Final Report

Science for early childhood teacher education students (ECTES): collaboration between teacher educators, scientists and engineers

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Acronyms

ECE: Early childhood education

ECTES: Early childhood teacher education students – Students enrolled in a Bachelor of Education (Early Childhood) degree at Curtin University of Technology (Bentley Campus, Perth).

PCK: Pedagogical Content Knowledge

STEM: Science, Technology, Engineering and Mathematics

Definition of terms

Collaboration – "An interactive process among individuals and organisations with diverse expertise and resources, joining together to devise and execute plans for common goals as well as to generate solutions for complex problems" (Gronski & Pigg, 2000, p. 783).

Consultant early childhood teachers – A group of four early childhood teachers who provided ongoing feedback and advice throughout the project.

Early childhood education – While the international definition of early childhood education refers to children from birth to 8 years of age, for the purpose of this project early childhood education refers to children from three to eight years of age.

Early childhood teachers – Professionals teaching in early childhood education classroom.

Early childhood teacher education students – Students enrolled in a Bachelor of Education (Early Childhood) degree at Curtin University of Technology (Bentley Campus, Perth).

Science/engineering academics – Professionals teaching at the higher education level within various STEM degrees.

Science Education Unit – A science curriculum and instruction unit undertaken in the third year of the Bachelor of Education (Early Childhood) degree.

Teacher educators – Professionals teaching at the higher education level within the Bachelor of Education degree at Curtin University.

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Executive summary

The aim of this project was to develop the professional capacities of early childhood teacher education students (ECTES) as effective teachers of science. For the purpose of this project, early childhood education is defined for children from three to eight years of age. Using a collaborative approach between teacher educators and science/engineering academics, the project aimed to address the lack of early childhood science resources through developing, implementing and evaluating various science modules for ECTES. The project aimed to increase the limited science content knowledge and poor confidence and attitudes towards science of ECTES. The project also aimed to develop a model of institutional interdisciplinary collaboration for developing curriculum and resources.

A practical action research methodology guided the project, involving iterative cycles of module development, implementation and evaluation. The participants consisted of one cohort of 38 ECTES within the Bachelor of Education (Early Childhood) program at Curtin University. These ECTES undertook their third year Science Education unit in Semester 2 2008 and were then followed through to their final teaching practice in Semester 2 2009. The project team consisted of five teacher educators and five science/engineering academics. Teacher educators and science/engineering academics collaboratively developed various science modules and then team taught aspects of these in the ECTES' Science Education workshops. Evaluation of the modules came from ECTES, the project team and a range early childhood teachers.

The major outcome of the project was a 128-page full colour resource book (with accompanying CD), *Planting the Seeds of Science*. *A flexible, integrated and engaging resource for teachers of 3 to 8 years olds.* This book comprises five science modules based on the themes of the environment, day and night, forensic science, cleanliness and solar energy. Each module was developed to be used as a flexible, adaptive and integrated curriculum, rather than a set teaching program. Each module contains of a range of possible science ideas and activities around the given theme, a list of resources, ideas for assessment, background scientific information, suggestions for curriculum integration, connections to the *Early Years Learning Framework* and the *Australian Curriculum: Science*, and a case study. This book can be accessed on the ALTC website: <http://seedsofscience.altc.edu.au/>.

Across the Science Education unit, the ECTES were found to increase their science teaching capacities. They developed greater confidence to teach science, better attitudes towards science, and enhanced science content knowledge. A combination of reasons were attributed to these improvements, including being shown how to teach science, active participation within the workshops, access to resources (including the resource book and the science/engineering academics), and increased science content knowledge.

In teaching science in the early childhood classroom, the ECTES embraced the modules to develop their programs. All components of the resource book were considered to be useful and relevant. The book was found to be a much needed resource to assist ECTES in teaching science in a flexible, integrated and engaging manner. A cross case analysis of ECTES and practising early childhood teachers' use of the modules revealed the following four strengths: the wide range of ideas and activities; the flexibility to adapt for a given context; integration across the curriculum; and ease of use in planning and programming. *Planting the Seeds of Science* was highly valued by those teachers who trialled it, and considered a much needed resource in teaching science in early childhood education.

A model of institutional interdisciplinary collaboration based on the theoretical concepts of social capital, structural holes and social brokers was developed. In this model, the social broker bridges the structural hole between different disciplines (in this project science /engineering and teacher education), thus having access to diverse information and interpretations, and an enhanced ability to combine information from the different disciplines. The specific model of collaboration developed noted the importance of institutional strategic support, team selection, a mechanism to shift perspective, and characteristics of the social broker (in this case the project manager) in contributing to the success of the project. Characteristics of the project manager included passion and belief, vision, wisdom, legitimate authority, a nurturing capacity, a flexible and emergent role, and being active for the entire project.

Characteristics of the project team that contributed to the success of the project included: reciprocal and open communication; passion through a shared culture that recognised the importance of science in early childhood education; democratic processes such as joint participation, shared decision making, knowledge ownership and trust; flexibility in the entire process and in each team member’s approach and participation; solidarity through emotional attachment to the project; positive emotional energy in the form of excitement and enthusiasm; and collegiality through meetings that had a professional agenda with a social atmosphere.

Project overview

This report outlines the Australian Learning and Teaching Council (ALTC) funded project conducted at Curtin University 2008–2010 titled, Science for early childhood teacher education students (ECTES): Collaboration between teacher educators, scientists and engineers.

Aims

With a focus on science education, the project addressed an area of continuing concern in teacher education in Australia — the need to develop ECTES' professional capacities as effective teachers of science. For the purpose of this project, early childhood education is defined for children from three to eight years of age.

Through a collaborative approach between teacher educators and scientist/engineering academics, the project aimed to address the lack of early childhood science resources, by developing, implementing and evaluating various science modules for ECTES. Acknowledging the continuing concern of limited science content knowledge and poor attitudes towards science, the project aimed to increase ECTES' professional capacities with regards to cognitive and affective dimensions for science education.

With a sub-focus on institutional interdisciplinary collaboration, the project also addressed a continuing concern in higher education of limited collaboration across different disciplines to develop curriculum and resources. To develop this sub-focus, the project aimed to develop a model of institutional interdisciplinary collaboration.

Background and Rationale

Development of science teaching capacities of ECTES

Various reports have identified urgent needs for science education in Australia, particularly in relation to maintaining and increasing the capability to teach science at all levels of schooling (eg Australian Academy of Technological Science and Engineering, 2002; Dow, 2003; Goodrum, Hackling & Rennie, 2001; Harris, Jensz & Baldwin, 2005; Tytler, 2007). The most recent reports at both the national and state levels have recommended the development of comprehensive 'action plans'. For example, the Australian Government sponsored the initial phase of production of a *National Action Plan for Australian School Science Education 2008-2012* (Goodrum & Rennie, 2007), and the Queensland Government produced a discussion paper suggesting possibilities for a 10-year plan for Science, Technology, Engineering and Mathematics (STEM) education and skills in Queensland (Department of Education, Training and Arts, 2007). In terms of the needs of students, teachers and the nation, these reports highlighted a 'crisis' in science education. Briefly, they presented convincing evidence of the declining number of students enrolling in science courses or science education courses; a limited number of appropriately trained teachers of science; and the inadequate science-related background of teachers, particularly those at primary and early childhood levels, in an increasingly scientific and technological society. In innovative and economic terms, the critical shortage of people with STEM knowledge, skills and/or appreciation represents a national concern.

Over the past decade, a number of initiatives have attempted to address the student-related dimensions of this problem, particularly increasing engagement in

STEM at the upper primary and secondary levels. Examples of these initiatives include the Australian Academy of Science ‘Primary Connections’ program, the Collaborative Australian Secondary Science Program (CASSP), the Creativity in Science and Technology (CREST) program, the Science Education Assessment Resource (SEAR) program, the Australian Science Teachers’ Association Science Awareness Raising Model, and the recent Scientists in Schools (SiS) program. In addition, resources have been dedicated recently to the development of high quality online, science and mathematics curriculum content for Australian schools by the Learning Federation <www.thelearningfederation.edu.au>. However, few of the initiatives to date have focussed specifically on the needs of teacher education students, and even fewer have addressed the needs of ECTES.

Along with limited science content knowledge, early childhood professionals display a lack of confidence and competence to teach science (Appleton, 2006; Harlen & Holroyd, 1997), a lack of understanding of what science looks like at the early childhood level and where science occurs in everyday situations, and an inability to extend or capitalise on young children’s thinking (Fleer, 2009). These, along with the lack of support for the place of science in early childhood education (which has an emphasis on literacy and numeracy), and the lack of resources supporting science education, have contributed to the limited implementation of science within early childhood education (Peterson & French, 2008).

Thus, there is a need for teachers and, subsequently, teacher education students, to develop appropriate professional capacities (in terms of pedagogies, content knowledge, and attitudes) and resources to deliver engaging science programs in the early childhood classroom. This project addressed these components of science teaching and learning as aspects of ECTES’ development through a collaborative approach between teacher educators, scientists and engineers.

Collaboration at the higher education level

While collaborative research can be considered a normal research practice, limited information has been presented on the actual collaborative practices and relational dynamics within such collaborations. There are many reasons for participating in research collaborations. Ritchie and Rigano (2007) found that bringing together researchers with different expertise and perspectives has the potential to address complex social problems, provides a supportive climate to encourage creativity and risk taking, and distributes workloads to enhance motivation and productivity.

Universities commonly offer interdisciplinary programs to provide students with the opportunity to study complex problems that are difficult to adequately address with the tools of any single discipline (Lattuca, Voigt & Fath, 2004). There is a move for university teaching to be conducted through cross-disciplinary teaching teams and by teaching students to integrate multiple modes of disciplinary thought (Klein & Newell, 1998; Newell, 1990). However, there has been only limited research into how interdisciplinary subjects are developed and taught within the traditional university environment where disciplinary structure is deeply embedded.

Previous collaborations between STEM and education faculties have produced mixed results. Historic divisions between these two sectors have not assisted collaborative efforts. This was highlighted in Hora and Miller’s (2009) qualitative case study of California State University, Northbridge. As part of the National Science Foundation (NSF)-funded System-wide Change for All Learners and Educators (SCALE) project, cross-cultural teams worked together to improve collaboration between STEM and education faculties in relation to teacher education programs and to improve STEM undergraduate education. The resultant collaboration was regarded as “modest” (Hora & Miller, 2009, p. ix). Four cultural schema relating to educational reform were found to restrict the collaborative efforts: scientific legitimacy and credibility were equated with research rather than teaching; the distinction between hard and soft sciences; the recognised tensions between institutional support for reform and the disciplines; and the divergent beliefs about the relative importance of content and pedagogy in teacher education STEM courses.

In a review of institutional change of 21 partnerships between STEM and education faculties, CASHE (2006) found that teacher education programs and teacher professional development programs had implemented curricular change as a consequence of the partnerships. In contrast, no curricular change had occurred in the STEM departments. Changes were found at the individual level rather than the institutional level, involving individual faculty members who were engaged in specific mathematics/science supported activities. In contrast, there were no department wide initiatives or ongoing collaborative efforts.

With limited information on actual collaborative processes between STEM and education faculties, this project aimed to develop a model of institutional interdisciplinary collaboration between teacher educators and science/engineering academics as they developed and implemented early childhood science curricula and resources.

Objectives

(i) Develop a range of innovative science curricula and resources appropriate for ECTES, through collaboration between teacher educators and science/engineering academics.

(ii) Implement these curricula and resources into the ECTES’ Science Education unit, through team teaching between teacher educators and science/engineering academics.

(iii) Evaluate the effectiveness of the Science Education unit in terms of increasing the ECTES’ confidence and attitudes towards science and science teaching and learning, and their science content knowledge.

(iv) Ongoing development, implementation and evaluation of the resources through the use of practising early childhood teachers.

(v) Develop ECTES’ capacities to develop science curricula that incorporate science content and pedagogy appropriate for the early child classroom.

(vi) Evaluate the effectiveness of the science resources in terms of the ECTES’ professional knowledge related to science teaching and learning.

(vii) Develop case studies of ECTES and practising early childhood teachers using the resource.

(viii) Use evaluation results to review and revise the curricula and resources for ongoing use in the Bachelor of Education program.

(ix) Develop a model of institutional interdisciplinary collaboration between teacher educators and science/engineering academics.

(x) Disseminate the project processes and outcomes to other institutions, teacher education programs, and professional development programs.

Project context and participants

The project involved three groups of participants: ECTES, project team members, and early childhood teachers.

ECTES in the Bachelor of Education (Early Childhood) degree at Curtin University (School of Education, Bentley Campus, Perth) were the main participants in the project. The degree is a four-year teacher education undergraduate program with total full-time student enrolment of approximately 200. One cohort of 38 students, who undertook their third year Science Education unit in Semester 2 2008, were followed through this project to their final teaching practice in Semester 2 2009.

The project team consisted of 10 members, five from teacher education and five from science/engineering, representing two universities within Western Australia. A summary of the project team's expertise and experience can be found in Appendix A. Four academics, along with the project manager, had experience in teacher education. Of the remainder, four were scientists while the fifth was an engineer. Each scientist/engineer was individually invited to be part of the project after discussions between the teacher educators and Dean of Science, Curtin University. They were selected based upon recognition of their exemplary teaching/learning record, ability to work in a group, and their perceived ability to interact in a positive and supportive manner with ECTES.

Early childhood teachers were used in two capacities:

1. A group of four were classified as consultants and gave ongoing feedback throughout the entire project. These four teachers had a range of early childhood classroom experience from five through to 20 plus years. All were based in Western Australia: three in Perth and one in regional Western Australia. Two were working in government schools, one was working in an independent school, and the fourth was retired. As an integral part of the project, they were kept informed of all processes and invited to participate in as many of these processes as possible.

2. A second group of three practising early childhood teachers agreed to trial and evaluate the modules in their classroom. All were based in the Perth metropolitan area and all taught in independent schools. These trials subsequently became case studies for the project.

Project framework and approach

This project is based upon two general theoretical frameworks. The first considers the characteristics of ECTES and approaches used to improve ECTES knowledge of and confidence towards science, with an emphasis on the place of science pedagogical content knowledge. The second theoretical framework relates to collaboration, discusses the characteristics of successful collaboration, and positions this project as an example of integrative collaboration.

Characteristics of ECTES in relation to science education

ECTES bring a range of characteristics when learning about science and how to teach science, due to their diverse backgrounds and individual experiences with science. ECTES tend to perceive themselves as 'non-science' people trying to become science students at university (Mulholland & Wallace, 2003). They consider themselves to have poor science knowledge (Appleton, 2006), and tend to have poor attitudes and beliefs about science and their capacity to be effective teachers of science (Watters & Ginns, 2000). This latter point can lead to an avoidance of teaching science (Harlen & Holroyd, 1997). Many ECTES remember negative science experiences, mostly in secondary school, resulting in their perceiving science as only for the intellectually gifted or as having a masculine image (Mulholland & Wallace, 1996; Skamp, 1989). Finally, ECTES tend to have well-developed but often simplistic views of the science teaching and learning process, leading to inappropriate science teaching strategies and learning experiences (Appleton, 2006). All of these factors contribute to the lack of confidence that ECTES have towards science and the teaching of science.

At the same time ECTES bring many strengths to their teaching and learning. These strengths include respect for children's intellect, curiosity and questioning; celebration of children's wonder; excitement associated with children's exploration and discovery; and a willingness to develop instruction based upon children's thinking that embraces inquiry (Howes, 2002). Howes (2002) suggested that working with their strengths provides ECTES a greater opportunity to connect with science in a manner that is comfortable to them and, subsequently, to believe in themselves as teachers of science.

These ECTES characteristics were taken into account in the development and implementation of the curricula and resources. In particular, effort was made to work ECTES strengths while also developing their science content knowledge and increasing their confidence and attitudes towards science.

Improving ECTES' knowledge and confidence towards science

A substantial body of research exists on how best to improve ECTES' science knowledge and confidence towards science. The majority of this research has been directed at improving science content knowledge and science curriculum and instruction units with the aim of improving the confidence of the ECTES (Appleton, 2003; Cahill & Skamp, 2003; Hand & Peterson, 1995; Riggs & Enochs, 1990). Notably, addressing science content knowledge on its own has produced limited improvements, highlighting the importance of an holistic approach within the science curriculum and instruction unit. The influence of the science teacher educator in improving the confidence of the ECTES by creating an effective science learning environment also has been examined to a lesser degree (Rice & Roychoudhury, 2003). In general, results indicate that learning environments need to be positive and supportive to minimise anxiety and encourage freedom to experiment and verbalise opinions (Huinker & Maddison, 1997; Mulholland & Wallace, 1994). Curriculum and instruction units should include a variety of authentic teaching methods that concentrate on student-centred learning experiences and make connections with prior knowledge. Additionally, ECTES should be supported by consistent feedback to allow for the development of science understanding and pedagogy, and improved beliefs and attitudes about science and themselves as teachers of science (Huinker & Madison, 1997).

Various researchers have advocated a pedagogical content knowledge (PCK) approach in science curriculum and instruction units, through successful experiences at the teacher education level, as a means of increasing ECTES' confidence towards science and science teaching (Appleton, 2003, 2006; Cahill & Skamp, 2003; Rice & Roychoudhury, 2003). PCK is one of many different forms of knowledge that teachers draw upon, which includes subject matter knowledge (or content knowledge) and general pedagogical knowledge (Shulman, 1986). PCK is considered different from the last two forms of knowledge as it is a form of knowledge in action (Zeidler, 2002). Appleton (2006) defined science PCK as "the knowledge a teacher uses to construct and implement a science learning experience or series of science learning experiences" (p. 35). Science PCK is a dynamic form of knowing as it has close links with a teacher's science content knowledge, and is developed through the teacher's own science experiences and science teaching practices (Appleton, 2003, 2006).

