Engagement in science, engineering and technology in the early years: A cultural-historical reading

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Abstract

This paper seeks answers to the question "what engages young children in science, engineering and technology (SET)?". A review of the SET literature is undertaken to find out what are the dominant themes noted in the research literature for engaging young children in SET. Two kinds of analyses are presented in this paper. The first analysis draws upon developmental theory because it is still the dominant worldview within early childhood education, and is closely aligned with constructivism, the major theory within SET education research. This analysis gives some insights into the concept of engagement from a developmental perspective. However, many of the findings identified in the studies reviewed could not easily fit within a traditional developmental framework. A second analysis was undertaken, using cultural-historical theory. It was found that engagement could be explained more fully when it was theorised in relation to Vygotsky's (1987) and Leont'ev's (1978) concept of "motives" in the context of Kravtsova's (2008) concept of the "zone of potential development". This latter theorisation allowed for a richer discussion of SET engagement for early childhood education. The paper concludes with a model of SET engagement for early childhood education.

Key Words

Early childhood, cultural-historical, sociocultural, early years, science education, technology education, engineering education.

Résumé

Cet article cherche des réponses à la question suivante «quoi engage les jeunes enfants dans les sciences, l'ingénierie et la technologie (SIT)». Une revue de la littérature SIT est entreprise pour savoir quels sont les thèmes dominants apparaissant dans les travaux de recherche pour faire participer les jeunes enfants en SIT. Deux types d'analyses sont présentés dans le présent article. La première analyse s'appuie sur la théorie du développement, car elle est toujours la théorie dominante du monde de la petite enfance, et est étroitement aligné sur le constructivisme, la théorie principale dans la recherche en éducation concernant la SIT. Cette analyse donne un aperçu de la notion d'engagement à partir d'une perspective de développement. Toutefois, bon nombre des constatations faites dans les études examinées n'ont pas pu s'inscrire dans un cadre de développement traditionnel. Une deuxième analyse a été entreprise, en utilisant la théorie historico-culturelle. Il a été constaté que l'engagement pourrait être expliqué plus en détail quand il est théorisé par rapport à la notion de "motifs" [Vygotsky (1987) et Leont'ev (1978)] dans le contexte du concept de "zone de développement potentiel" de Kravtsova (2008). Cette théorisation a permis une plus riche discussion de l'engagement dans les SIT pour l'éducation des jeunes enfants. L'article conclut avec un modèle d'engagement en SIT pour l'éduction pendant la petite enfance.

Mots Clés

Petite enfance, culturel et historique, socioculturel, premières années, l'enseignement des sciences, l'enseignement de la technologie, la formation en ingénierie.

Introduction

> We live in a society exquisitely dependent on science and technology, in which hardly anyone knows anything about science and technology (Carl Sagan, cited in PMSEIC, 2003, p. 5).

A growing trend in many industrialised nations around the world is the challenge of attracting people into, and maintaining the workforce for, science, engineering and technology (SET). At the same time the literature identifies that children are not engaging with SET and that disengagement has become an increasingly important factor in SET education, as children advance through the school system, with a critical point being reached in the middle years of secondary schooling. PMSEIC (2003) notes the following:

> …falling science enrolments in senior secondary school and university, concerns over professional conditions and the morale of science teachers, poor industry-science links, lack of national coordination and the accelerating global pace of change… (PMSEIC, 2003, p. 3).

Goodrum, Hackling and Rennie (2001) also paint a picture of disengagement within science education in the middle years of schooling. Further, engagement features significantly among the "core challenges in contemporary" society identified in the report "Enterprise Education" (2004, p. 158). In their analysis of best practice in 200 Australian primary and secondary schools over a period of two years, it was noted that successful engagement was conceptualised as engaging "the disengaged, those who are at risk, and those who are vulnerable to missing out on life's opportunities without a full and optimistic education". Engagement in SET appears to be a major problem for many Western societies (see Osborne, 2007 (UK), Skogh, 2004 (Sweden), Cunningham et al., 2005 (US) and Barwick, 2000 (New Zealand)).

A 20-nation survey by Schreiner & Sjøberg (2004 in Osborne, 2007) highlights the international nature of declining interest in school science by students, particularly girls. Osborne (2007) reviews the literature documenting the students' lack of interest in careers in science, technology, engineering and mathematics and the growing body of evidence that "science is failing to engage young people" (p. 1).

