure to connect theory with practice (Fitzgerald, 2020; Herbet and Hobbs, 2018).

Outcome 1

The TEMAG, 2018 report into School–University partnerships in Australia identified 'explicitly building the confidence, pedagogical skills, knowledge and attitudes for effective teaching' as key to quality ITE (p. 15). All stakeholders perceived that PSTs built on their scientific conceptual knowledge and skills and students built on their scientific knowledge. The cultural-discursive arrangements of actual science classrooms enabled PSTs and their students in their ‘sayings’ to employ scientific metalanguage and explain scientific phenomena. Furthermore, teachers observed their students incorporating their new scientific conceptual knowledge into different contexts after taking part in the program.

Outcome 2

It was evident that the program was successful in connecting theory and practice in science teacher education. The findings clearly revealed that the PSTs believed that they were more effectively able to connect theory and practice after taking part in the program in both 2013 and 2016. The cultural-discursive arrangements of authentic sites enabled the PSTs in their ‘sayings’ for the application of theory. The material-economic arrangements of the physical classroom/school setting enabled PSTs in their ‘doings’ to apply theory with their students which was not possible in a traditional university tutorial room. The social-political arrangements of the school setting enabled ‘relatings’ between PSTs and their students, and practical class management opportunities to trial pedagogical models.

Outcome 3

The research revealed that the social-political and material-economic arrangements of this school–university partnership model setting enabled ‘relatings’ and ‘doings’ in a safe and relaxed environment for PSTs to build confidence in the facilitation of science.

The model

The school–university partnership model is identified as addressing the problem identified in the literature of lack of time in the classroom in ITE for preparation of classroom-ready graduates. The model provides PSTs with extra practical experience in the classroom, not replacing professional experience but complementing it. Key aspects of this model identified were PSTs collaborating with peers to build relationships with students in small groups over five or six weeks. In this setting, PSTs were able to trial innovative practices, develop knowledge and skills and build confidence in a relaxed environment moving towards classroom readiness. The experience of this school–university partnership model was described by a PST as ‘a real treat’ and a ‘deep and meaningful learning experience’. However, with teacher education increasingly being offered online, together with PSTs who are employed full time during school hours, and the changing modes of ITE (such as more intensive shortened semesters), there are challenges to overcome in providing a teaching model incorporating extra practical experiences in the classroom.

Recommendations for areas of improvement

Teacher and PST participants highlighted the following areas for improvement: providing more time to implement the 5E sequence, working closely with each school science curricula, more differentiation of student groups, and more time to learn science pedagogical content knowledge. These recommendations enabled the teacher educators to restructure and reframe aspects of the planning and organisation of subsequent programs.

Limitations

The sample size was small, with three schools participating in 2013 and five in 2016 and a very small sample of school students in the research, and therefore, it would be unwise to generalise from the findings. These data are only from 2013 and 2016 iterations of the program and do not include 2014 and 2015 as discussed in the methodology section but further research is currently occurring in 2023 (as previously mentioned). It also needs to be noted that the learning outcomes of the school students are derived from the perspectives of PSTs, teachers and the students themselves, not a formal measurement of student achievement.

Further research and implications

This research addresses in part the urgent calls for further evidence-based ITE models to provide graduates who are 'confident, effective and classroom-ready' (Paul et al., 2021, p. 48). There is evidence that PSTs' confidence, knowledge and skills were enhanced by the application of this school–university partnership model and it provided extra time in the classroom in addition to formal professional practice. Further research would be valuable to examine application of similar models in other subject areas or to further examine the uptake of content knowledge, teaching strategies and skills for the classroom, employing a school–university partnership approach to ITE as recommended in the TEMAG (2014) report. Looking at the uptake of content knowledge with school students as part of school–university approaches to ITE would also be a valuable area of research. With the challenges of changing modes of ITE (such as more intensive online teacher education and increasing economic pressures for PSTs often requiring them to work long hours while studying which severely limits extra time in the classroom), research looking at creative and innovative solutions is required to provide PSTs with rich first-hand teaching experiences in education. Teacher educators have a responsibility to prepare future teachers to present quality experiences that engage and interest students. Ideally teachers should possess the knowledge and understanding to ensure school students are provided with opportunities to build on their skills to critically analyse evidence and make informed decisions about matters such as the environment and health, particularly in this rapidly changing world. This small-scale research indicates that this school–university partnership model encouraged both PSTs and school students to engage in science and according to PSTs, teachers, and school students' perspectives, build on their science knowledge and understanding.

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