While science PCK is necessary in order to teach science, it is not automatically generated from science content and other forms of knowledge (Appleton, 2006). As a means of developing science PCK, Appleton and Kindt (2002) and Appleton (2003) suggested ECTES develop a repertoire of "units that work", rather than isolated science activities, that consist of a series of activities organised in a pedagogical sequence designed to facilitate ECTES' conceptual understanding. They suggested that such units would include learning experiences, key teaching strategies, and explanatory science notes. Appleton (2003) went on to suggest that science content would be most meaningful to ECTES when it is dealt within a pedagogical context, which includes a focus on student preconceptions, and how to deal with these while teaching. These findings suggest that participating in authentic science experiences where both content and pedagogy are made explicit provides an opportunity to increase the science PCK of ECTES.

In the development and implementation of the curricula and resource book an emphasis was placed on developing a positive and supportive learning environment where ECTES were provided with the opportunity to reflect upon their learning, while developing science PCK through interactive science learning experiences.

Characteristics of successful collaboration

Collaboration has been described as "an interactive process among individuals and organisations with diverse expertise and resources, joining together to devise and execute plans for common goals as well as to generate solutions for complex problems" (Gronski & Pigg, 2000, p. 783). A true collaborative relationship is both mutually dependent on and beneficial to each partner (Miller & Hafner, 2008).

There are numerous indicators of successful collaborations including mutuality, supportive and strategic leadership, assets-based building, and sound processes (Miller & Hafner, 2008). Mutuality refers to the sense of parity and mutual participation among participants (Zetlin & MacLeod, 1995). The "more fully a collaborative partnership considers the various types of expertise possessed by its members, the more richness of understanding and direction it will receive" (Zetlin & MacLeod, 1995, p. 6). Successful collaborations are dependent on supportive and strategic leadership at multiple levels, including top-level institutional leaders, partnership-level leaders and day-to-day leaders (Miller & Hafner, 2008). An assets-based focus relates to building on partners' current strengths rather than focussing on weaknesses (Miller & Hafner, 2008). Carefully constructed, sound processes are the cornerstone to effective collaborations. These include clearly articulated and communicated steps and procedures, strategic use of funds, clear and meaningful definition of roles for all participants (so that everyone knows what is expected of them), and substantial and specifically detailed integration of resources across partners to ensure that both groups are involved at various levels of the collaboration (Miller & Hafner, 2008).

Three major obstacles to a successful collaborative relationship have been identified (Miller & Hafner, 2008). The first obstacle acknowledges that all collaborative relationships between diverse partners are complex and difficult. This obstacle is intensified when participants come from different backgrounds and possess different ideas about the issues to be addressed (Gray, 1985, 2004). An inability to find suitable ways to understand others' perspectives can hinder collaborative initiatives (Gray, 2004). The second obstacle acknowledges the inequitable distribution of power between partners and participants. No relationship is neutral; with those who possess social, financial and political resources tending to dominate most aspects of any collaborative relationship (Miller & Hafner, 2008). The final obstacle to a successful collaborative relationship is flawed planning, implementation and evaluation processes (Miller & Hafner, 2008). Ill-conceived and poorly implemented processes can undo any collaborative efforts. Effective communication both within and between partner organisations can assist in developing focused programs.

Various examples of science education at the higher education level have been described (Lasley, Matczynski and Williams, 1992; Eick, 2003; Moscovici and McNulty, 2003). Issues found in these collaborations were the demand on dialogue and collective goal setting, and institutional compromise. However, advantages associated with the collaborations included mutual benefit of the relationship; the bringing of complementary skills, talents and knowledge together (which included different personalities); networking with influential others who could assist the collaborative effort; a trusting, working relationship and a strong commitment to a clear vision; open lines of communication; a shared 'culture'; and institutional support. While collaborative relationships require an investment in time, energy and emotion from each partner, well managed collaborations can result in benefits to all partners and successful outcomes.

An awareness of these characteristics was required in the development of a model of interdisciplinary collaboration.

Integrative collaboration

Various patterns of collaboration have been identified. This project is an example of integrative collaboration (Ritchie, 2007). Integrative collaboration requires prolonged periods of committed activity by partners. Within such collaborations, partners thrive on dialogue, risk taking, and a shared vision, and are motivated by the desire to transform a situation. Participants may construct a common set of beliefs that sustain them during opposition or insecurity. Within integrative collaborations, partners may experience a profound sense of solidarity during the creation of a new vision through successful interactions.

Within this research, an integrative pattern of collaboration was utilised with an emphasis on process, dialogue and empowerment.

Methodology

Overview

The project was guided by a practical action research methodology, distinguished by an iterative cycle of planning, action, observations and reflection (Creswell, 2005). Action research enables researchers to "gather information about, and subsequently improve, the ways their particular educational setting operates, their teaching, and their student learning" (Creswell, 2005, p. 550). Through the process of action research, appropriate curricula and resources were developed, implemented and evaluated. The action research cycle was repeated throughout the project, with all three groups of participants (ECTES, project team and early childhood educators) contributing.

The project was split into four stages, each comprising a different semester. An overview of stages, major processes, and data sources used in the project is presented in Table 1 below. Data sources included ECTES, the project team, consultant early childhood teachers and practising early childhood teachers. Each stage involved a different group evaluating the modules as they were developed. Working with the action research cycle, the modules were continually updated across the two years based on all feedback.

Table 1: Overview of stages, major processes and data sources in the project

Major Processes	Stage 1 Sem 2 2008	Stage 2 Sem 1 2009	Stage 3 Sem 2 2009	Stage 4 Sem 1 2010
Develop modules	Project team	Project team	Project team	Project team
Implement modules	Project team	Consultants	ECTES, practising teachers	
Evaluate modules	Project team, ECTES, consultants	Consultants	ECTES, practising teachers	Project team
Evaluate content/confidence	ECTES		ECTES	
Develop case studies	ECTES		ECTES, practising teachers	Project team
Develop model of collaboration				Project team

Throughout the project, multiple methods of data collection obtained data from multiple sources. A summary of this data collection can be found in Table 2 below. Methods of data collection included semi-structured interviews, open and closed questionnaires, observations, posters, Discussion Group, and case studies.

Table 2: Summary of data sources and methods of data collection

	Data Sources			
Methods	**ECTES**	**Project team**	**Consultants**	**Practising teachers**
Semi-structured interviews	√	√		√
Closed questionnaires	√			
Open-ended questionnaires	√	√	√	
Observation	√	√		√
Posters	√			
Discussion Group	√	√	√	
Case studies	√	√		√

An overview of each stage of the project is provided below.

Stage 1 (Semester 2 2008): Development, implementation and initial evaluation

Stage 1 involved the development of initial modules; implementation of these modules into the Science Education unit; evaluation of the modules and the ECTES' confidence, attitudes and learning; and application of this learning to the ECTES' teaching practice. As a means of formative assessment, a Discussion Group was also held in Stage 1.

Development of initial resources

Based upon the scientist/engineer area of expertise, five modules were developed around the general themes of the environment, day and night, forensic science, cleanliness and solar energy. The first module on the environment was the pilot module and was developed by the teacher educators. A philosophy based on best practice in early childhood education, along with a template of content, was initially established from which to develop the modules.

The modules were developed to be used as a flexible, adaptive and integrated curriculum, rather than a teaching program or a syllabus. Thus, the information presented within each module was developed to provide a range of possible science ideas and activities that could be used in the classroom. This approach to curriculum acknowledges that the teacher best knows their children and their interests, the teaching context, and the outcomes they wish to achieve.

The role of the scientist/engineer working with the teacher educators in developing the modules was emergent and highly collaborative. The scientist/engineer was considered the 'science/engineering content' expert, while the teacher educators were the 'early childhood' and 'pedagogy' experts. There was continuous feedback between the scientist/engineer and the teacher educators as each module developed. This process took between three to six months, as a sequence of possible ideas and activities were discussed, developed, discarded or refined.

Implementation into the Science Education unit

Science Education unit overview
The developed resources were implemented into a 12-week science curriculum and instruction unit during the third year of a four-year Bachelor of Education (Early Childhood) degree during Semester 2 2008. There were 38 ECTES in this unit. The weekly three-hour workshops delivered during the unit aimed to develop ECTES' science PCK through active scientific inquiry. The Project Leader was the principal lecturer for the workshops. Each workshop consisted of a mini-lecture (of 30 to 40 minutes) that presented the science curriculum and each science conceptual area. This was followed by a range of hands-on activities specific to one science conceptual area. A sequential range of science activities were either presented in each workshop or provided in a detailed handout relating to that workshop. The science learning experiences within the workshop were characterised by active participation, placement within an authentic early childhood context, discussion of children's views of science, and learning within a social constructivist environment.

Implementation of modules into the Science Education unit
Each scientist/engineer took an active role in the workshop at which the module they had assisted in developing was delivered. While this involvement varied depending on the content of each workshop it included a short presentation by the

scientist/engineer providing background science content knowledge (this became the mini-lecture), answering a range of questions from the pre-service teachers, and assisting with the learning experiences in the workshop. Through discussion between the principal lecturer and the scientist/engineer, selected activities from the developed modules were chosen to be presented in the workshops. The principal lecturer was present at all workshops, while other teacher educators involved in the project were present in various workshops taking on the role of additional tutor or participant-observer as required.

Evaluation of ECTES' confidence and attitudes

Evaluation of the ECTES' confidence and attitudes toward science were measured by two closed questionnaires and an open-ended questionnaire. Confidence was measured with a modified Personal Science Teaching Efficacy (PSTE) scale from the *Science Teaching Efficacy Belief Instrument* (STEBI-B) (Huinker & Madison, 1997). Four additional questions were included at the start of this questionnaire to address ECTES' perceived science teaching abilities. These specific questions were:

1. My own interest in teaching science is best described as (not interested through to very interested)
2. My own background knowledge for teaching science is best described as (limited through to extensive)
3. My confidence in teaching science is (not very confident through to confident)
4. I am enthusiastic about teaching science (rarely through to always).

This questionnaire can be found at Appendix B.

Attitudes toward science were measured with two scales from the *Test of Science Related Attitudes* (TOSRA): Attitudes to Scientific Inquiry and Adoption of Scientific Attitudes (Fraser, 1981). This questionnaire can be found at Appendix C. For both questionnaires, pre- and post-tests were administered in Weeks 2 and 12, respectively. Statistical differences between the pre- and post-tests were obtained with the use of a paired *t*-test.

In Week 12, the ECTES were presented with two open-ended questions relating to confidence and science knowledge. If the ECTES believed their capacities for each of these components had improved over the semester they were asked to provide reasons for this improvement. Common themes were identified from the responses to each question. The percentage of ECTES who commented on each theme was then calculated.

Evaluation of ECTES' learning through their posters

To further measure their learning over the semester, the ECTES were required to produce a poster that summarised what they had learnt in relation to science content, pedagogy and the learning environment from each of the four workshops where a scientist/engineer presented. This poster formed part of their formal assessment within the unit. Responses from the posters were read and common themes identified. The percentage of ECTES who commented on each theme was calculated. Requirements for the poster are presented at Appendix D.

Applying learning to teaching practice

At the end of the Science Education unit the ECTES participated in a three-week teaching practice in a pre-primary (four-five year olds) classroom. The ECTES were encouraged to use the modules to assist them to teach science during this time. However, this could not be mandated as the ECTES were required to follow their cooperating teacher's advice. As part of the poster presentation, the ECTES were also asked what science they taught in the classroom and how they applied their learning from the Science Education unit within the classroom. This was supported with interviews of three purposively selected ECTES to provide more detail on how they had incorporated the modules within their planning and teaching.

Discussion Group (formative assessment)

A Discussion Group was held at the end of 2008 to provide formative assessment of the project from the various perspectives of the different stakeholders. In particular, the purpose of the Discussion Group was to provide feedback on the modules, the roles of the scientists/engineer, and the process used to date. Twelve stakeholders were present: three scientists, four ECTES, three teacher educators, and two consultant early childhood teachers. As the Discussion Group was a formative assessment, the results are presented in the Evaluation section of this report.

Stage 2 (Semester 1 2009): Detailed evaluation by consultants (formative assessment)

Stage 2 involved a detailed evaluation by three of the consultant early childhood teachers. In this evaluation they were asked to provide constructive critique of the five modules in relation to the following points:

- Useability: for ECTES and early career teachers in early childhood centres?
- Appropriateness: for use in an early childhood centre?
- Presentation: In what way could the lay out and presentation of the book be constructed for ease of use?
- Justification: How do you find this resource in relation to flexibility, engagement and integration?
- Inclusivity: Comment on the inclusiveness of the book in relation to science teaching and learning in all systems and sectors of early childhood education.
- Comprehension: Comment on the *How to use this book* section in relation to clarity, accurateness and readability.

As this critique was a formative evaluation, the results are presented in the Evaluation section of this report.

Stage 3 (Semester 2 2009): Implementation into final teaching practice and final evaluation

Stage 3 involved the ECTES implementing the modules in their eight-week final teaching practice, the ECTES performing a final evaluation of the resource, and the development of case studies of both ECTES and practising early childhood teachers as they used the resource. The final questionnaire sent to the ECTES can be found at Appendix E. This final questionnaire also included the modified PSTE that was given to the ECTES back in Stage 1 to assess their ongoing confidence.

The case studies were developed through observation and semi-structured interviews with the ECTES and practising early childhood teachers. Each module within the final resource has a one-page case study highlighting how a teacher applied the module(s) in the classroom. Information relating to two ECTES and three practising early childhood teachers was collected. One ECTES' case study related to her experiences over the three-week teaching practice, while the other ECTES' case study occurred over the eight-week final teaching practice.

Stage 4 (Semester 1 2010): Development of model of collaboration

Stage 4 involved the development of the model of collaboration, along with developing the case studies of the scientists/engineer. The model was based upon the theoretical framework of social capital, structural holes and social broker. These aspects are presented in more detail in the outcomes for Stage 4. Case studies of the scientists/engineer were developed by observation in the workshops, semi-structured interviews and an open-ended questionnaire. These case studies led to the identification of factors that contributed to the success of the collaboration.

Project outcomes – using and advancing existing knowledge

Develop a range of innovative science curricula and resources appropriate for ECTES

The main project outcome across the two-year project was a 128-page full colour book (with accompanying CD), *Planting the Seeds of Science. A flexible, integrated and engaging resource for teachers of 3 to 8 year olds* (Howitt & Blake, 2010). This book can be found at the ALTC website <http://seedsofscience.altc.edu.au/>. Information from the resource book is presented throughout this section to highlight specific outcomes achieved during the project. More detailed information can be found in the book itself.

Innovative approach

The approach to curriculum design was innovative in that the five modules in the book were developed to be used as a flexible, adaptive and integrated curriculum, rather than a teaching program or a syllabus. Thus, the information presented within each module was developed to provide a range of possible science ideas and activities that could be used in the early childhood education classroom. This approach to curriculum acknowledges that the teacher best knows their children and their interests, the teaching context, and the outcomes they wish to achieve.

Philosophy and template

Each module was developed around a philosophy that embeds five main principles, which are based upon best practice in early childhood education:

1. acknowledgement of the place of young children as natural scientists
2. active involvement of children in their own learning through play and guided inquiry
3. recognition of the place of a socio-cultural context for children's learning
4. emphasis on an integrated approach to children's learning experiences, and
5. the use of a variety of meaning making practices for children to demonstrate their understanding and learning.

The template for each module was based on the following information:

- an overview
- an introduction with a range of ideas and activities
- focus questions relating to the introduction
- a range of follow-up sub-themes, each with their own ideas and activities
- a conclusion with a range of ideas and activities
- a list of resources that include people, websites, narrative and factual books, and raps and rhymes
- suggestions for diagnostic, formative and summative assessment
- background information in the form of questions and scientific answers that can easily be explained to children
- suggestions for curriculum integration

- suggestions for addressing the five Learning Outcomes of the *Early Years Learning Framework*
- suggestions for addressing the three strands of the *Australian Curriculum: Science*, and
- a case study illustrating how the module has been implemented in the early childhood classroom.

Summary of modules

Based upon the areas of expertise of the scientists/engineer, five modules were developed around the general themes of the environment, day and night, forensic science, cleanliness and solar energy. A summary of the five modules, adapted from Howitt and Blake (2010), is presented below. This information is taken directly from the book. Further information relating to the content of each module can be found in *Planting the Seeds of Science*.

Module 1: Look what we found in the park!
Children love exploring their outside environment. *Look what we found in the park!* allows children to develop a greater sense of their local environment and their place within it.

The module starts with children exploring a local park, bush area or beach, the school yard or the school's suburb and collecting a range of objects that provoke interest. These objects then become the basis for activities to increase knowledge of their natural environment, connections with it, and an awareness of their responsibility towards that environment.

Look what we found in the park! provides children with the opportunity to discover and explore in detail trees and their many components (leaves, barks, nuts, seeds, sticks and flowers), produce park art, celebrate the many shades of green or brown found in nature, map the park, adopt an animal as a mascot, turn their classroom into a park, and revisit their park in a different season.

Module 2: Is the grass still green at night? Astrophysics of the dark
The rhythm of day and night is a part of everyone's life and children can easily relate their experiences of day light and night time dark. *Is the grass still green at night? Astrophysics of the dark* introduces children to scientific concepts related to day and night.

This module is designed to expand a child's knowledge of why there is a light and a dark part of every day through developing a greater understanding of the characteristics of day and night, exploring shadows, and observing the relationship between Earth and the Sun.