Whilst the motivational/affective domains have been investigated in the secondary sector, particularly the middle years (see Darby 2005, Yung & Tao, 2004, Pugh 2006), little research has been directed to the early years (Ravanis, Koliopoulos & Boilevin, 2008; Fleer, March & Gunstone, 2006; Fleer & March, 2008; Lowe & Fisher, 2000). As such, we know very little about SET engagement for early childhood education. In this paper, we seek to review the broader literature on engagement in SET in order to determine likely contributing factors for engagement in early years SET. We draw upon both developmental theory and cultural-history theory in order to analyse the outcomes of the literature and to build a theoretical model of SET engagement for early childhood education.

We begin our paper with a discussion of the term engagement, followed by a review of relevant literature on early childhood SET engagement. In the final part of this paper, we undertake the theoretical analyses, and conclude the paper with a cultural-historical theory of engagement in SET for the early years.

What is SET engagement?

In reviewing the early childhood SET education literature, we note that researchers have concentrated largely on conceptual change (e.g. Christidou & Hatzinikita, 2006),

metacognition (e.g. Larkin, 2006), teaching of appropriate content (e.g. Garbett, 2003), and the importance of the informal learning context (e.g. Cumming, 2003), rather than engagement per se. Yung and Tao (2004) point to the lack of specific research into the affective domain of science education, an area related to engagement. In line with cultural-historical theory (see Leont'ev, 1978; Vygotsky, 1987), the authors see a need for not merely enhancing students' cognitive understanding in science learning but also "empowering them with the motivation and confidence to do so" (p. 403).

"Child engagement" in relation to inclusive early childhood settings, has been defined in simple terms as "appropriate interactions with the environment including materials and people" (Bailey & Wolery, 1992 in Kishida & Kemp, 2006, p. 14). In an important paper on school engagement, examining the Fair Go Project (FGP), a NSW-wide research partnership student engagement initiative commencing in 2000, Johnson and O'Brien (2002) studied the classroom pedagogies that brought enhanced outcomes for educationally disadvantaged primary school students in south-western Sydney. These authors provide a broad definition of engagement whereby "students feel that school and education is 'for them'" (Johnson & O'Brien 2002, p. 2). Another useful definition is included in the report "Enterprise Education" (2004), where an engaged primary school child "makes a head and heart contribution"; is "task oriented and outcomes focussed"; "applies understanding to move forward"; and "manages resources and time effectively" (p. 153). Aspects of these broad definitions can be found in the literature on factors contributing to SET engagement.

Contributing factors to SET engagement

In line with constructivist thinking, Johnson and O'Brien (2002) assert that "perhaps the learners themselves" are "the only ones able to completely determine" if they are "engaged in their learning" (p. 11). Johnson and O'Brien (2002) argue that on task behaviour is an important criterion for determining student engagement. They point out that engagement is more than 'compliance' or 'on task' behaviour. Such 'on task' behaviour is defined as "little 'e' engagement" (Johnson & O'Brien 2002, p. 10). In contrast, big 'E' engagement 'involves a longer-term, deeper engagement with school and education. There is a sense among students that "school is for me"' (Johnson & O'Brien, 2002, p. 10). In their research they recognised that there were "significant pedagogical connections" between the two, and that this deeper kind of engagement could only really be assessed by the students' themselves. 'On task' or little 'e' engagement may be observable, but with Big 'E' engagement, they assert that "student voices are the true measure of engagement" by which they are suggesting that indications of "active and critical" engagement cannot always be observed, but must be gleaned from students' work and the conversations that occur in classrooms around learning (Johnson & O'Brien, 2002, p. 10). Johnson and O'Brien (2002) identified the following indicators of engagement:

- Their learning extends beyond teacher, task and time and they are pushing boundaries, transferring learning to different times and contexts;
- They are reflecting on their learning (for example, as evidenced in entries in reflective journals);
- Learning interactions move beyond classroom and school;
- There is a focus on continued and recognised student achievement;
- Students demonstrate long-term satisfaction with the learning process;
- There is social and cultural support for all learning;
- Students demonstrate self-understanding of short and long term learning purposes (paraphrased from Johnson & O'Brien, 2002, p. 11).

In addition, Johnson and O'Brien (2002) found in their analysis of successful indicators of engagement that real world purpose of task/problem solving were important for engaging students in learning, involvement of the family was seen to be important, students could build on their existing knowledge, that students had a keen desire for task completion and 'having a go', and a collective enterprise towards a common goal was significant.

Williams (2004) in a project to develop support material and a website for the design and technology curriculum in the UK identified behavioural indicators of children's thinking associated with creative action in the classroom, when SET engagement:

- Supported questioning and challenge;
- Allowed connections and seeing relationships;
- Envisaged what might be;
- Explored ideas, keeping options open;
- Reflected critically on ideas, actions and outcomes (Williams, 2004, p. 199).

Williams (2004) also noted that teachers can increase student creativity and engagement by setting a clear purpose for children's work and by building specific creativity objectives into teacher planning.

In a four-year longitudinal study undertaken by Tytler and Peterson (2005) a sample of 12 (initially 14) children were interviewed and observed in class from prep, at age five to grade five at age 10. Tytler and Peterson (2005) searched for ways of understanding the children's growing capabilities and found that, from prep, those children who approached explorations in a speculative, inquiring manner were those who showed the earliest growth in conceptual knowledge. For example, children who further questioned the data they were gathering, rather than being content with the first explanation, learned more science. One of the children studied by Tytler and Peter-

son (2005) had been doing science experiments at home from an early age and seemed to the authors to be more self-motivated when exploring phenomena than the other children, paying attention to scientific design. Here, early interest in science is evident in the prior to school years and this early engagement generates deeper learning.

Early interest was also a factor identified by Redman (1996). Redman (1996) undertook a study comprising initial surveys and subsequent detailed questionnaires completed by 65 teachers in 18 schools designed to determine, inter alia, which attributes teachers thought most essential in the exemplary primary school science teacher, to determine the weighting placed by the teachers on those attributes, to compare those attributes to the outstanding primary school science teacher and to make some comparisons with international research. She noted that "the importance of science to the young child is acknowledged as the place where interest can be captured and harnessed" (Redman, 1996, p. 35). Early interest and enthusiasm for technology and design education has also been noted by Jane (1995) who found engagement and learning were enhanced when children had ownership of their learning, were encouraged to take risks, and were engaged in problem-solving activities.

Much of the early childhood SET research literature that identifies engagement mentions family or home context for building upon prior learning in order to capture children's interest before formal schooling begins (Hall & Schaverien, 2001). For example, Gordon (2006) undertook a phenomenological study of eight families who participated in a Starwatcher Programme in NSW. Families were given surveys to complete at the conclusion of their Starwatcher activities. This occurred over six nights. Interviews with 6 of the 8 families took place over a period of 12 months. The study sought to determine what influences successful learning of astronomy science within a family centred program. Gordon (2006) argues that many scientific concepts in astronomy are out of the physical reach of adults and children, and therefore must be experienced perceptually (although not as obvious, this is also the case for many other scientific concepts such as conservation of energy). She argues that traditional linear learning models are not effective for the teaching of astronomy. Her research (which featured observations of how children interacted in programs) found that children needed a differentiated learning model, where children could move from one experience to the next, revisiting experiences during one session or over multiple sessions. She termed this 'butterfly learning'. Her research demonstrated that engagement in astronomy was enhanced when children revisited prior learning, had multiple opportunities for learning, experienced a varied presentation, including visual and audio input, and importantly, could self-select experiences across a broad range of experiences. The importance of gaining a 'big picture' of cosmology was highly significant for learning about the night sky. In addition, Gordon (2006) found that when story telling was used, alongside of the multiple visual experiences and visualisation of possibilities, that children

began to develop scientific rather than everyday understandings of the scientific terms, such as a black hole. The story telling allowed 'the children and adults to fit familiar terminology to unfamiliar events and objects; the stories of the constellations also connected families to the history and heritage of astronomy' (Gordon, 2006, p. 101). In summary, Gordon's research found that children and families were most engaged when the following dimensions were considered:

- Visual imagery (pictures, slides, videos, telescope images);
- Story telling and deconstructed language (e.g. Using everyday notations along side of scientific terms);
- Experiential learning (physical practice and hands on activities);
- Sense of belonging in the learning space (Starwatcher programme);
- Community orientation to learning rather than viewing learning from an individual's perspective;
- Continuous placement of understanding within the big picture (e.g. Keeping the big picture intact, rather than breaking learning down into digestible chunks);
- Learning model utilising 'Butterfly Learning'.