Is the grass still green at night? Astrophysics of the dark begins with children discussing living and working during day time, and living and working at night time. The night time discussion acknowledges that some children are afraid of the dark and sensitively addresses this issue. It also discusses monsters, and allows children to confidently experience being in the dark. A comparison between day and night is then made. Children investigate how shadows are made, by examining shadows of themselves, the changing shapes of shadows, and shadows on balls. Using the relationship between the Sun and the Earth, children explore day and night with various hand-held models. Finally, they answer the question 'Is the grass still green at night?'

Module 3: We're going on a (forensic) bear hunt!
Children love being part of a mystery. *We're going on a (forensic) bear hunt!* introduces children to the fundamental principles of forensic science, and allows them to solve a class mystery.

The children are initially presented with a set of bear footprints. However, any footprints appropriate for the context could be used. For example, unique Australian animals such as the emu, kangaroo or lizard, or farm animals such as the horse, pig or duck. Through the completion of various basic forensic activities where children collect clues and evidence using their observational, descriptive and classification skills, they solve the mystery. The song and actions to Michael Rosen's story *We're going on a bear hunt* are used to elaborate the experiences.

We're going on a (Forensic) bear hunt! provides children with the opportunity to solve a class problem while at the same time becoming more familiar with their body. Children compare their footprint, handprint and hair with those that the bear has left behind, as they learn about their own uniqueness. Children observe the detail of cuts to patterned paper as they determine what instrument cut the paper. They also investigate which type of food can be used to make obvious fingerprints. Finally, they bring all the evidence together to determine who left the footprints in the classroom.

Module 4: Muds and suds: The science of cleanliness
Cleanliness and hygiene are concepts that children can readily relate to by the time they start school. *Muds and suds: The science of cleanliness* is designed to expand children's basic knowledge of these concepts in relation to themselves and their everyday life.

This module aims to promote in children a greater sense of responsibility in maintaining their own health through an understanding of how and why both animals and humans wash themselves, the differences between dirty and clean, and how soap works.

The module begins with the children being introduced to the Joy Crowley book, *Mrs Wishy-washy*, to discuss why and how the animals in the story were cleaned. Children then investigate various ways that animals stay clean, make a comparison of how they get dirty and how they get clean, explore the properties of mud, and find out how soap works. Opportunities to investigate bubbles and discover how wet objects dry out are also provided.

Module 5: The Sun changes everything!
Children can easily relate to their experiences of warmth from the Sun and other heat sources. *The Sun changes everything!* has been designed around everyday experiences to expand children's knowledge about how the Sun's heat and light energy influence their lives.

Energy is a very abstract concept for young children to comprehend. It is therefore best to focus on how energy is associated with situations undergoing change that they can easily relate to, rather than trying to define energy. Hence, the emphasis within this module is on the influence of the Sun's energy on a child's everyday life and how the Sun's energy creates changes.

The module begins with a puppet, symbolising an Australian reptile in search of a suitable place to warm up. A frilled neck lizard called Freda is used to introduce reptiles and their need of the Sun's light energy. The characteristics of a lizard are then compared with those of a human. This is followed by a sequence of activities to investigate the power of the Sun by identifying warm and cool places inside and outside of the classroom, and how a range of familiar objects can change if left in sunlight. The module concludes with the production of a basic solar cooker to make 'sun-bread'. Freda features throughout the module with reference to her need of the Sun's heat to live.

3D Mind Maps

One unexpected outcome in developing the *Muds & suds: The science of cleanliness* module was the development of two procedures for using 3D mind maps as an effective teaching and learning strategy. Three-dimensional mind maps are a tool for providing engaging, kinaesthetic and sensory experiences for young children, where real objects are used to promote the sharing of knowledge and the creation of connections (Howitt, 2009). Information relating to the use of 3D mind maps was published in Howitt (2009) and Howitt and Blake (2009).

Increase ECTES' science teaching capacities across the Science Education Unit

This outcome has been reported in Howitt et al (2009). Parts of this section have been adapted from that paper. Across the Science Education unit, the ECTES were found to increase their science teaching capacities. They developed greater confidence to teach science, better attitudes towards science, and enhanced science content knowledge. A combination of reasons were attributed to these increases including: being shown how to teach science; active participation within the workshops; access to resources (including the book and the scientists/engineer); and increased science content knowledge.

Increased confidence to teach science

ECTES' confidence to teach science increased significantly over the Science Education unit. Mean total values (across the 13 items in the scale) for PSTE increased from 39.0 to 49.4 ($t = 7.21$, $p < 0.001$, $n = 26$). As minimum and maximum values of PSTE range from 13 to 65, this equates to almost one whole unit increase across a five-point scale. The pre-service teachers tended to rank themselves as 'average' at the beginning of the science methods course, yet by the end had ranked themselves as 'above average'. Attitudes of ECTES towards science also increased significantly over the Science Education unit. Mean values of Attitude to Scientific Inquiry increased from 3.9 to 4.3 ($t = 4.87$, $p < 0.001$, $n = 26$), while Adoption of Scientific Attitudes increased from 3.9 to 4.1 ($t = 2.11$, $p < 0.01$, $n = 26$). Both scales have a maximum value of five.

The majority of ECTES (82 per cent) believed that being shown how to teach science to young children was the main reason for their increased confidence. Being shown how to teach science included the use of engaging, hands-on learning, letting children explore, integration across the curriculum, use of cooperative learning experiences, and the importance of determining children's prior knowledge.

> Being provided with so many ideas to support science teaching, particularly in relation to where to start with very young children, and what sequence should be followed. I also have a better understanding of each of the science areas. [ECTES17_2008_OEQ_Q1]

Over half of the ECTES identified the science activities, resources and ideas presented in the workshop as assisting their confidence to teach science.

> I have learnt so much within this unit and because of this my confidence has grown hugely. By carrying out investigations for ourselves each week, I was able to see how easy and fun science is and can therefore be taught. Everything that we have been taught can be used in the classroom and it is very exciting! I can't wait to teach science, and I used to not enjoy science through school. [ECTES6_2008_OEQ_Q1]

Fifty percent of the ECTES mentioned science content knowledge as the reason for their increased confidence to teach science.

> I believe that my confidence has improved because I now have a stronger understanding of scientific concepts and explanations, and I know how to present them to my students. By making science activities more hands on and active, I am confident that children will be eager and willing to participate. [ECTES1_2008_OEQ_Q1]

These results show that the ECTES have not only increased their pedagogy, knowledge of activities that work, and science content knowledge, but they have also increased their science PCK. Being shown what science to teach, how to teach that science, and how to explain it to young children has not only resulted in increased confidence to teach science but an eagerness to move into the classroom and share science with the children.

Increased science knowledge

Of the 38 ECTES, almost two-thirds (63 per cent) believed the active participation within the workshop contributed to their increased knowledge. Additionally, 45 of the ECTES believed having a science/engineering academic in the workshop assisted in their knowledge of science, while a further 34 per cent commented on the use of the developed modules. Most responses from the ECTES included comments that related to two or three of the identified categories, as illustrated below.

> By the scientists coming in especially the first workshop [astronomy] it has cleared up a great deal of misconceptions I had about space. By me learning the scientific ideas I now feel more confident in teaching it to children. [ECTES3_2008_OEQ_Q2]

> There were many aspects of science that I did not fully understand before I started this unit. The modules, however, increased my knowledge and made me think about my misconceptions. I now also know that science is all around us and know what to teach and how to teach it. [ECTES9_2008_OEQ_Q2]

> The modules that we have been given in class have been a great help to my understandings and ideas. The hands on learning experiences have allowed us to discover knowledge for ourselves. [ECTES10_2008_OEQ_Q2]

ECTES' reasons for increased science knowledge were attributed to active participation within the workshops where they experienced firsthand authentic science activities for the early childhood classroom; access to the scientist/engineer in the workshops to clarify points and ask additional questions relating to science content knowledge and to procedures related to activities; and access to the modules which had a wide range of information relating to activities, resources, science knowledge and integration.

Durability of science teaching ability

Table 3 below presents the percentage response rate to the four questions relating to the ECTES' perceived science teaching ability. Over the 2008 semester, the ECTES increased their interest in teaching science, knowledge for teaching science, confidence in teaching science, and enthusiasm for teaching science. This increase tended to reflect a whole unit increase across the five-point response scale.

Additionally, the ECTES maintained their level of engagement across the next 12 months, as reflected in the similar values from Oct 2008 to Oct 2009.

Table 3: Durability of ECTES' perceived science teaching ability, across 3 times periods, August 2008 (n=28), October 2008 (n=32) and October 2009 (n = 16).

1. My own interest in teaching science is best described as		Not interested				Interested
	Aug 2008	0	11	39	43	7
	Oct 2008	0	0	22	34	44
	Oct 2009	0	0	13	56	31
2. My own background knowledge for teaching science is best described as		Limited				Extensive
	Aug 2008	18	28	50	4	0
	Oct 2008	3	9	31	54	3
	Oct 2009	0	0	50	50	0
3. My confidence in teaching science is		Not very confident				Confident
	Aug 2008	4	39	50	7	0
	Oct 2008	0	3	16	62	19
	Oct 2009	0	0	24	38	38
4. I am enthusiastic about teaching science		Rarely				Always
	Aug 2008	0	4	28	50	18
	Oct 2008	0	0	12	44	44
	Oct 2009	0	0	6	31	63

These results highlight that, across the Science Education unit, the ECTES have increased their PCK. This increase has been a consequence of carefully constructed science learning experiences presented in both the modules and the Science Education unit where science content, pedagogy and a range of appropriate activities have been presented.

Poster analysis

Two examples of ECTES' posters can be found in Appendix F. Analysis of the posters revealed that increased science knowledge was not simply the consequence of being presented with more scientific information. Rather, there was interplay between learning through doing, while also having a science/engineering academic to answer questions, and the provision of materials (the modules) to obtain more information. When asked to comment on what content they had learned, ECTES' responses were not solely restricted to science content knowledge but included science pedagogy and how to adapt science ideas for the early childhood classroom. Aspects of ECTES' enhanced learning of pedagogy and the learning environment presented in the posters included the use of active learning, questioning, group work, engaging learning experiences, resources that use everyday materials, and a realisation that messy can be educational.

Teaching science in the early childhood classroom

In teaching science in the early childhood classroom, the ECTES embraced the flexible and integrated nature of the modules to develop their programs. All components of the book were found to be useful and relevant and the book proved to be a much needed resource to assist the ECTES to teach science in a flexible, integrated and engaging manner.

Applying learning to teaching practice – Semester 2 2008

Thirty-two of the ECTES went on the three-week teaching practice during Semester 2 2008. Of these, 28 (94 per cent) stated that they taught some science. Seventeen of these 28 ECTES (61 per cent) indicated they had used the modules to plan their science lessons: nine used the cleanliness module, five used the forensic science module, two used the astronomy module, and one used the solar energy module.

Over half of these 17 pre-service teachers commented they had adapted the ideas presented in the modules to their specific context. Comments on how the students applied what they had learned during the Science Education unit included the importance of engagement and exploration, the use of hands-on learning and multi-sensory activities, the use of questioning, the importance of obtaining prior knowledge in the teaching and learning process, the use of small group work, and using shared knowledge and ideas.

In planning their lessons, the ECTES used the modules in various ways. Some relied almost entirely on the modules, while others referred to specific sections of the modules depending on the context of the learning. This is reflected in the below comments from the three ECTES interviewed after their three-week teaching practice.

> I chose aspects of the [forensic science] module and altered the activities to be age appropriate. The children … were engaged, motivated and immensely excited about the activities. Transferring the knowledge I learnt about forensic science and how to teach it to children proved effective. [ECTES1_2008_INTERVIEW]
>
> The cleanliness module really assisted my planning. I was able to base all my lessons around the module with ease. The children enjoyed the program. The module was easy to modify for a Kindergarten level. [ECTES2_2008_INTERVIEW]
>
> I incorporated several ideas from the cleanliness module. One of the most interesting experiences I had with the children was when I introduced them to the two mud activities [chocolate mousse and wet clay ideas from the module]. I [also] provided mud made from cornflour, water and cocoa [an idea not included in the module]. The children absolutely loved these activities as they had the opportunity to explore the materials, … discover science for themselves, and most of all, the experience was fun! [ECTES3_2008_INTERVIEW]

Applying learning to teaching practice – Semester 2 2009

Twenty-nine of the ECTES went on the eight-week final teaching practice. Of these, 17 responded to the questionnaire. Of these 17 respondents, 15 (88 per cent) stated they taught some science. Seven of these 15 (47 per cent) indicated they used the resource to plan their science lessons, with the park, forensic science and the cleanliness modules being used.

Of those ECTES who used the resource, most referred to specific sections of the modules in order to fit into the context of their teaching and learning. Some ECTES combined ideas from two modules. Those who used the book found all sections to be relevant and useful to their needs. This is illustrated with various comments from the ECTES' final questionnaire.

> I loved all of the activities in the book because they are developmentally appropriate and easy to implement. All of the supporting information for the activities are (sic) also very helpful as it gives me a clear understanding of the purpose of them. [ECTES1_2009_QB4]

> I was able to use the focus questions when interacting with the children. The integration allowed me to plan the activities and select the outcomes. The resources provided me with things to support the children's learning. I used the scientific Q&A to make sure my own knowledge was developed enough so I could answer the children's questions. [ECTES25_2009_QB4]

> The activities suggested can be easily applied to the classroom. The resources offer ideas of questions to ask children and how to access effectively. I like how it provides the different assessment types. The integration with the eight learning areas is explicit. [ECTES27_2009_QB4]

All ECTES who used the book believed it assisted them in developing greater confidence to teach science, better attitudes towards science, and assisted them to become more enthusiastic and interested in science. These ECTES found the book to be a useful and holistic resource. All agreed that the ideas and activities presented in the book were flexible, integrated and engaging for both themselves and their students.

Future teaching of science in the classroom

When asked of their perceptions of the usefulness of the book in their future classroom, all 17 ECTES believed it would be a useful resource. The range of ideas and activities, scientific Q&A, assessment ideas, ideas for integration across the curriculum, and list of resources were considered real strengths of the book. This is illustrated with various comments from the final ECTES' questionnaire.

> Before the introduction of this book Science was a subject I dreaded to teach; partly because I wasn't too sure what activities could be used and partly because I wasn't confident enough to face or answer the children's questions. This book helps in that information is clear and detailed and easy to modify. It also provides a wonderful guide for answering children's questions. [ECTES13_2009_QD2]

> I think the book makes science easier for teachers to plan and teach. By including the activities, resources and assessment it allows teachers to follow a program and then access the children's knowledge. Before the science unit was undertaken and the book, I was very apprehensive about teaching science, especially planning hands-on and fun learning experiences. The book demonstrates how this can be done and I believe makes science more accessible to all! [ECTES20_2009_QD2]

All ECTES believed that the book was a much-needed resource in early childhood education and, once teaching in their classroom, they would be using it. The entire book was considered its strength, as illustrated by the following quote.

> All aspects of the book I find to be a strength. Every part of the book comes together as a supportive tool to teach science. I especially think the flexibility of the resource to be a major strength because as a teacher that's what you have to be. [ECTES25_2009_QD4]

Case studies

In *Planting the Seeds of Science*, five case studies are presented of teachers using the modules in the classroom. These case studies include two ECTES and three practising early childhood teachers. All five teachers used the modules in a different way and modified certain activities to suit their context. The perceived strengths of the modules as expressed by the teachers are presented in Table 4 for each case study.

Table 4: Strengths of the modules based on five case studies.

Case Study	Strengths of the modules
1	Rich integrated learning experiences, structure of modules, flexibility to explore topics creatively, removed anxiety attached to science, easy to use and easy to plan, large choice of activities and ideas
2	Easy to use, variety of activities and ideas, flexibility that acknowledges the teacher knows the class best, allowed teacher to follow children's interests, Q&A assisted with correct scientific facts, assessment ideas made tasks easier
3	Extremely useful guide to planning and delivering science, easy to use, flexibility to take activities and ideas and make them appropriate for the context, integration across the areas of the curriculum, age appropriate themes and context
4	Range of activities and ideas, flexibility to pick and choose activities that were appropriate to the class, contained essential information required for planning and documenting learning, integration across the areas of the curriculum.
5	Assisted programming in many ways, wide range of practical ideas and activities, activities easy to organise and to conduct with the children, integration across the areas of the curriculum, allowed you to teach in a holistic manner, depth of science content knowledge presented, practical and child-friendly

Common strengths of the modules from the five case studies were the:

- range of ideas and activities presented
- flexibility to adapt for a given context
- integration across the areas of the curriculum
- ease of use in planning and programming

These comments reinforce that the resource book of the modules is being used in the manner intended: as a flexible, integrated and engaging science resource. It has been found to be extremely useful for both ECTES and practising early childhood teachers, and considered by all who have tested the modules to be a much-needed resource in early childhood education.

Model of institutional interdisciplinary collaboration

The model of institutional interdisciplinary collaboration is based on the theoretical concepts of social capital and structural holes, and the networks associated with each of these. Social capital relates to the reproduction of network structure as a general social resource for network members (Walker, Kogut & Shan, 1997). In contrast, structural holes relate to the alteration of network structure by entrepreneurs for their own benefit (Walker, Kogut & Shan, 1997).

Social capital

Social capital is “the sum of the resources, actual or virtual, that accrue to an individual or a group by virtue of possessing a durable network of more or less institutionalised relationships of mutual acquaintance and recognition” (Bourdieu & Wacquant, in Walker, Kogut & Shan, 1997, p. 109). The notion of social capital implies a strategy of maintaining the structure of existing relationships. Thus, social capital acts as both a constraint as well as a resource.

The type of network influences the amount and control of social capital (Walker, Kogut & Shan, 1997). For example, members of a ‘closed’ network are connected to each other. In a closed network, organisations have access to social capital, which assists the development of norms for acceptable behaviour and the diffusion of information about behaviour. As the predictability of behaviour is increased in a system that is already connected, self-seeking opportunities are constrained and cooperation enabled. In contrast, organisations with ‘open’ networks have little social capital on which to rely. Without adequate relationships to determine behaviour and carry information, organisations are less able to identify or control opportunism

Many organisational network structures show uneven relationships. Some positions have dense relationships, indicating high levels of social capital. Others occupy positions with few relationships, suggesting a low social capital. The degree of social capital available to an organisation is determined by its position in the network structure (Walker, Kogut & Shan, 1997).

Structural holes

Emphasising the importance of open rather than closed networks, Burt (1992) argued that the network positions associated with the highest economic return lie *between*, not *within*, dense regions of relationships. These sparse regions he termed *structural holes*. Structural holes present opportunities for brokering information flows among organisations, creating potential advantage for developing new ideas and interpretations.

Burt (1992) assumed that partner selection, more than social capital, determined effective cooperation between organisations. In Burt’s view, the benefits of increasing social constraint from establishing relationships in closed regions of the network are offset by a reduction in independence. Organisations with relationships in open networks have greater latitude in their cooperative strategies. These organisations have higher economic gains because they are most able to parlay their superior (less redundant) information into increasing their control (Burt, 2004).

The social capital of brokerage

Given the greater homogeneity within rather than between organisations, people whose networks bridge the structural holes between organisations have earlier access to a broader diversity of information and have experience in translating information across organisations (Burt, 2004). This is the social capital of brokerage. Burt (1998, 2004) considered that people whose networks bridge structural holes between organisations have an advantage in detecting and developing rewarding opportunities. Such social brokers:

- can see early and more broadly and translate information across organisations, providing a vision of options otherwise unseen
- are more likely to have good ideas (that are valued)
- are more familiar with alternative ways of thinking and behaving, giving them more options to select from and synthesise.

The link between good ideas and structural holes is then the key to the social capital of brokerage.

Burt (2004) proposed four levels of brokerage through which a person could create value.

1. The simplest act of brokerage is to make people on both sides of a structural hole aware of interests and difficulties in the other group. People who can communicate these issues between groups are important because as much conflict and confusion in organisations results from misunderstandings of the constraints on colleagues in other groups.
2. The next level of brokerage is transferring best practice. People familiar with activities in two groups are more able than people confined within either group to see how a belief or practice in one group could create value in the other. These people also know how to translate the belief or practice into language that is appropriate for the target group.
3. The third level of brokerage is to draw analogies between groups apparently irrelevant to one another. People who recognise that the way other groups think or behave may have implications for the value of operations in their own group will have an advantage over those who do not. This step can be difficult and confronting, especially for people who have spent a large amount of time inside one group. The challenge is to recognise whether there are, by analogy, elements of belief or practice in one group that could have value in another.
4. The fourth level of brokerage is synthesis. People familiar with activities in two groups are more likely to see new beliefs or behaviours that combine elements from both groups.

Social brokers are critical to learning and creativity (Burt, 2004; Uzzi, 2005). By spanning structural holes, social brokers have early access to diverse, often contradictory information and interpretations, which gives them a competitive advantage in seeing good ideas. While ideas are produced via a variety of paths from a variety of sources, idea generation at some point involves someone moving knowledge from one group to another or combining pieces of knowledge across groups.

Model of institutional interdisciplinary collaboration

A diagrammatic representation of the relationship between social capital, structural holes and the social broker is presented in Figure 1. This model shows two clusters or islands of social capital, each representing organisations with their own social structure. A structural hole exists between the two islands. This structural hole is bridged by the social broker who is familiar with aspects from each cluster. By spanning the structural hole, the social broker develops new relationships, moves knowledge from one cluster to the other, sees new ideas and opportunities, and combines elements from both clusters into creative and productive outcomes.

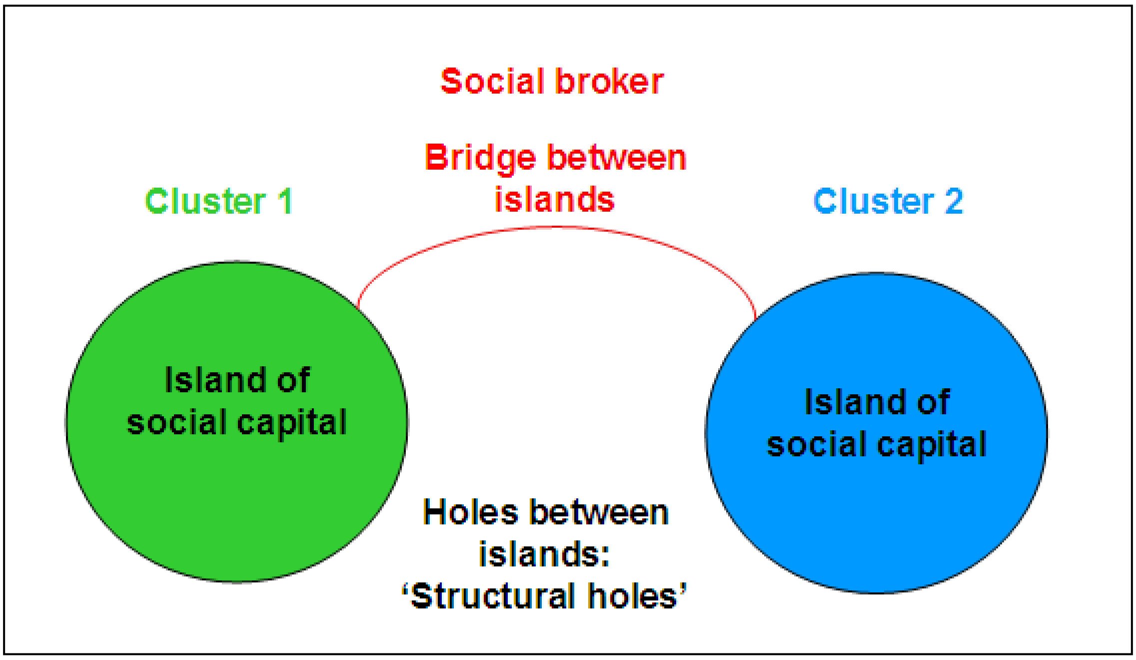

Figure 1: Diagrammatic representation of the relationship between social capital, structural holes and the social broker

Based upon Figure 1, a specific model of institutional interdisciplinary collaboration in the context of this project is presented in Figure 2.

The clusters represent the two different disciplines within the project: science and engineering academics and early childhood science teacher educators. Each of these clusters has their own social capital in terms of knowledge and resources within each discipline. Although science and engineering could be considered as separate clusters and each of these disciplines split into many clusters, for the purposes of this model they are considered as one. The project manager who was familiar with both clusters became the social broker. The collaborative work of both clusters, with the assistance of the social broker, provided the knowledge and skills necessary to develop and implement the resources into the Science Education unit.

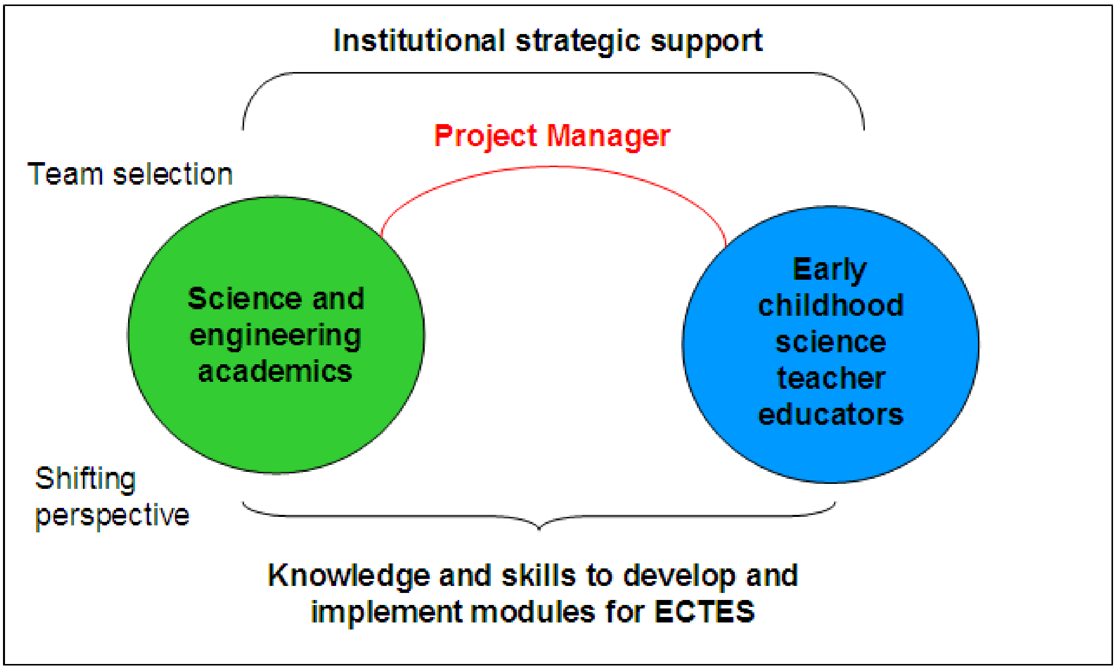

Figure 2: Specific model of institutional interdisciplinary collaboration

Components of the model that contributed to the success of the project were

- institutional strategic support
- team selection
- a mechanism for shifting perspective
- characteristics of the project manager.

Each of these components is discussed in turn.

Institutional strategic support
Strategic institutional support from both disciplines was necessary for the project to progress and to succeed. This support came from the Dean of Science and the Deputy Head of Education (both at Curtin University) who provided ongoing support and belief in the project as well as additional ideas and views throughout the project.

Team selection
Team selection has long been considered an essential element to ensuring the success of a project. While the early childhood teacher educators initiated the project, they worked with the Dean of Science to identify and invite particular science/engineering academics onto the project. Selection was based upon recognition of their exemplary teaching/learning record, ability to work in a group, commitment to excellence, and their perceived ability to interact in a positive and supportive manner with ECTES.

Mechanism for shifting perspective
Bringing different disciplines together means finding mechanisms to merge different perspectives. Researchers from different disciplines have different ways of thinking, each with their own system of values (Somekh, 1994). Thus, a mechanism for assisting team members to recognise their different perspectives of the project, and then develop new perspectives to find solutions for the project, was essential (Miller & Hafner, 2008). In order for the science/engineering academics to gain an appreciation of early childhood education, they were provided with an introductory

session at Discoverland (for children under eight years of age) at Scitech, where they were encouraged to play. Scitech is an interactive science centre based in Perth. This allowed them to experience science through the eyes of a child, and realise the important place of play in learning for young children.

Project manager characteristics

The project manager was chosen based on her experience with early childhood education, science, and teaching science in early childhood education. Thus, she became an ideal social broker as she had experience with both disciplines, admittedly more in early childhood education than in science.

The project manager, in the role of social broker, had the following characteristics:

- **passion and belief** in the project and its purpose
- **vision** to see many possibilities, especially when discussing and developing ideas and activities with the scientists/engineer and how they could be used in an early childhood setting
- **wisdom** from experience within the early childhood education sector
- **legitimate authority** recognised by all members of the project team, due to experience in early childhood education
- a **nurturing capacity** that carefully manages all aspects of the collaborative process while appreciating all members of the project team, thus highlighting effective communication skills
- accepting of a **flexible and emergent role**, as both a manager and a research assistant
- **active** for the entire project in both the managerial and the research assistant role, including assisting with dissemination of the project.

Characteristics of the project team

The project team possessed certain characteristics which contributed to the success of the project: communication, democratic processes, flexibility, passion, solidarity, collegiality and positive emotional energy. Each is described in turn.

Communication has always been essential to developing good relationships. Reciprocal and open lines of communication were present through the entire project. Additionally, dynamic dialogue encouraged the exchange, sharing and appreciation of other’s ideas.

Passion was demonstrated by all members throughout the project. There was a strong commitment to a clear vision, and a shared culture that recognised the importance of science in early childhood education. All team members were committed to making a difference.

Democratic processes refers to joint participation, shared decision making, knowledge ownership and trust (Avgitidou, 2009). In the development of the modules, trusting working relationships were established where any and all ideas and suggestions were encouraged. This occurred not only through initial brainstorming sessions, but through the ongoing nature of the development of the modules. All members of the project team were considered creators, transmitters and facilitators of knowledge creation. This was achieved through the acknowledgement of each other’s strengths, and the acceptance of all ideas and suggestions. There was a mutual respect between team members with regard to the experience and the skills they brought to the project.

Flexibility acknowledges the dynamic natures of the collaboration process (Vangen & Huxham, 2003). While there was always a 'big plan picture', the detailed processes were highly emergent as the project developed. Adjustments to the project were made as and when required, just as team members' expertise was used when and where it would benefit the project outcomes. Thus, not only was the collaborative process flexible, but all team members were flexible in their approach and their participation.

Solidarity refers to the feeling of membership or belonging to a group (Ritchie & Rigano, 2007). As the project progressed, and the team members became more aware and focussed on the developing modules and shared experiences with the ECTES and each other, so their own emotions and attachment to the project became more intense. Solidarity emerged from these successful interactions, resulting in both professional and personal growth for the individual and the team.

Positive emotional energy was present through the length of the project. This refers to feelings of confidence, elation, strength, enthusiasm and initiative (Ritchie & Rigano, 2007). Positive emotional energy produces synergistic qualities, where comments from one member fuel other members, creating a "collective effervescence" (Ritchie & Rigano, 2007, p. 132). As the project progressed, an air of excitement and enthusiasm permeated as modules and experiences were shared and discussed.

Collegiality was a significant point to the success of the project. Regular monthly meetings were held that had a professional agenda with a social atmosphere. These Friday afternoon meetings were held in a relaxed environment that allowed for collegial conversation and the free flow of ideas. Positive emotional energy would abound in these meetings where updates of the progress of the project were eagerly sought. Variations of the meeting venues provided interest and stimulus, while still maintaining the professional agenda.

Project outcomes and approach – potential for implementation in other institutions

The project focus (development of early childhood science materials) and its associated student clientele (ECTES), along with the model of institutional interdisciplinary collaboration and its associated clientele (academics) make the project outcomes and approach amenable to other institutions, as well as to other programs or parts of programs within Curtin University.

Project outcomes

Science Education is a core component of any Bachelor of Education program for teaching in early childhood. Hence, the science resource developed as part of the project is suitable for use in any Bachelor of Education program within Australia, and would also be appropriate for use outside the Australian context. The five modules, based around the general themes of the environment, astronomy, forensic science, cleanliness and solar energy, could be used and/or adapted to anywhere inside and outside Australia. The flexibility and integrated nature of each module, along with the overall structure of the modules, adds to the potential for use as an early childhood science resource.

In addition, the ideas and activities presented in the resource can also be used in Science Education workshops in any Bachelor of Education program. This could be a single activity or a sequence of activities that follow one of the general themes in the modules. This has already occurred within Perth universities due to various dissemination strategies.

The outcomes of the project pertaining to the enhancement of students’ science teaching capacities have potential for development in other units of a bachelor or education degree. ECTES’ initial perceptions of mathematics are just as poor as those of science. Given the integrated approach taken in the resource, a logical expansion would be to use the same ideas and activities within the mathematics education units, but with a mathematics emphasis, to determine if confidence and attitudes towards mathematics increase.

The model of institutional interdisciplinary collaboration, based on the framework of social capital, structural holes, and social brokerage, is applicable to any collaborative teaching and/or research at any institution. This model of collaboration can be applied to any number of courses in higher education, where interdisciplinary knowledge, skills and expertise would assist in students’ learning.

Project approach

The flexible and adaptive model of curriculum design and development for the resource could be used to develop further science resources within both early childhood and primary education. The principle of providing a range of science ideas and activities, as opposed to a teaching program or a syllabus, allows choice for teachers to decide what is most appropriate for their students and context. Such an approach acknowledges the teacher knows their class best. The same approach could be used to develop resources for different learning areas, such as mathematics and literacy.

The ECTES were an important part of the evaluation of the book. The approach used in this project valued their input and feedback, and provided them with the opportunity to be part of a research project. Such an approach introduces students to the research process, allows them to establish wider connections, and acknowledges their talents. Similar types of projects within different disciplines could utilise students’ talents, while introducing them to the research process.

The characteristics of the social broker described in this report can be used to assist in the selection of appropriate project managers for collaborative research in and between institutions. The importance of legitimate authority, where project managers have some experience in the different collaborative disciplines, is crucial if they are to act as effective social brokers.

Success of the project – supportive and impeding factors

Factors critical to the success of the project

The following factors were critical to the success of the project overall and the approach taken to its development.