Out of school learning has also been the focus of research by Cumming (2000). Cumming (2003) undertook a study of children aged four to seven, utilising parent diaries, which shows that more scientifically correct information about food concepts takes place outside school than children may acknowledge in the classroom situation. Other studies have suggested that ascertaining the child's existing level of understanding is important for engagement. Johnson and O'Brien (2002) assert that "insufficient time is spent on considering the prior learning and life experiences of students" (p. 7).

Research which has focused on the value of learning SET content for building motivation and engagement has not been specifically undertaken. However, some researchers have examined motivation in relation to content knowledge acquired through particular teaching programs, such as Five E's model–Engagement, Exploration, Explanation, Elaboration and Evaluation. Boddy, Watson and Aubusson (2003) researched ten children from a Year 3 classroom within a low socio-economic status (SES) community. Field notes taken by a participant observer and video taping of whole class sessions (28 children) over ten lessons formed the data set. Those findings relevant to this review show that motivation led to learning and learning can also lead to motivation (synergistic, i.e. when children's interest is captured as they learn more). As children learn more they become more engaged in the topic. Recognising children's prior learning was also an important contributing factor to building programs which engaged children. Technical content has also been shown to feature in technological engagement, as noted by Skogh (2004). Skogh (2004) undertook a longitudinal study

of 26 girls aged 7–10 which examined their experiences with technology in the home and at school. She noted a correlation between experiences with technology and image of technology.

> The girls' confidence in their technical capabilities was also found to be dependant on the extent to which they had positive technical experiences *(positive in the sense that the girl in question feels that she has dealt successfully with the technical tasks that she faced—not necessarily that she has experienced them as fun)*. (Skogh, 2004, p. 117 our emphasis).

In the Fair Go Project (FGP) initiated in Australia, Johnson and O'Brien (2002) studied the classroom pedagogies that brought enhanced outcomes for educationally disadvantaged primary school students in South-West Sydney. Important principles in engagement identified and not previously discussed included:

- Intellectual challenge ensuring that both the learning and the learner are valued;
- Students need to experience "a sense of membership" through reciprocal relationships with teachers in which they are valued (including "active efforts by teachers to communicate with individual pupils and help them with their concerns" (Rudduck et al., 1996, p. 85 in Johnson & O'Brien, 2002, p. 7);
- High teacher expectations (Low teacher expectations link to underachievement and disengagement on the part of students);
- 'Connecting with the significant others' in the lives of children, i.e. their families;
- Engagement occurs on a continuum (Wehlage 1989 in Johnson & O'Brien, 2002, p. 9);
- Engagement is 'meaningful', involves 'personal identification with the process of learning' (Rudduck et al, 1996 in Johnson and O'Brien, 2002, p. 9);
- 'about that sense of social context'—gives teachers and pupils a common social purpose (Johnson & O'Brien 2002, p. 9,10).

These pedagogical features of children's engagement in SET identified by Johnson and O'Brien (2002), move beyond the concept of engagement being located "in the child's head", and point to the relations between teachers, children and school structures. In a study by Newmann and Wehlage (1995) which sought to specifically examine school structure in relation to student performance, found that authentic pedagogy was a key to student engagement. Extensive field research between 1990 and 1995, in 44 US schools (1500 elementary, middle and high school students) was undertaken. The findings suggest that when schools restructure around a vision for high quality student learning or "authentic student achievement", that the following three principles facilitate engagement in SET:

- Construction of knowledge—students learn to organise, interpret and analyse information;
- Disciplined enquiry—using established knowledge, students develop a deep understanding and express it in an elaborate way;
- Value beyond school—students' work and problem solving has value in the real world.

Authentic pedagogy, according to Newmann and Wehlage (1995) involves "teachers (bringing) the vision to life in their classroom". School organisation factors for enhanced learning cited in Newmann and Wehlage (1995) include, "staff development that enhances technical skills consistent with the school's mission" and "parent involvement in a broad range of school affairs" (Newmann & Wehlage 1995, p. 3).

Systemic and structural pedagogical reform has also been the focus of research attention in the Queensland School Reform Longitudinal Study (QSRLS, 2000). In this observational study of 975 classrooms in 24 schools in Australia, carried out by the University of Queensland School of Education for Education Queensland, over three years from 1998 to 2000, four areas were identified as impacting on general student engagement—intellectual quality (higher order thinking; deep knowledge; deep understanding; substantive conversation; knowledge as problematic; metalanguage), connectedness (knowledge integration; background knowledge; connectedness to the world; problem-based curriculum), supportive classroom environment (student direction, social support, academic engagement, explicit quality performance criteria, self-regulation), and recognition of difference (cultural knowledges, inclusivity, narrative, group identity, active citizenship).