- All members had a *common belief in the purpose and importance* of the project. Even though the project team consisted of different disciplines (science, engineering and teacher education), there was a strong commitment to a clear vision and a shared culture that recognised the importance of science in early childhood education. This provided ongoing purpose and motivation for all team members.
- *Selection of the best possible project team* to ensure success. This selection was based upon members' exemplary teaching/learning record, ability to work in a group, commitment to excellence, and their perceived ability to interact in a positive and supportive manner with ECTES. This selection was also made in collaboration with representatives from the different disciplines.
- A *practical and flexible approach* across the entire project. The emergent nature of the project encouraged creativity in developing science ideas and activities for use with the ECTES in the workshops and in the book. Adjustments to the project were made as and when required, just as team members' expertise was used when and where it would benefit the project outcomes. Thus, not only was the collaborative process flexible, but all team members were flexible in their approach and their participation.
- *Open lines of communication* between all team members. Reciprocal and open lines of communication were present through the entire project. Additionally, dynamic dialogue between team members encouraged the exchange, sharing, and appreciation of other's ideas. This led to further creativity.
- *All members of the project team were considered creators, transmitters and facilitators of knowledge creation.* This was achieved through the acknowledgement of each other's strengths, and the acceptance of all ideas and suggestions. It was supported by a mutual respect between team members in regards to the experience and the skills they brought to the project.
- *Selection of an appropriate project manager* who had experience in both early childhood education and science. Having experience in both disciplines allowed the project manager to span the structural hole and thus see new ideas and opportunities.
- *Emergent role of the project manager*. The role of the project manager was a cross between management and research assistant. This allowed the strengths of the project manager to be utilised in the best possible manner for the success of the project. This was further supported by employing the project manager for three days per week to allow sufficient time to work as both a manager and research assistant.
- *Developing collegiality* through regular monthly *meetings that had a professional agenda with a social atmosphere.* These meetings were held in a relaxed environment that allowed for collegial conversation and the free flow of ideas, while also covering the necessary aspects of formal meetings.
- *Embedding various cycles of evaluation from multiple stakeholders* while developing the book. In the true nature of an action research project, all

feedback was assessed for its usefulness and modifications continually made to the book. This feedback included the ECTES, valued their input and feedback, and provided them with the opportunity to be part of a research project.

Factors that impeded the success of the project

Factors that impeded the success of the project were mostly factors not under the control of the project team and mostly related to staffing and workload issues.

- *Limited time to work on project due to academic commitments*. The science/engineering academics who were part of this project were still required to maintain their full academic teaching load. Thus, due to their normal teaching duties there were times when working on the project and providing feedback was difficult. While the science/engineering academics team taught in at least one Science Education workshop with the teacher educators, there were times when teaching duties made it difficult to be present at the second workshop.
- *Limited interaction with off-campus team member*. One member of the project team was at a different institution to the other members. This resulted in limited interaction with this member. At times this member felt isolated. Various steps were taken to remove this isolation, including frequent communication and updates through the project manager and having meetings at the other institution and 'neutral' convenient locations.

Dissemination of project outcomes

Project materials

The main product of the project is a 128-page full-colour book and CD, *Planting the Seeds of Science. A flexible, integrated and engaging resource for teachers of 3 to 8 year olds* by Howitt and Blake (2010).

Copies of this book are to be distributed to all participants in the project, including the ECTES.

A copy of the book can be accessed on the ALTC website: <http://seedsofscience.altc.edu.au/>.

A CD of the book is available free of charge from: Dr Christine Howitt, Science and Mathematics Education Centre, Curtin University, GPO Box U1987, Perth, WA, 6845, Tel. (08)9266-2328, c.howitt@curtin.edu.au.

Planting the Seeds of Science comprises the following chapters:

- Introduction
- How to use this book as a flexible and adaptive curriculum
- Philosophy
- Module 1: Look what we found in the park!
- Module 2: Is the grass still green at night? Astrophysics of the dark
- Module 3: We're going on a (Forensic) bear hunt!
- Module 4: Muds and suds: The science of cleanliness

- Module 5: The Sun changes everything!
- References
- Resources
- Contributors.

Each module contains the following information:

- an overview
- an introduction with a range of ideas and activities
- focus questions relating to the introduction
- a range of follow-up sub-themes, each with their own ideas and activities
- a conclusion with a range of ideas and activities
- a list of resources that include people, websites, narrative and factual books, and raps and rhymes
- suggestions for diagnostic, formative and summative assessment
- background information in the form of questions and scientific answers that can easily be explained to children
- suggestions for curriculum integration
- suggestions for addressing the five Learning Outcomes of the Early Years Learning Framework
- suggestions for addressing the three strands of the Australian Curriculum: Science, and
- a case study illustrating how the module has been implemented in the early childhood classroom.

Activities, presentations, and publications

A wide range of dissemination types were used throughout the project. These included a Poster Session; presentations at a range of conferences, workshops and local meetings; professional development for early childhood teachers; newsletters; publication in a range of journals, and a book chapter. The majority of these fell under ALTC's 'engaged' form of dissemination as they included active involvement with ECTES and early childhood teachers that included consultation during the project. A summary of all forms of dissemination is presented in Appendix G.

- The Poster Session was held in November 2008. Here, the ECTES presented their posters to an invited audience that covered a range of stakeholders. The posters highlighted what the ECTES had learnt from having a scientist/engineer in their workshop, and how they translated that information from the workshop into their three-week teaching practice. This Poster Session provided the first opportunity to highlight the ongoing development of the modules, and the process involved, to a wider audience.
- Presentations were given at four state, one national and nine international conferences. These presentations were based on the development of the resource, the processes used, and the development of the model of collaboration. A large number of international conferences occurred towards the end of the project, as each of the scientists presented at their respective

discipline conference (for example, physics education or chemistry education) on the success of the project.

- Workshops were presented at two state, one national and one international conference, to a range of science educators and early childhood teachers. These presentations centred on specific ideas or activities that had been developed for the resource. Most of these were illustrating the 3D Mind Maps teaching and learning strategy.
- Three local meetings were held at tertiary institutions, where the emphasis was on the collaborative approach used in the project and the potential for scholarship of teaching and learning.
- Three professional development sessions were held for early childhood teachers. These hands-on sessions were based on activities from small sections of one of the module. They provided an introduction to the resource for a different group of stakeholders.
- Information was presented in three state/national newsletters, along with one international newsletter. This information provided an overview of the project and its success to date.
- Six state journal articles and two national journal articles have been published. These tended to concentrate on the sharing some of the ideas and activities developed in the modules.
- One book chapter, based on the proceedings of a conference, has been accepted for publication. This book chapter presents the increased accessibility to science for the ECTES through a collaborative approach.

Linkages

Linkages to other ALTC projects

Developing primary teachers education students' professional capacities for children's diverse mathematics achievement and learning needs

The current project was linked to the above project through the integrated nature of the development of the science resource. Certain staff members were involved in both projects, specifically in the development of the mathematical content of the resource. Additionally, certain mathematical activities developed for the science resource were taken across into the above project. The integrated nature of the current project, and the reciprocal use of certain ideas and activities, led to a natural linkage of the two projects.

Disciplinary and interdisciplinary linkages

Due to the nature of this project, there were clear disciplinary and interdisciplinary links. Disciplinary linkages occurred across early childhood teacher education and early childhood education. In early childhood teacher education linkages occurred through the development of the resources, where information was sought from literacy and numeracy educators. In early childhood education, linkages were formed as a consequence of dissemination of the project and consultation during the project with the Department of Education, Association of Independent Schools of Western Australia, and the Catholic Education Office of Western Australia sectors. All three sectors have shown interest in furthering the project. Additional linkages were formed with primary teacher education at the National Institute of Education in Singapore as a consequence of attending the International Science Education Conference in November 2009.

Interdisciplinary linkages occurred as a consequence of the multi-disciplinary nature of the project team. Linkages were established between physics, chemistry and engineering academics with early childhood teacher education through the development, implementation and evaluation of the modules. This was highlighted by the inclusion of a Primary Science Day at the national Chemistry Education Conference in November 2008. This was the first time that a Primary Science Day had been included in a predominantly secondary/tertiary conference. The Primary Science Day became possible as the organiser of the conference was a member of the project team, and embraced the possibility of enhancing chemistry in primary science education. Additionally, Engineers Australia is keen to further its linkages with the project, as a mechanism of introducing engineering into early childhood/primary education.

Linkages have also been formed with project managers from a variety of ALTC projects, who are keen to learn more about the processes used in this project that contributed to its success.

Evaluation of the project

Overview

Both formative and summative assessments were present throughout this project. The formative assessment fed into the development of the modules, while the summative assessment included the formal independent evaluation. Evidence of the impact of the project and the value to early childhood education is also discussed.

Formative assessment

Due to the use of an action research methodology, formative assessment formed an ongoing part of this research. Specific points of formative assessment included the Discussion Group in Stage 1, the consultant's feedback in Stage 2, and evaluations of dissemination through professional development sessions and through a scholarship of teaching meeting. Results from each of these is summarised below, with the specific methods associated with the former elements presented in the Methodology chapter.

Stage 1 Discussion Group

Five main advantages to the modules were identified.

1. Flexibility: The ability of the module to be modified and adapted to individual class needs, and the ease of integration across the learning areas.
2. A resource for teaching and learning science: A self-contained resource that is ready and easy to use.
3. Increased engagement in science: Modules assist in developing teacher and student enthusiasm, creativity and engagement in science. Modules relate to children's everyday experiences.
4. Structure of the module: The components of the module are presented in a logical and sequential order, allowing it to be self-contained.
5. Philosophy of the module: The philosophy behind the modules clearly supports a child-centred approach that is fundamental to early childhood education.

Suggestions for improving the modules related to: providing more science content; emphasising that it is NOT a teaching program; emphasising the flexibility of the modules; providing objectives to help explain science to parents; and suggesting that teachers manipulate the focus questions to suit the age group and the classroom context.

Four main advantages of having the scientists involved in the project were identified. These revolved around increasing the science knowledge base, trying out complex ideas in a hands-on format in the workshops, shifting views of science and scientists (especially their passion and enthusiasm for being a part of this project), and the ECTES finding confidence and belief in themselves through the support given by the scientists.

Suggestions for improvement were based on the inconsistent use of handouts by the scientists in the workshops, and how to more actively involve the scientists in the whole workshop.

The process of developing the modules was seen as a positive, flexible and enjoyable experience, where open lines of communication were essential.

Encouraging scientists to be creative was also considered to be essential. More time to work on the modules, and developing better relationships between the ECTES and scientists, were seen as major limitations of the process.

Stage 2 Consultant early childhood teachers' feedback

The consultant early childhood teachers' feedback contained many gratifying and positive comments, suggestions for the content and presentation improvement, and helpful criticisms to consider for the overall quality of the book. For each section reviewed, a few comments have been highlighted:

1. Useability
Positive responses related to the ease of use and clarity of set out including: easy to navigate and convenient to use; relevant and current; best practice in modelling and planning science teaching for ECE is demonstrated and promoted; consistency to the layout and format of each module.

In a negative voice, it was thought some modules were too wordy and perhaps, too many activities that could serve to overwhelm the new teacher.

Useful suggestions included the addition of palm cards or perforated stiff cardboard pages containing questions and information. These could be placed in a pocket in the book and removed when required. Tabs, coloured sections and/or symbols that delineate module section and coding information throughout the book, were also suggested.

Modifications to the module as a consequence of these comments: many coloured photographs in the book give it an uncluttered wordy appearance, and each new module will have stiffened cardboard as a separator.

2. Appropriateness
All respondents thought the book was appropriate for the intended age group because it was child-centred and suited their inquisitive nature, related to relevant resources, and reflected the key principles of teaching science in ECE. Writers were congratulated for the effort and depth of thoughtfulness to make the book so appropriate. No suggestions for this section were offered and the only concern related to teaching *The Sun changes everything!* module in relation to resources required.

Modifications to the module as a consequence of these comments: suggestions on where to find certain recyclable materials included.

3. Presentation
Warnings were offered about expecting teachers to read a resource with "heavy text" and again it was noted "too wordy" in places. Many suggestions to make the resource more appealing and usable for teachers at the beginning of their career were offered.

All respondents thought it would be useful to have a chart that could easily see how the modules and activities were easily linked to curriculum learning areas and the 5E science teaching and learning model. The addition of a CD to provide an alternative presentation was a strong suggestion adding this would support teachers and could include graphic overview, planners and direct connections to the web. There were items of suggestion for the graphic designer like text boxes to highlight a point, mind-maps and size and type of font.

Modifications to the module as a consequence of these comments: many coloured photographs in the book give it an uncluttered appearance, table showing integration of activities across the learning areas has been included, and CD has been added to the book.

4. Justification
Many positive comments were presented in this section. The philosophy was considered to be an excellent summary to remind teachers of the governing principles that guide good planning and teaching. Support also for the philosophy's direction, encouragement and

assistance for informing parents. The flexibility of the book enables “implementing concepts at your own discretion [to make] it easy to integrate the modules with other work and your own context.” Other positives included: no time limit on lessons and experiences suggested; enables teacher to follow children’s interests, curiosity and investigation; integration is a key feature; as a resource it suits both ECTES and experienced teachers; the literacy links are crucial for this stage of development and overall, is easily adaptable.

A suggestion for improvement asked that an annotated coding system for different learning areas be placed alongside the activities.

5. Inclusivity

As the modules support Primary Connections, the 5E model and uses the internet for resources, it was generally thought to be inclusive of all systems and sectors in all locations. However, considering this book may have wider reaches than its current intended audience, there was caution to be mindful not to orientation it exclusively toward Western Australian resources. Also, given the vastness of Western Australia, teaching and learning contexts vary greatly so inclusive language for rural and city schools should be considered: ie the addition of ‘bush’ when setting the scene to investigate a natural environment (*Look what we found in the park!).*

Modifications to the module as a consequence of these comments: The Western Australian context has been highlighted, and teachers are encouraged to find the equivalent resource in their state/territory. More inclusive language for rural/regional schools has been incorporated.

6. Comprehension

This was perhaps the most positive section of the responses. “*How to use the book* was beautifully written.” Respondents carefully reviewed and pointed out positive features such as: process rather than product, critical importance of teaching science well, draws the attention to items that inexperienced teachers may overlook, encourages confidence to teach science, and tactfully helps teachers understand that it’s OK to “not know the answer”.

A paragraph on the use of assessment and evaluation for follow-up and future planning, and the explicit role of the teacher was thought to be necessary in this section of the book.

Modifications to the module as a consequence of these comments: information on the explicit role of the teacher has been added to the book.

Evaluation of professional development sessions

Three school professional development sessions were evaluated with a simple questionnaire given at the end of the session. A copy of the questionnaire can be found at Appendix H. The three workshops were delivered to early childhood and primary school teachers and are described in Table 5.

Table 5: Summary of professional development workshops evaluated

Workshop	Date	Audience	Number of persons	Topic
1	July 2009	4 Perth schools	25	Activities from the *Muds & suds* module, with emphasis on 3D mind maps and getting dirty/getting clean
2	Nov 2009	Primary Science Showcase, Department of Education, Perth	50	Activities from the *Muds & suds* module, with emphasis on 3D mind maps and getting dirty/getting clean
3	Nov 2009	Early Childhood Network, Association of	40	Introduction to project and book. Short activities from each of the five modules.

	Independent Schools of WA, Perth

Results from the evaluation are summarised in Table 6. These results clearly demonstrate that the teachers gained valuable information from the workshops. The majority of teachers intended to share the information with colleagues, and use the information in their own teaching. They believed they had been presented with both new science content and teaching strategies to use in the classroom.

Table 6: Percentage response of teachers' perceptions to the professional development in Workshops 1, 2 and 3 (n = 13, 38, 37, respectively)

		Percentage Response				
Question	**Workshop**	**SD**	**D**	**N**	**A**	**SA**
1. I intend to share the information from this workshop with my colleagues.	1 2 3	0 0 0	0 0 0	0 5 5	31 37 19	69 58 76
2. I intend to use the information from this workshop in my own teaching.	1 2 3	0 0 0	0 0 0	0 3 3	31 50 16	69 47 81
3. I have been presented with new science content that I can use in my classroom.	1 2 3	0 3 0	0 10 0	7 10 6	31 45 32	62 32 62
4. I have been presented with new teaching strategies that I can use in my classroom.	1 2 3	0 0 0	0 0 3	0 5 8	38 37 35	62 58 54

Major points the teachers gained from the workshops included:

- 3D mind maps
- the use of hands-on activities
- linking science and literacy
- the easy application to the early childhood classroom
- applying the investigation process in early childhood
- using open-ended inquiry in early childhood; and
- the knowledge science is everywhere, can be integrated across the curriculum, is fun, and can involve simple activities.

Evaluation of scholarship of teaching meeting

One presentation on the project was given to the Networks Enhancing the Scholarship of Teaching (NEST) at Murdoch University in April 2010. The purpose of the presentation was to provide a description of the project and present the model for the first time to generate discussion. This presentation was evaluated with a simple questionnaire provided at Appendix I. Twelve academics from a range of Western Australian universities attended this presentation.

Results from this questionnaire are summarised in Table 7. These results demonstrate that the academics gained valuable information from the presentation, which they intended to share with their colleagues. Over half of the participants were also interested in gaining further information about the presentation.

Table 7: Percentage response of academics' perceptions to the NEST presentation (n = 9).

Question	SD	D	N	A	SA
1. I have been presented with information that is relevant to my area of expertise.	0	0	23	33	44
2. I intend to share information from this presentation with colleagues.	0	0	0	56	44
3. I would be interested in gaining further information from this presentation.	0	0	11	33	56

Major points that the academics took away from the presentation included:

- the research design
- the range of dissemination strategies
- status of project manager as a co-author
- project team cohesion
- role of the project manager as a social broker
- selection of project team
- the use of an emergent curriculum to develop the modules
- addressing a significant issue within early childhood education
- the benefits of taking people outside their comfort zone and changing their practice, and
- the benefits of good project management.

Suggestions for improvement were to make the model of collaboration more detailed, and to be careful with the descriptions used for the range of academics within the project. Both of these comments have subsequently been addressed.

Summative assessment

Summative assessment occurred through the final ECTES questionnaire at the end of ECTES eight-week teaching practice, and through the formal independent evaluation.

Final ECTES questionnaire

The main results from this final questionnaire have been presented under the Project Outcomes section and will not be repeated here.

Independent evaluation

An independent evaluation was conducted by Professor Darrell Fisher, Science and Mathematics Education Centre, Curtin University. A copy of this evaluation was presented with Part 2 of the report requirements. The major findings from the independent evaluation are presented below.

The evaluation used a wide range of data sources (ECTES, project Team, experienced early childhood educators, and members of the Reference Group) along with a wide range of methods to determine the effectiveness of the project. These methods included:

- the final resource developed called *Planting the Seeds of Science*;
- quantitative and qualitative data collected over the two years of the project;
- minutes of meetings and other documents describing the processes used; and
- both written and verbal feedback from the project team, Reference Group and the ECTES.

The evaluation assessed each of the eight outcomes/deliverables listed in the original project proposal. Each of these outcomes is described below, with a synthesis of the evaluator's findings.

Outcome 1. Collaboratively engaged scientist, engineers, teacher educators and experienced early childhood teachers to develop a science resource for ECTES

Feedback from the project team, experienced early childhood teachers, and the Reference Group highlighted the highly collaborative nature of the development of the science resource. As the evaluator noted, "The formation and management of these groups allowed a sense of combined ownership to develop together with a free flow of information and innovative ideas between the stakeholders" (Fisher, 2010, p. 7). This sentiment was further supported by a comment from one of the members of the Reference Group.

> Its key strength is that it demonstrated that teacher educators and scientists can work together in highly collaborative, productive and enjoyable ways, to enhance the science-related skills and confidence of teacher education students. Communication within the Group was not just efficient, but fantastic.

The results presented in the evaluation clearly showed that Outcome 1 had been achieved to a high standard.

Outcome 2. Develop science resources for ECTES

This outcome was achieved through the development of the 128-page resource book, *Planting the Seeds of Science,* which contained five science modules. Feedback from the project team, ECTES, experienced early childhood teachers, and the Reference Group highlighted the important place of this newly developed resource within early childhood science education. This was highlighted by a quote from one of the members of the Reference Group.

> This was an extremely exciting project that has a very useable product at the end. This resource will be keenly sort after by the early childhood community. The activities are based on excellent early childhood pedagogy and will inspire young children and teachers to investigate and discover. It will contribute to the making of a new generation of scientists.

It was also supported by the ECTES, as they used the book on their teaching practice.

> I loved all of the activities in the book because they are developmentally appropriate and easy to implement. All of the supporting information for the activities are also very helpful as it gives me a clear understanding of the purpose of them. Everything is set out really well.

The evaluator found that Outcome 2 had been achieved to an outstanding level.

Outcome 3. Increase the confidence in ECTES

Increase in confidence of ECTES towards science was quantitatively assessed using two well-established closed questionnaires, and qualitatively assessed with an open-ended questionnaire. These results highlighted that ECTES increased their interest, confidence and enthusiasm for teaching science, along with their attitudes towards science, across the Science Education unit. Further, the ECTES' interest, confidence and enthusiasm were maintained for an additional 12 months after the Science Education course.

The comments from the open-ended questionnaire provide "an understanding for the positive growth shown … above and support the assertion that there was an improvement in the confidence and attitude towards science in the ECTES" (Fisher, 2010, p. 12).

> I have learned so much within this unit and because of this my confidence has grown hugely….I can't wait to teach science, and I used to not enjoy science through school.
>
> Before I saw science as the science I learnt in high school and I knew I didn't understand it so I couldn't teach it. Now I know science can be adapted to everything and it can be done in a fun way.

From the evidence presented, the evaluator was confident that "an increase in the confidence and attitudes toward science in the ECTES has been achieved in this project" (Fisher, 2010, p. 14).

Outcome 4. Enhance the science content knowledge of ECTES

While cognitive growth was not assessed in this project, the evaluator noted that a wide range of other instruments were used to determine ECTES' perceptions of their increased science content knowledge. This included the use of a closed questionnaire, an open-ended questionnaire and analysis of the posters which the ECTES produced.

ECTES' perceptions of their background knowledge increased over the Science Education unit, and were maintained for an additional 12 months. ECTES comments reflected this are presented below.

> All the lessons in this unit either supported and extended my knowledge or taught me something completely new. I went home every week to share with my family or test them to see if they knew what I had learnt.
>
> Having the scientists as a part of the classes has helped me gain a lot more knowledge in a more detailed fashion.

This evidence, along with the discussions that the evaluator had with "the ECTES during one of their meetings where they spoke confidently about their growth in knowledge of science, highlights that the outcome of increased science content knowledge has been achieved" (Fisher, 2010, p. 16).

Outcome 5. Implement a discussion group and use feedback to improve the project

The Discussion Group on November 11, 2008 provided information relevant to this outcome. The purpose of the meeting was to provide formative evaluation of the project and in particular feedback on the modules. The 12 participants included members of the project team, ECTES and experienced early childhood teachers. Five main advantages of the modules were identified. Suggestions for improvement were also identified, and subsequently acted on to improve the modules.

The evaluator noted that, as a consequence of this type of formative feedback occurring throughout the life of the project, "it is not surprising that the final product referred to in Outcome 2 is of such quality" (Fisher, 2010, p. 16).

Outcome 6. Implement a half-day forum for ECTES to share their science experiences with various stakeholders and audiences

This forum occurred in November 2008 as a Poster Session during which the ECTES were required to showcase what they had learned as a consequence of the newly developed modules and having a science/engineering academic participate in their science workshops. Other participants included the scientists; teacher educators; early childhood teachers; representatives from government, Catholic and independent systems and sectors; and representatives from science education organizations (Scitech and Science Teachers' Association of Western Australia). The posters contained information about each of the modules where a scientist or engineers was involved (astronomy, forensic science, cleanliness and solar energy) and a section on application of learning to their three-week teaching practice.

Feedback from one of the scientists in the project team commented on the value of the session:

> The poster display that the pre-service teachers put on was amazing. Never seen anything like it before. It was a brilliant way to share assignments and there were many people there to witness this creativity – people from inside and outside of the university came and witnessed it. The students were valued and acknowledged for the great work they'd done. It was a great idea.

The evaluator found the half-day forum to be "an excellent form of dissemination to showcase what the ECTES had learned over the semester and how they had applied this learning to their three-week teaching practice" (Fisher, 2010, p. 17).

Outcome 7. Actively support ECTES as they develop their science programs in a classroom context

The evaluator attended a morning tea organised by the project team for the ECTES, to reconnect the students with the scientists and discuss any issues that the students had in relation to their forthcoming teaching practice. The evaluator commented that “It was pleasing to observe the warm, supportive and collaborative environment and the animated discussions that occurred between the scientists and the students. It was clear that the students were receiving great support as they prepared to implement their science programs” (Fisher, 2010, p. 17).

The evaluator found that there was clear support for the ECTES as they prepared for their final teaching practice.

Outcome 8. Identify and interpret an appropriate model to describe the collaboration of stakeholders within the project

The model was developed based on a theoretical framework of structural holes and social capital. The model was developed based on observations of how the project team worked together, case studies of the science/engineering academics and results of an open-ended questionnaire given to the project team. The success of the project was identified as a result of the following team characteristics: communication, democratic processes, flexibility, solidarity/supportive, passion, collegiality and positive emotional energy.

The evaluator commented that “The members of this project have demonstrated quite clearly that scientists and teacher educators are able to work together to achieve planned outcomes” (Fisher, 2010, p. 19). This was reflected in the comments of one scientist:

> Scientists and educators can work together to get achievable outcomes. We need this to happen more often if we are to engage more kids in science and to give teachers (primary in particular) more confidence.

The evaluator found that Outcome 8 had been achieved.

Conclusions

In conclusion, the evaluator found that the project had been highly successful in the following ways (Fisher, 2010, p. 21):

- the processes that were planned were actually put into place in a most effective manner with little variation from the processes that were initially proposed;
- the planned outputs and outcomes of the project have been achieved in a most positive way;
- two significant unintended outputs or outcomes were participation in the inaugural Primary Science Day of the National Chemistry Conference and the discovery and subsequent development of 3D Mind Maps as a component of one of the modules;
- measures have been put in place to promote sustainability of the project’s focus and outcomes through the dissemination of the products; and
- the collaborative model created by this project is indeed a process that will be of assistance to other institutions.

The evaluator also noted that “the need to continue the work of this project into the future is vital and a means of support should be found. There is a high demand for appropriate science resources in the early childhood classroom” (Fisher, 2010, p. 21).

The evaluator concluded the evaluation with the following comments (Fisher, 2010, p. 22):

> It was a pleasure to review such a successful project and it was quite impossible to find anything negative on which to comment. In all ways, the project has achieved its outcomes and importantly all members of the project team were such willing participants. It really was a collaborative project and a model for others.

Evidence of the impact of the project and the value to the sector

Evidence of the impact of this project to the teaching and learning of science in early childhood education has been presented in the Project Outcomes, the Formative and Summative Assessment, and the Independent Evaluation sections.

The professional capacities of ECTES, in the form of increased confidence to teach science, better attitudes towards science, as well as enhanced science content knowledge, were found to improve over the course of this project. This was attributed to a combination of developing appropriate science pedagogical skills, having access to science/engineering academics, and using the resource, *Planting the Seeds of Science*. ECTES were found to transfer this newly developed confidence into the early childhood classroom, and not only teach science but enjoyed doing so.

The ECTES found *Planting the Seeds of Science* to be a resource that would enhance their confidence, attitudes, enthusiasm and interest in science. They also found it to be an holistic, flexible, integrated and engaging resource that could be easily used in the early childhood classroom for planning and programming effective science learning experiences.

The evidence of the success of the project is reflected in the following unsolicited email from an ECTES in July 2010, who was on their final teaching practice.

> I have been using the modules you gave us and they are FANTASTIC! The other teachers at my prac school are amazed at all the brilliant activities and the kids love them!

The value of *Planting the Seeds of Science* to the early childhood sector is highly significant. As noted in the literature review, the limited science resources available in this sector is a factor that has contributed to an avoidance of teaching science. The provision of this resource addresses a huge need within the sector. As noted by various members of the Reference Group within the independent evaluation, it is imperative that *Planting the Seeds of Science* be commercialised and made readily available to early childhood teachers, educators and ECTES on a national basis.

This project also has value to the higher education sector and to the successful conduct of collaborative projects. The project has highlighted that teacher educators and science/engineering academics can readily work together for a common cause. The model of collaboration developed as a consequence of the project has potential for any collaborative research or interdisciplinary teaching. The theoretical framework of structural holes highlights the important role of the project manager to bridge different disciplines and bring divergent views together. Additionally, the identified characteristics of the project manager should be considered as criteria for selecting persons to this extremely important role.

With ongoing dissemination and sustainability, this project has enormous potential to influence the early childhood and the higher education sector.

References

Appleton, K. (2003). How do beginning primary school teachers cope with science? Towards an understanding of science teaching practice *Research in Science Education, 33*(1), 1–25.

Appleton, K. (2006). Science pedagogical content knowledge and elementary school teachers. In K. Appleton (Ed.). *Elementary science teacher education. International Perspectives on contemporary issues and practice,* (pp. 31–54). Mahwah, NJ: Lawrence Erlbaum Associates.

Appleton, K. & Kindt, I. (2002). Beginning elementary teachers' development as teachers of science. *Journal of Science Teacher Education, 13*(1), 43–61.

Australian Academy of Technological Sciences and Engineering (ATSE) (2002). *The Teaching of Science and Technology in Australian Primary Schools*. Melbourne: ATSE.

Avgitidou, S. (2009). Participation, roles and processes in a collaborative action research project: A reflexive account of the facilitator, *Educational Action Research, 17*(4), 585–600.

Burt, R. S. (1992). *Structural holes.* Cambridge, Mass.: Harvard University Press.

Burt, R. S. (1998). Personality correlates of structural holes. *Social Networks, 20*(1), 63–87.

Burt, R. S. (2004). Structural holes and good ideas, *American Journal of Sociology, 110*(2), 349–399.

Cahill, M. & Skamp, K. (2003). Novice's perceptions of what would improve their science teaching, *Australian Science Teachers' Journal. 49*(1), 6–17.

Change and Sustainability in Higher Education (CASHE). (2006). Report on course and curriculum changes in Maths and Science Partnership (MSP) Programs. Retrieved February 6, 2010, from <http://hub.mspnet.org/index.cfm/13463>

Creswell, J. W. (2005). Educational research: Planning, conducting and evaluating quantitative and qualitative research (2nd ed.). NJ: Pearson Prentice Hall.

Department of Education, Training and the Arts. (2007). *Towards a 10-year plan for science, technology, engineering and mathematics (STEM) education and skills in Queensland.* Brisbane: Queensland Government. Department of Education, Training and the Arts.

Dow, K.L. (Chair, Committee for the Review of Teaching and Teacher Education.) (2003). *Australia's Teachers: Australia's Future: advancing innovation, science, technology and mathematics*. Canberra: Commonwealth of Australia.

Eick, C. J. (2003, March). The new science educator's perspective on building collaborations. In D. Duggan_Hass (Chair), *Symbiosis on campus: Collaborations of scientists and science educators.* Symposium conducted at the meeting of the annual meeting of the National Association for Research in Science Teaching, Philadelphia, PA.

Fisher, D. (2010). *Evaluation report for project CG8-724. Science for early childhood teacher education students (ECTES): Collaboration between teacher educators, scientists and engineers.* Report for ALTC.

Fleer, M. (2009). Understanding the dialectical relations between everyday concepts and scientific concepts within play-based programs, *Research in Science Education, 31*(8), 1069–1089.

Fraser, B. J. (1981). *Test of Science-Related Attitudes (TOSRA).* Melbourne, Victoria: Australian Council for Educational Research.

Garbett, D. (2003). Science education in early childhood teacher education: Putting forward a case to enhance student teachers' confidence and competence, *Research in Science Education, 33*(4), 467–481.

Goodrum, D., & Rennie, L. (2007). *Australian School Science Education: National Action Plan 2008-2012, Volume 1, The National Action Plan.* Canberra: Department of Education, Training and Youth Affairs. <http://www.dest.gov.au/sectors/school_education/publications_resources/profiles/Australian_School_Education_Plan_2008_2012.htm>

Goodrum, D., Hackling, M. & Rennie, L. (2001). *The status and quality of teaching and learning of science in Australian schools: A research report*. Canberra: Department of Education, Training and Youth Affairs.

Gray, B. (1985). Conditions facilitating interorganizational collaboration, *Human Relations, 38*, 911–936.

Gray, B. (2004). Strong opposition: Frame-based resistance to collaboration,. *Journal of Community Applied Social Psychology, 14*(2), 166–176.

Gronski, R., & Pigg, K. (2000). University and community collaboration, *American Behavioural Scientist, 43*(5), 781–792.

Hand, B. & Peterson, R. (1995). The development, trial and evaluation of a constructivist teaching and learning approach in a preservice science teacher education program, *Research in Science Education, 25*(1), 7–-88.

Harris, K-L, Jensz, F. & Baldwin, G. (2005). *Who's teaching Science*. Report prepared for the Australian Council of Deans of Science. Melbourne: ACDS.

Harlen, W., & Holroyd, C. (1997). Primary teachers' understanding of concepts of science: Impact on confidence and teaching, *International Journal of Science Education, 19*(1), 93–105.

Hora, M. T., & Millar, S. B. (2009). A final case study of SCALE activities at California State University, Northbridge: How institutional context influenced a K-20 STEM education change initiative (WCER Working Paper No 2009-5). Madison: University of Wisconsin-Madison, Wisconsin Center for Education Research. Retrieved February 5, 2010, from <http://www.wcer.wisc.edu/publications/workingPapers/paper.php>

Howes, E. V. (2002). Learning to teach science for all in elementary grades: What do preservice teachers bring? *Journal of Research in Science Teaching, 39*(9), 845–869.

Howitt, C. (2009). 3-D mind maps: Placing young children in the centre of their own learning, *Teaching Science, 55*(2), 42–46.

Howitt, C. & Blake, E. (2009). Young children, oral language and 3-D mind maps, *Practically Primary, 14*(3), 28–32.

Howitt, C. & Blake, E. (Eds.). (2010*). Planting the seeds of science: A flexible, integrated and engaging resource for teachers of 3 to 8 year olds.* Western Australia.

Howitt, C., Blake, E., Calais, M., Carnellor, Y., Frid, S., Lewis, S., Mocerino, M., Parker, L., Sparrow, L., Ward, J. & Zadnik, M. (2009). Collaborating with 'real' scientists and engineers to increase pre-service early childhood teachers' science content knowledge and confidence to teach science. In M. Kim, S. Hwang and A. Tan (Eds.), *Proceedings of the International Science Education Conference. Science*

Education: Shared Issues, Common Future (pp. 931–967). Singapore: National Institute of Education.

Huinker, D. & Madison, S. K. (1997). Preparing efficacious elementary teachers in science and mathematics: The influence of methods courses, *Journal of Science Teacher Education, 8*(2), 107–125.

Klein, J. T. & Newell, W. H. (1998). Advancing interdisciplinary studies. In W. Newell (ed.) *Interdisciplinary essays from the literature* (p. 3–22). New York: College Board Publications.

Lasley, T. J., Matczynski, T. J., & Williams, J. A. (1992). Collaborative and noncollaborative partnerships in teacher education, *Journal of Teacher Education, 43*(4), 257-261.

Lattuca, L. R., Voigt, L. J. & Fath, K. Q. (2004). Does interdisciplinarity promote learning? Theoretical support and researchable questions. *The Review of Higher Education, 28*(1), 23–48.

Miller, P. M. & Hafner, M. M. (2008). Moving towards dialogical collaboration: A critical examination of a university school community partnership, *Educational Administration Quarterly, 44*(1), 66–110.

Moscovici, H. & McNulty, B. (2003). The effect of collaboration: Learning together towards the development of the mutualistic science educator of the future. In D. Duggan_Hass (Chair), *Symbiosis on campus: Collaborations of scientists and science educators.* Symposium conducted at the meeting of the annual meeting of the National Association for Research in Science Teaching, Philadelphia, PA.