In bringing together this brief discussion of the relevant literature for early childhood engagement in SET, it is evident that there is a broad range of indicators of engagement. Knowing which are relevant for the early childhood period is difficult to determine without some form of theoretical analysis. In the next section, we re-examine this literature in relation to developmental theory.

Contributing Factors to Set Engagement – A Developmental Analysis

A Cartesian view of "engagement"

Pugh et al. (2006) in reviewing the current educational psychology literature noted that engagement comprises three major components—behaviour, affect and cognition—which combine to confer an emotional quality and intensity to students' involvement. This is consistent with school engagement categories named by Fredricks, Blumenfeld and Paris (2004), i.e. behavioural, emotional, and cognitive engagement. These cate-

gories are consistent with the traditional knowledge foundations of early childhood education evident in most European heritage communities. In most Western early childhood programs curricula and pedagogy have traditionally been organised in relation to outcomes in social-emotional development, cognitive/language development, and physical development. This constitutes a traditional developmental view of teaching and learning in early childhood education, and follows Cartesian logic, where the mind and the body are separated out from one another. Because early childhood SET education does not feature highly in the early childhood literature, when compared with the body of literature that has been generated for secondary and university SET education, and to a large extent primary SET education, we have chosen to analyse the literature in relation to these developmental categories. Because much of the early childhood SET education literature has been framed from a constructivist perspective (Fleer & Robbins, 2003a, 2003b; Ravanis, Koliopoulos & Boilevin, 2008) even though researchers are increasingly examining socio-scientific issues, Albe (2008), and because there is a limited pool of literature for early childhood SET education (e.g. Christidou & Hatzinikita, 2006; Cumming, 2003; Mawson, 2003; Pantidos, 2008; Rennie, 2003), and even less for SET engagement (Fleer, March & Gunstone, 2006), we believe it is important to undertake a traditional analysis, in the first instance.

Our analysis

In drawing upon the traditional early childhood categories of physical development, social-emotional development, and cognitive development, in combination with the elements of engagement identified by Pugh et al. (2006), we can cluster the outcomes of the engagement literature into the domains of behaviour—observable physical development; emotional development; and cognitive development, as shown below in Table 1. The literature reviewed in the above section has been organised to fit within these categories, and those relevant studies are referenced within Table 1.

Behavioural features that are foregrounded in this analysis include, on task behaviour (but not as directly observable), goal oriented activity, persistence, risk taking, and substantive conversations. An analysis of the emotional dimensions of engagement are most limited, indicating that little attention is drawn to this area in research—as defined by Pugh et al., (2006). Interest is explicitly mentioned by only three of the researchers whose work was reviewed. As would be expected, cognition featured quite strongly in the studies reviewed. Ownership of learning, risk taking, problem-solving, technical content, academic engagement, are featured as key areas for engagement in SET. What is also evident when a developmental analysis is undertaken is that much of the contextual elements noted in the literature above (e.g. home connections) are difficult to include in the table. Many of the engagement features identified in the literature could not be included in the traditional developmental analysis grid.

TABLE 1

A developmental analysis of engagement in early childhood SET education

Component	***Elements***	***Psychological literature on engagement***	***SET engagement literature related to these categories***
Behaviour – physically observable activity	Participation in class discussions Regular attendance Initiation of action Making an effort On task behaviour Goal-directed activity Persistence Paying attention	Caraway, Tucker, Reinke, & Hall, 2003; Connell, 1990; Furrer & Skinner, 2003; Skinner, Wellborn, & Connell, 1990 in Pugh et al (2006)	On task behaviour – not directly observable; Goal-directed activity; "Having a go"; persistence (Johnson & O'Brien, 2002) Substantive conversation (QSRLS, 2000) Clear purpose (Williams, 2004)
Emotional	Students display: o Enthusiasm o Curiosity o Excitement o Interest o Intrinsic motivation	Ainley, 1993; Caraway et al., 1990; Connell, 1990; Furrer & Skinner, 2003; Patrick, Skinner, & Connell, 1993; Skinner et al., 1990 in Pugh et al (2006)	Early interest; speculative and enquiring; (Tytler & Peterson, 2005) Early interest (Redman, 1996)
Cognition	Use deep level learning strategies Display self-regulation Focused on *content*	Ainley, 1993; Blumenfeld, Megendoller, & Puro, 1992; Greene & Miller, 1996; Meece, Blumenfeld, & Hoyle, 1988, in Pugh et al (2006)	"School is for me" (Johnson & O'Brien, 2002) Ownership of own learning; take risks; use problem-solving strategies (Jane, 1995) Content drives motivation (Boddy, Watson and Aubusson, 2003) Technical content (Skogh, 2004) Construction of knowledge (Newmann and Wehlage 1995) Deep knowledge; problem based curriculum; academic engagement (QSRLS, 2000)

The classification framework on engagement put forward by Pugh et al., (2006) provides insights into engagement in SET for the early years. As mentioned above, the framing of these categories—behavioural, emotional and cognitive development—is consistent with how early childhood education is conceptualised. However, this framing also appears to follow a narrow and traditional psychological pathway where engagement is broken down into behaviours, into feelings and into learning. This categorisation of early childhood education has been contested within both the sociological, ecological and cultural-historical literature directed to childhood (e.g. Fleer, Hedegaard & Tudge, 2009; Moss & Petrie, 2002; Turmel, 2008) and the early childhood education literature (e.g. Edwards, 2009; Blaise, 2005, 2009). As such, it is important to turn to a different type of analysis—one that draws upon cultural-historical theory. This type of analysis should allow more of the studies reviewed in the first part of this paper to be included within the analysis table.

Contributing Factors to Set Engagement – A Cultural-Historical Analysis

In this section, we seek to go beyond the Cartesian (developmental) analysis given in the previous section, and draw upon cultural-historical theory for a different kind of analysis (see also Fleer & Robbins, 2003a, 2003b; Ravanis, Koliopoulos & Boilevin, 2008; Robbins, 2005 for early childhood studies which draw upon Vygotskian theory). We begin this section by giving a dialectical theorisation of engagement, followed by an explanation of the analysis framework, concluding with a summary of the analysis (presented as Table 2 below). More space is devoted to explaining this theory because it is not as well understood as a traditional developmental view. In addition, we theorise engagement from a cultural-historical perspective because this has not been undertaken in the literature before, and therefore more discussion is devoted to this task.

A dialectical view of "engagement"

We consider the psychological concepts of "motives" (Hedegaard, 2002; Kravtsov & Kravtsova, 2009; Leont'ev, 1978), "imitation" (Vygotsky, 1987), and the zone of proximal development (Vygotsky, 1997, 1998; Kravtsova, 2008), as foundational for discussing engagement from a cultural-historical perspective. These cultural-historical concepts are theorised using dialectical logic, and thus avoid the mind-body split discussed in the previous analysis.

One of the defining features of Vygotsky's theoretical position focused on the significance of the social context. Vygotsky and Luria (1994) argued that "Social forms of behaviour are more complicated and are in advance in their development in the child"

(p. 153). That is, children engage in activities within their social world and through this interaction work collectively with others, often above what they could do independently. The concept of imitation is important here for understanding how children become primed or oriented towards social action. Vygotsky (1998) had a particular view of this concept, arguing not for an everyday reading of this term, but rather a specific psychological view which saw children 'socially primed to pay attention' to particular activities in their social world.

> Speaking of imitation, we do not have in mind a mechanical, automatic thoughtless imitation but sensible imitation based on understanding the imitative carrying out of some intellectual operation. …. Everything that the child cannot do independently, but which he can be taught or which he can do with direction or cooperation or with the help of leading questions, we will include in the sphere of imitation (Vygotsky, 1998, p. 202).

For instance, a toddler may see adults designing and assembling a wooden structure, such as a set of shelves, but the toddler is unlikely to pay attention to how the unit was designed. The toddler cannot imitate the actions of the adults crafting a design, laying out the materials and organising the equipment. We are more likely to see a toddler picking up the nails and the hammer and to simply focus on the hammering action. Using the tools is meaningful and contains particular social rules for what the nails and the hammer can be applied to (i.e., on the wood, and not on the walls of the house). The toddler imitates these socially meaningful actions, knowing that the hammer and nail relate to the wood. As the toddler experiences more over time, the social rules expand, and the toddler and later the preschooler, begins to notice adult designing, making and apprising with the materials (technology and engineering) or begins to notice about what kinds of materials are best used for hammering, such as plastic lids are easy to hammer into pine (science). Vygotsky (1966) argued that initially children imitate familiar and important activities, and through imitative action in play, they generate a 'motive' for playing with these actions to generate deeper social meaning about the rules and concepts that frame their social world.