Mulholland, J. & Wallace, J. (1994). Knowing and learning about science in a preservice setting: A narrative study, *Research in Science Education, 24*(2), 236–245.

Mulholland, J. & Wallace, J. (1996). Breaking the cycle: Preparing elementary teachers to teach science, *Journal of Elementary Science Education, 8*(1), 17–38.

Mulholland, J. & Wallace, J. (2003). Facilitating primary science teaching: A narrative account of research as learning, *Teachers and Teaching: Theory and Practice, 9*(2), 133–155.

Newell, W. H. (1990). Interdisciplinary curriculum development, *Issues in Integrative Studies, 8,* 69–86.

Peterson, S. M. & French, L. (2008). Supporting young children's explorations through inquiry science in preschool, *Early Childhood Research Quarterly, 23*, 395–408.

Rice, D. C. & Roychoudhury, A. (2003). Preparing more confident preservice elementary science teachers: One elementary science methods teacher's self-study, *Journal of Science Teacher Education, 14*(2), 97-125.

Riggs, I. M. & Enochs, L. G. (1990). Towards the development of an elementary teacher's science teaching efficacy belief instrument. *School Education, 74*(6), 625–637.

Ritchie, S. M. (2007). Studying research collaborations. In S. M. Ritchie (Ed.). *Research collaboration: Relationships and praxis.* Rotterdam: Sense Publishers.

Ritchie, S. M. & Rigano, D. L. (2007). Solidarity through collaborative research, International *Journal of Qualitative Studies in Education, 20*(2), 129–150.

Shulman, L.S. (1986). Those who understand: Knowledge growth in teaching, *Educational Researcher, 26*, 1403–1418.

Skamp, K. (1989). General science knowledge and attitudes towards science and science teaching of pre-service primary teachers: Implications for pre-service units, *Research in Science Education, 19*, 257–267.

Somekh, B. (1994). Inhabiting each other's castles: Towards knowledge and mutual growth through collaboration, *Educational Action Research, 2*(3), 357–381.

Tytler, R. (2007). *Re-imagining Science Education: Engaging students in science for Australia's future*. Melbourne: Australian Council for Educational Research.

Uzzi, B. B. (2005). Collaboration and creativity: The small world problem, *American Journal of Sociology, 111*(2), 447–504.

Vagen, S. & Huxham, C. (2003). Nurturing collaborative relations: Building trust in interorganizational collaboration, *Journal of Applied Behavioural Science, 39*(5), 5–31.

Walker, G., Kogut, B., & Shan, W. (1997). Social capital, structural holes and the formation of an industry network, *Organization Science, 8*(2), 109–125.

Watters, J. J., & Ginns, I. S. (2000). Developing motivation to teach elementary science: Effect of collaborative and authentic learning, *Journal of Science Teacher Education, 11*(4), 301–321.

Zeidler, D. L. (2002). Dancing with maggots and saints: Visions for subject matter knowledge, pedagogical knowledge, and pedagogical content knowledge in science teacher education reform, *Journal of Science Teacher Education, 13*(1), 27–42.

Zetlin, A. G., & MacLeod, E. (1995). A school-university partnership working toward the restructure of an urban school and community, *Education and Urban Society, 27*(4), 411–421.

Appendices

Appendix A: Overview of the project team, including role, affiliation, area of expertise and university teaching experience

Role	Name and affiliation	Expertise	Experience
Project Leader	Dr Christine Howitt, Curtin University	Early Childhood science education	10 years
Project manager	Ms Elaine Blake, Curtin University	Early Childhood education in schools	20+ years
Scientist	Associate Professor Marjan Zadnik, Curtin University	Astronomy	20+years
Scientist	Associate Professor Simon Lewis, Curtin University	Analytical chemistry and forensic science	15 years
Scientist	Associate Professor Mauro Mocerino, Curtin University	Organic chemistry	20+ years
Engineer	Dr Martina Calais, Murdoch University	Renewable energy systems	5 years
Teacher Educator	Associate Professor Sandra Frid, Curtin University	Early Childhood mathematic education	20 years
Teacher Educator	Dr Yvonne Carnellor, Curtin University	Early Childhood teacher education	12 years
Dean of Science	Professor Jo Ward, Curtin University	Mathematics/science outreach	20+ years
Deputy Head of Education	Associate Professor Len Sparrow, Curtin University	Primary mathematics education	20+ years

Appendix B: Modified Personal Science Teaching Efficacy (PSTE) from STEBI-B

Please check the box that best describes your own attitudes and perceptions about teaching science

1. My own interest in teaching science is best described as	Not interested ☐	☐	☐	☐	Very interested ☐
2. My own background knowledge for teaching science is best described as	Limited ☐	☐	☐	☐	Extensive ☐
3. My confidence in teaching science is	Not very confident ☐	☐	☐	☐	Confident ☐
4. I am enthusiastic about teaching science	Rarely ☐	☐	☐	☐	Always ☐
5. I will continually search for better ways to teach science	Rarely ☐	☐	☐	☐	Always ☐
6. Compared with other subjects I will find it easy to teach science	Rarely ☐	☐	☐	☐	Always ☐
7. My knowledge of the steps necessary to teach science concepts effectively is	Limited ☐	☐	☐	☐	Extensive ☐
8. I will be effective in monitoring children doing science activities or experiments	Rarely ☐	☐	☐	☐	Always ☐
9. I will generally teach science effectively	Rarely ☐	☐	☐	☐	Always ☐
10. I understand science concepts well enough to be effective in teaching science	Rarely ☐	☐	☐	☐	Always ☐
11. I will find it easy to explain to students the science behind the activities they do	Rarely ☐	☐	☐	☐	Always ☐
12. Students' science questions will be easy for me to answer	Rarely ☐	☐	☐	☐	Always ☐
13. My skills in teaching science are best described as	Limited ☐	☐	☐	☐	Extensive ☐
14. Given a choice, I will invite the principal to	Rarely				Always

evaluate my teaching	☐	☐	☐	☐	☐
15. When a student has difficulty understanding a science concept, I will be able to help the student understand it better	Rarely ☐	☐	☐	☐	Often ☐
16. When teaching science, I will welcome students' questions	Rarely ☐	☐	☐	☐	Often ☐
17. Turning students on to science will be	Difficult ☐	☐	☐	☐	Easy ☐

Appendix C: Modified Test of Science Related Attitudes (TOSRA)

Please check the box that best describes your own attitudes towards science, where
SD = Strongly Disagree; D = Disagree; N = Neutral; A = Agree; SA = Strongly Agree.

	SD	**D**	**N**	**A**	**SA**
1. I would prefer to find out why something happens by doing an activity or experiment than by being told	☐	☐	☐	☐	☐
2. I dislike repeating activities or experiments to check that I get the same results	☐	☐	☐	☐	☐
3. Doing activities is not as good as finding out information from tutors	☐	☐	☐	☐	☐
4. I enjoy reading about things which disagree with my previous ideas	☐	☐	☐	☐	☐
5. I would rather agree with other people than do an activity or experiment to find out for myself	☐	☐	☐	☐	☐
6. I am curious about the world in which we live	☐	☐	☐	☐	☐
7. I would prefer to do activities than read about them	☐	☐	☐	☐	☐
8. Finding out about new things is unimportant	☐	☐	☐	☐	☐
9. I would prefer to do my own activity than to find out information from a tutor	☐	☐	☐	☐	☐
10. I find it boring to hear about new ideas	☐	☐	☐	☐	☐

Please check the box that best describes your own attitudes towards science, where SD = Strongly Disagree; D = Disagree; N = Neutral; A = Agree; SA = Strongly Agree.

	SD	D	N	A	SA
11. I would rather find out about things by asking an expert than by doing an experiment	☐	☐	☐	☐	☐
12. I like to listen to people whose opinions are different from mine	☐	☐	☐	☐	☐
13. It is better to ask the tutor the answer than to find out by doing an activity or experiment	☐	☐	☐	☐	☐
14. I science experiments, I like to use new methods which I have not used before	☐	☐	☐	☐	☐
15. I would rather solve a problem by doing an activity rather than being told the answer	☐	☐	☐	☐	☐
16. I am unwilling to change my ideas when evidence shows that the ideas are poor	☐	☐	☐	☐	☐
17. I would prefer to do an activity on a topic than to read about it in a science magazine	☐	☐	☐	☐	☐
18. In science activities, I report unexpected results as well as expected ones	☐	☐	☐	☐	☐
19. It is better to be told scientific facts than to find them out from experiments	☐	☐	☐	☐	☐
20. I dislike listening to other people's opinions	☐	☐	☐	☐	☐

Appendix D: Requirements for the poster

You are required to produce a poster that outlines what you have learnt as a consequence of having scientist/engineer in your workshops, and what you have taken from workshop and applied to your teaching practice. The posters will be presented at a forum to be held the week after your school placement.

Assessment requirements

You are required to develop a poster that addresses the following two aspects.

1. **Reflection on the four workshops**

Reflect on *what* you learned from the four workshops where scientists/engineer assisted in developing resources (Astronomy, Forensics, Cleanliness, Sustainability/Solar Energy). Think about the significant features of these workshops that could assist you in the teaching and learning of science. For each workshop, state what you have learned in relation to content, pedagogy and learning environment. *Why* were these things significant to you? You are encouraged to reflect on the four workshops immediately after completing them, rather than leaving the reflection until the end of the semester.

2. **Application of learning**

Relate how learning from these workshops was applied to your 3-week teaching practice. Discuss how you used some of the information gathered from the workshops within your teaching practice. You are not required to use information from all four workshops during your teaching practice. Rather, you are required to look closely at, and reflect upon, what and how you taught during your teaching practice, and comment on how this may have been influenced by a certain workshop(s). You are welcome to include anecdotes or examples from your teaching practice to illustrate certain points.

Information was also presented on poster specifications and what makes a great poster.

Appendix E: ECTES' Final Questionnaire

COLLABORATIVE SCIENCE PROJECT

Feedback on *Planting the Seeds of Science*

The purpose of this questionnaire is to obtain feedback on the *book Planting the Seeds of Science*, which has been developed as a resource to encourage ECTES teachers to teach more science in early childhood.

Please note that we are very interested to find out how the book was used as a whole, and not just specific to science.

Your thoughtful responses within this questionnaire will make this resource even better. You will be receiving a copy of *Planting the Seeds of Science* in 2010 once this process has been completed. This questionnaire should take a minimum of 30 minutes to complete.

There are five parts to this questionnaire.

Part A provides an overview of what you taught on your ATP. The information provided here is not specific to science, so we ask that everyone answers this part of the questionnaire.

Part B provides information on how you used the book while you were on ATP. Only those ECTES who used the book on ATP need answer this question. If you used ideas or activities from the book in any learning area, we want to know about it.

Part C asks you to describe your use of the book in detail. If you did not use the book on ATP you are asked to complete Part C1.

Part D provides an overview of how you might use the book in your future teaching. It also asks for feedback on how we can make the book better. We ask that everyone completes this part of the questionnaire.

Part E presents an opportunity to be interviewed as an ongoing part of this project.

Once complete, please place in the stamped addressed envelope and post back to SMEC by Friday October 30th 2009

A. Overview

A1. What year level(s) did you teach? K PP Y1 Y2 Y3 Other ________

A2. What general theme(s) did you cover on your ATP? ____________________________________

____

A3. In which school sector were you teaching? Government Independent Catholic

A4. Did you use *Planting the Seeds of Science* **in any way** in developing your teaching programs while on ATP?

Yes No

A5. In which of the following learning areas did you **use or adapt** any information from the modules?

Arts English H&PE Maths LOTE Science S&E T&E

A6. Did you teach any science while on your ATP? Yes No

A7. What science theme(s) did you teach while on ATP?

____

____

A8. Did you show *Planting the Seeds of Science* to your cooperating teacher? Yes No

A9. What was their general reaction to this book?

____

____

A10. Did you use any other science resource(s) on your ATP, such as *Primary Connections*?

Yes No

What was the name of the other resource(s)? ____

A11. If you used another science resource(s), did you combine it with information from *Planting the Seeds of Science*? Yes No

A12. How did you combine the resources?

____

____

____

____

B. Use of *Planting the Seeds of Science* on ATP

Only answer this part if you used *Planting the Seeds of Science* while on ATP.
If you did not use the book at all on ATP please go to Question C1.

B1. Which module(s) from *Planting the Seeds of Science* did you refer to while on ATP? Please tick all those modules that you referred to in any way.

☐ Look what I found in the park!

☐ Is the grass still green at night? Astrophysics of the dark.

☐ We're going on a (forensic) bear hunt

☐ Muds and Suds: The science of cleanliness

☐ The Sun changes everything!

B2. How frequently did you refer to *Planting the Seeds of Science* during your ATP? Please tick the appropriate box below.

☐ Did not use
☐ Infrequently (less than once a week)
☐ Frequently (once or twice a week)
☐ All the time (every day or second day)

B3. How useful were the following parts of *Planting the Seeds of Science* to you while on ATP? Please circle the appropriate response.

	Did Not Use	**Not Very Useful**	**Useful**	**Very Useful**
a) Philosophy	DNU	NVU	U	VU
b) How to use the book	DNU	NVU	U	VU
c) Activities	DNU	NVU	U	VU
d) Resources	DNU	NVU	U	VU
e) Assessment	DNU	NVU	U	VU
f) Scientific Q&A	DNU	NVU	U	VU
g) Integration of eight curriculum learning areas	DNU	NVU	U	VU
h) Science Learning Area overview	DNU	NVU	U	VU

B4. For any part(s) marked as 'Very Useful' in Question B3, why were they very useful to you?

B5. For any part(s) marked as 'Not Very Useful' in Question B3, why were they not very useful to you?

B6. Please answer the following questions in relation to how *Planting the Seeds of Science* assisted you while you were on ATP. Please circle the appropriate response.

	Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
a) Using this book has assisted me in developing greater **confidence** to teach science in the early childhood classroom	SD	D	N	A	SA
b) Using this book has assisted me in developing better **attitudes** towards science in the early childhood classroom	SD	D	N	A	SA
c) Using this book has assisted me in becoming more **enthusiastic** towards science in the early childhood classroom	SD	D	N	A	SA
d) Using this book has assisted me in becoming more **interested** in teaching science in the early childhood classroom	SD	D	N	A	SA
e) I have found this book to be **useful** for teaching science in the early childhood classroom	SD	D	N	A	SA
f) I have found this book to be an **holistic** resource for teaching science in the early childhood classroom	SD	D	N	A	SA
g) I found the ideas and activities presented in this book to be **flexible** in their use	SD	D	N	A	SA
h) I found the ideas and activities presented in this book to be **integrated** across the curriculum	SD	D	N	A	SA
i) I found the ideas and activities presented in this book to be **engaging** for both myself and the children	SD	D	N	A	SA
j) I found this book provided a much needed science **resource** in the early childhood classroom	SD	D	N	A	SA

C. Description of use

Please provide detailed information in this part on why you did not, or how you did, use the book.

C1. If you did not use *Planting the Seeds of Science* on ATP, what are the particular reasons for this?

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C2. If you did use *Planting the Seeds of Science* on ATP, please provide an overview of what you did (refer to your own book if necessary).

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C3. If you modified any activity/activities from *Planting the Seeds of Science*, please provide a short overview of what you modified and how you modified the activity.

D. How you might use this book, and how we can make it better (everyone to answer)

Please look back at your version *of Planting the Seeds of Science* and answer the following questions.

D1. How useful **do you think** were the following parts of *Planting the Seeds of Science* will be to you when **you are teaching in your own classroom**? Please circle the appropriate response.

	Did Not Use	**Not Very Useful**	**Useful**	**Very Useful**
a) Philosophy	DNU	NVU	U	VU
b) How to use the book	DNU	NVU	U	VU
c) Activities	DNU	NVU	U	VU
d) Resources	DNU	NVU	U	VU
e) Assessment	DNU	NVU	U	VU
f) Scientific Q&A	DNU	NVU	U	VU
g) Integration of eight curriculum learning areas	DNU	NVU	U	VU
h) Science Learning Area overview	DNU	NVU	U	VU

D2. For any part(s) marked as 'Very Useful' in Question D1, why do you think they will be very useful to you in your future teaching?

D3. Please answer the following questions in relation to how well **you think** *Planting the Seeds of Science* can assist you once **you are teaching in your own classroom**. Please circle the appropriate response.

	Strongly Disagree	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**
a) I think using this book can assist me to develop greater **confidence** to teach science in the early childhood classroom	SD	D	N	A	SA
b) I think using this book can assist me to develop better **attitudes** towards science in the early childhood classroom	SD	D	N	A	SA
c) I think using this book can assist me to become more **enthusiastic** towards science in the early childhood classroom	SD	D	N	A	SA
d) I think using this book can assist me to become more **interested** in teaching science in the early childhood classroom	SD	D	N	A	SA
e) I think this book will be **useful** for teaching science in the early childhood classroom	SD	D	N	A	SA
f) I think this book will be an **holistic** resource for teaching science in the early childhood classroom	SD	D	N	A	SA
g) I think the ideas and activities presented in this book will be **flexible** in their use	SD	D	N	A	SA
h) I think the ideas and activities presented in this book will be **integrated** across the curriculum	SD	D	N	A	SA
i) I think the ideas and activities presented in this book will be **engaging** for both myself and children	SD	D	N	A	SA
j) I think this book will provide a much needed science **resource** in the early childhood classroom	SD	D	N	A	SA
k) I will most likely **use this book** when teaching my own class	SD	D	N	A	SA

D4. What do you consider to be the strengths of this book?

D5. How can we make this book better? Please note that it will be published in full colour, and include many photographs of the actual activities.

D6. Do you have any other comments about the book *Planting the Seeds of Science*?

E. Would you like to be interviewed for this project?

If you used *Planting the Seeds of Science* on ATP, in any way, we would love the opportunity to interview you by phone.

If you are interested in being interviewed, please provide your contact details below.

Name: ____

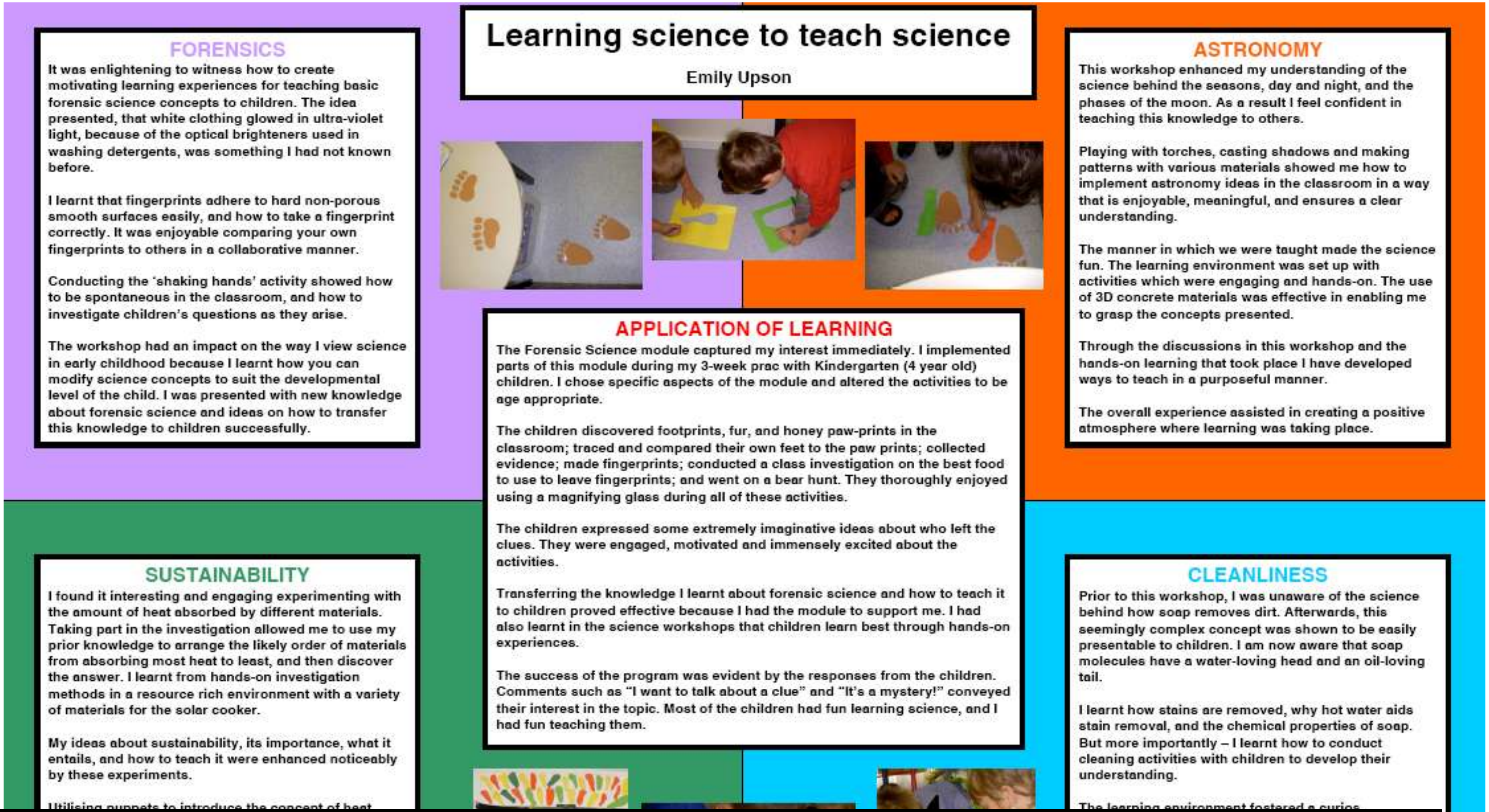
Phone number: ____

Best days/times to be contacted: ____

Thank you for your time

Once complete, please place in the stamped addressed envelope and post back to SMEC by Friday October 30th 2009

Appendix F: Examples of posters



Learning science to teach science

Emily Upson

FORENSICS

It was enlightening to witness how to create motivating learning experiences for teaching basic forensic science concepts to children. The idea presented, that white clothing glowed in ultra-violet light, because of the optical brighteners used in washing detergents, was something I had not known before.

I learnt that fingerprints adhere to hard non-porous smooth surfaces easily, and how to take a fingerprint correctly. It was enjoyable comparing your own fingerprints to others in a collaborative manner.

Conducting the 'shaking hands' activity showed how to be spontaneous in the classroom, and how to investigate children's questions as they arise.

The workshop had an impact on the way I view science in early childhood because I learnt how you can modify science concepts to suit the developmental level of the child. I was presented with new knowledge about forensic science and ideas on how to transfer this knowledge to children successfully.

ASTRONOMY

This workshop enhanced my understanding of the science behind the seasons, day and night, and the phases of the moon. As a result I feel confident in teaching this knowledge to others.

Playing with torches, casting shadows and making patterns with various materials showed me how to implement astronomy ideas in the classroom in a way that is enjoyable, meaningful, and ensures a clear understanding.

The manner in which we were taught made the science fun. The learning environment was set up with activities which were engaging and hands-on. The use of 3D concrete materials was effective in enabling me to grasp the concepts presented.

Through the discussions in this workshop and the hands-on learning that took place I have developed ways to teach in a purposeful manner.

The overall experience assisted in creating a positive atmosphere where learning was taking place.

APPLICATION OF LEARNING

The Forensic Science module captured my interest immediately. I implemented parts of this module during my 3-week prac with Kindergarten (4 year old) children. I chose specific aspects of the module and altered the activities to be age appropriate.

The children discovered footprints, fur, and honey paw-prints in the classroom; traced and compared their own feet to the paw prints; collected evidence; made fingerprints; conducted a class investigation on the best food to use to leave fingerprints; and went on a bear hunt. They thoroughly enjoyed using a magnifying glass during all of these activities.

The children expressed some extremely imaginative ideas about who left the clues. They were engaged, motivated and immensely excited about the activities.

Transferring the knowledge I learnt about forensic science and how to teach it to children proved effective because I had the module to support me. I had also learnt in the science workshops that children learn best through hands-on experiences.

The success of the program was evident by the responses from the children. Comments such as "I want to talk about a clue" and "It's a mystery!" conveyed their interest in the topic. Most of the children had fun learning science, and I had fun teaching them.

SUSTAINABILITY

I found it interesting and engaging experimenting with the amount of heat absorbed by different materials. Taking part in the investigation allowed me to use my prior knowledge to arrange the likely order of materials from absorbing most heat to least, and then discover the answer. I learnt from hands-on investigation methods in a resource rich environment with a variety of materials for the solar cooker.

My ideas about sustainability, its importance, what it entails, and how to teach it were enhanced noticeably by these experiments.

Utilising puppets to introduce the concept of heat

CLEANLINESS

Prior to this workshop, I was unaware of the science behind how soap removes dirt. Afterwards, this seemingly complex concept was shown to be easily presentable to children. I am now aware that soap molecules have a water-loving head and an oil-loving tail.

I learnt how stains are removed, why hot water aids stain removal, and the chemical properties of soap. But more importantly – I learnt how to conduct cleaning activities with children to develop their understanding.

The learning environment fostered a curios

Astronomy

Content: This module covered how the Earth rotates around the Sun and the phases of the Moon. We also learned what causes day and night and the changing of the seasons. This has helped me to understand a concept that I have had trouble with throughout my schooling. I now feel that I could explain day and night and the rotation of the Earth to the students in my class with confidence, and enjoy teaching it.
Pedagogy: The use of concrete materials helped to engage us in the activities. We were given the opportunity to manipulate concrete materials to explore how shadows are

Hands on Science in Early Childhood Education

Lauren Holmes

Sustainability

Content: In this module I learned the meaning of sustainability; not only what it is and why it is important, but how to incorporate it into the classroom and our everyday lives. We learned measures that could be taken in schools to make them more environmentally friendly, like rubbish free lunches, vegetable gardens, recycling scrap paper, and making solar cookers. We also had the opportunity to plan, create and modify our own solar cooker.
Pedagogy: The most motivating part of this module was the chance to work with chocolate and marshmallows! The

Appendix G: Summary of dissemination throughout the project

Date	Name	Type	Details
July 2008	Australian Association for Research in Education	Newsletter	Short summary of project under Research Grants
Sept 2008	Curriculum Leadership	Electronic journal	4-page overview of the project and its anticipated outcomes. Title of article was "The Collaborative Science project: Preparing pre-service early childhood teachers to teach science". Volume 6, Issue 28, 5 September, 2008 Published online at http://cmslive.curriculum.edu.au/leader/early_childhood_science_education,25011.html?issueID=11579
Nov 2008	Science Education unit	Poster session	ECTES presented their posters to an invited audience. Posters highlighted what they had learnt from having scientist/engineers in their workshops, and how they translated information from the workshops into their 3-week practicum. 30 ECTES, 19 invited visitors, 8 members of the project team
Dec 2008	National Chemistry Education Conference, Fremantle	National conference	Inaugural Primary Science Day. Workshop presentation using components from *Muds and suds* module. Title of workshop was "Muds and Suds". 25 teachers.
March 2009	National Workshop on Interactive Learning in Undergraduate Physics	National workshop	Presentation titled "Applying peer instruction and interactive learning to different contexts and levels".
March 2009	ECTES' ATP	Letter	Letter to cooperating teachers informing them of the project, and requesting assistance during the ECTES' ATP. Letter was titled "Participation in evaluation of *Planting the Seeds of Science*".
April 2009	Journal of the Science Teachers' Association of Western Australia	Journal	Write up of Primary Science Day from National Chemistry Conference. "Getting down and dirty in the name of primary and early childhood chemistry" Volume 45(1), 8-9.

April 2009	Primary Science Conference, Perth	State conference	Workshop on 3-D mind maps (using components from *Muds and suds* module). 40 teachers.
April 2009	National Association for Research in Science Teaching, California	International conference	Conference presentation titled “Collaborative science: Scientists, engineers, teacher educators and pre-service teachers working together to develop resources for pre-service early childhood science education”. 20 tertiary persons.
June 2009	Engineers Australia	Newsletter	Article was titled “Planting the seeds of science for early childhood pre-service teachers”. Engineers Australia WA Division Newsletter, June 2009.
June 2009	Teaching Science	Journal	Article on 3D mind maps titled “Placing young children in the centre of their own learning”. Volume 55(2), 42-46.
July 2009	Australasian Science Education Research Association, Geelong, Victoria	International conference	Conference presentation titled “The Collaborative Science Project: Planting the seeds of science for early childhood pre-service teachers, an initial evaluation”. 50 tertiary persons.
July 2009	Communities Working Together , Perth	Staff development day	Workshop on the science of cleanliness (using components from *Muds and suds* module). 25 teachers.
August 2009	Western Australian Institute for Educational Research, Perth	State conference	Presentation titled “‘It’s a mystery!’ A case study from the Collaborative Science Project.” 20 tertiary persons.
August 2009	Raising Achievement in Schools Conference, Perth	State workshop	Presentation titled “The Collaborative Science project: Developing flexible, integrated and engaging science resources for early childhood”. Workshop on 3-D mind maps (using components from *Muds and suds* module). 40 teachers.
September 2009	Early Years in Education Society Conference, Perth	State workshop	Workshop on 3-D mind maps – helping to connect young children’s ideas. 80 teachers.

September 2009	Journal of the Science Teachers’ Association of Western Australia	Journal	Overview of project titled “Planting the seeds of science for early childhood pre-service teachers” Volume 45(3), 5.
September 2009	Journal of the Science Teachers’ Association of Western Australia	Journal	Article titled “Tree weaving: Weaving science, art and language together”. Volume 45(3), 9. Article adapted from *Look what we found in the park!* module.
September 2009	Practically Primary	Journal	Article titled “Young children, oral language and 3-D mind maps”. Volume 14(3), 28-32.
October 2009	Engineers Australia Education Committee, Perth	Presentation	Information session on the project to 10 members of the committee.
October 2009	ATSE, Perth	State conference	Presentation titled “Teacher Education: The Collaborative Science Project.” 80 persons.
November 2009	Primary Science Showcase, Perth	Professional development	Workshop on the science of cleanliness and 3D mind maps (using components from *Muds and suds* module). 50 teachers.
November 2009	Early Childhood Network, Perth	Professional development	Workshop on “Planting the seeds of science”, components from each module. 40 teachers.
November 2009	ALTC West Australian Networking and Dissemination, Curtin University	Poster Presentation Forum	Poster titled “The Collaborative Science Project – An overview”. 40 tertiary persons.
November 2009	International Science Education Conference, Singapore	International conference	Presentation titled “Collaborating with ‘real’ scientists and engineers to increase pre-service early childhood teachers’ science content knowledge and confidence to teach science”. 20 tertiary persons.

			Workshop on 3D mind maps. 60 tertiary persons.
December 2009	Journal of the Science Teachers' Association of Western Australia	Journal	Article titled "The painted handshake: Merging forensic science and health". Volume 45(4), 10. Article adapted from *We're going on a (forensic) bear hunt!* module.
December 2009	Focus: ATSE Newsletter	National newsletter	Article titled *Planting the seeds of science!*
March 2010	Primary Science Conference, Perth	State conference	Workshop on "What can you do with a stick?" (using components from *Look what I found in the park!* module). 20 teachers.
April 2010	Journal of the Science Teachers' Association of Western Australia	Journal	Article titled "The 'light and dark box': Challenging pre-primary children's ideas about whether the grass is still green at night." Volume 46(1), 13-14. Article adapted from *Is the grass still green at night? Astrophysics of the dark* module.
April 2010	Faculty of Science & Engineering, Teaching & Learning Expo	Local meeting	Presentation titled "Win, win, win! Scientists, teacher educators and pre-service teachers collaboratively informing practice." 40 tertiary persons.
April 2010	Networks Enhancing the Scholarship of teaching (NEST), Murdoch University	Local meeting	Presentation titled "Win, win, win, win! Scientists, engineers, teacher educators and pre-service teachers collaboratively informing practice." 12 tertiary persons.
April 2010	Scholarship of Teaching and Learning Writers' Workshop, Curtin University	Local meeting	Presentation titled "Raising the profile of science" that illustrated the scholarship of teaching and learning within the project. 25 tertiary persons.
June 2010	Emergent Science Newsletter, Issue 2, June 2010	International newsletter	Planting the seeds of science in early childhood education.
June 2010	International Organisation for Science and	International conference	Presentation titles "Win, win, win, win! Scientists, engineers, teacher educators and pre-service teachers collaboratively informing practice." 20 tertiary persons.

	Technology Education, Slovenia		
June 2010	ICASE 2010 Estonia	International conference	Conference presentation titled "'Real science' in early childhood education: Scientists working with early childhood pre-service teachers." 40 tertiary persons.
July 2010	Australasian Science Education Research Association, Port Stephens, NSW	International conference	Conference presentation titled "*Planting the seeds of science*: Development and evaluation of a new early childhood science resource." 15 tertiary persons.
July 2010	Higher Education Research and Development Society of Australasia, Melbourne, Victoria	International conference	Conference presentation titled "Using holes to create bridges: Developing a model of collaboration and creativity between scientists and teacher educators." 20 tertiary persons.
August 2010	International Conference on Chemical Education, Taiwan	International conference	Conference presentation titled "Planting the seeds of science for early childhood pre-service teachers: Scientists, teacher educators and pre-service teachers working collaboratively."
October 2010	Early Childhood Australia National Conference, Adelaide, SA	International conference	Conference presentation titles "'It's a mystery!' A case study of implementing forensic science into kindergarten as scientific inquiry." Paper accepted.
2011	Issues and challenges in science education research: Moving forward	Book chapter	Edited by Kim Chwee Daniel Tan, Mijung Kim and SungWon Hwang. Chapter 11. Increasing accessibility to science in early childhood teacher education through collaboration between scientists, engineers and teacher educators. Accepted for publication by Springer.

Appendix H: Evaluation Form for school professional development sessions

Evaluation

This information is required as part of the funding arrangements of the Australian Learning and Teaching Council.

Please respond to the following questions by circling the appropriate response.
SD = Strongly Disagree; D = Disagree; N = Neutral; A = Agree; SA = Strongly Agree

1. I intend to share the information from this workshop with my colleagues.	SD	D	N	A	SA
2. I intend to use the information from this workshop in my own teaching.	SD	D	N	A	SA
3. I have been presented with new science content that I can use in my classroom.	SD	D	N	A	SA
4. I have been presented with new teaching strategies that I can use in my classroom.	SD	D	N	A	SA

5. What are the major points that you will take away from this workshop?

Appendix I: Evaluation Form for NEST Presentation

Evaluation

This information is required as part of the funding arrangements of the Australian Learning and Teaching Council.

Please respond to the following questions by circling the appropriate response.
SD = Strongly Disagree; D = Disagree; N = Neutral; A = Agree; SA = Strongly Agree

1. I have been presented with information that is relevant to my area of expertise.	SD	D	N	A	SA
2. I intend to share information from this presentation with colleagues.	SD	D	N	A	SA
3. I would be interested in gaining further information from this presentation.	SD	D	N	A	SA

4. What are the major points that you will take away from this presentation?