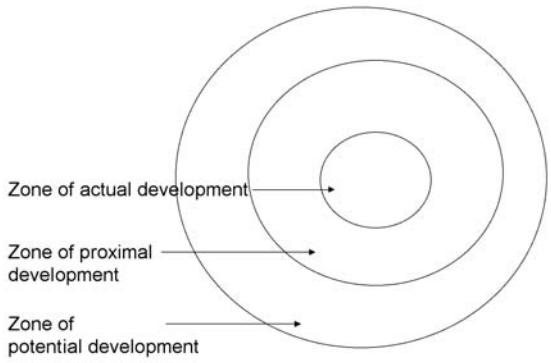
Considering the concept of 'imitation' is not enough for understanding engagement in SET. The concept of 'motives' is important here and is dialectically related to 'imitation'. Leont'ev (1978) suggested that in Vygotsky's general collective meaning of activity, that researchers must consider specific activities "each of which answers a definite need of the subject, is directed toward an object of this need, is extinguished as a result of its satisfaction, and is produced again perhaps in other, altogether changed conditions" (p. 62). The central idea in Leont'ev's theory is that every activity is driven by distinct motives and these motives do not arise from within, but rather are the

objects of the material world. As such, motives are socially produced within the human world and "an individual activity bears the birthmarks of and reflects these collaborative practices, never becoming completely isolated from the social processes that give rise to it" (Stetsenko & Arievitch, 2004, p. 487). Stetsenko and Arievitch (2004) suggest that although the positioning of motives outside of individuals seems counter intuitive, it is nevertheless a central and important concept in cultural-historical theory. As children grow they "increasingly enter into connection with historically established human experience, and come to know objective reality with increasing breadth and depth" (Leont'ev & Luria, 2005, p. 47).

If we return to the example of the design and assembling of a wooden shelf, an older child may observe this activity and note that making things is a valued family activity. The older child will notice what the toddler does not, that there are particular actions governed by rules for making things—designing, and selecting tools and materials. Through repeated viewings of different things being made at home by the family, this experience has the potential to generate a motive for designing and making things (Leont'ev, 1978). That is, a motive is generated for engaging in particular types of SET experiences. Activity theory as conceptualised by Leont'ev (1978) predominantly focuses our attention on the social context, or the activity. The child's perspective in relation to engagement in SET is not as well defined in Activity Theory. However, the child's perspective is evident in the theoretical writings of El'konin (1999). El'konin (1999), in returning to Vygotsky's original theorization, foregrounds the importance of the dialectical relations between the 'child' and the 'object' through the 'social'. In particular, the *child's changing relations* to her/his environment is foregrounded. For instance, the toddler is oriented towards a hammer (object) and hammering with the adults (social). As the toddler gains more experience of the world, the child moves from a focus on using tools (object) to how the objects are associated with making activities for the use of the family (social)—thus making central the child's changing view of reality (and the objects). El'konin's (1999) theorization of motives makes visible the *child's perspective* within the child-social-object relations, and is helpful for gaining a deeper understanding of the child's lived world and their relation to it. That is, how engagement is socially and culturally constructed. These relations have also been theorised by Kravtsova (2008) in the context of the zone of potential development. This concept is particularly useful for thinking about engagement from a pedagogical perspective. As such, Kravtsova's theorisation is discussed here (see Figure 1).

Vygotksy's zone of actual development and the zone of proximal development are well understood in the literature. In short, actual development is what a child can do without adult assistance, whilst the zone of proximal development, is what the child does with support from others. These concepts are often discussed from a pedagogi-

FIGURE 1



Zones of development (Kravtsova, 2008)

cal perspective, rather than from an assessment perspective (see Chaiklin, 2003). That is, when viewed from an assessment perspective, they draw attention to the kinds of supports given to children, as evidence for measuring the dynamic and evolving capabilities (or proximal development) of children. When viewed from a pedagogical perspective, they foreground what teachers do to support children. In a dialectical view, both are related to each other. Within the zone of proximal development, the child is willing and able to engage in the activities suggested by the adult and actively supported through some form of scaffolding by the teacher. What is less well known is Kravtsova's (2008) theory of the zone of *potential* development. This zone represents the social and cultural world of the child that lies within the sphere of *possible* engagement. That is, it is the social and cultural activity that surrounds the child—it is the real social world of the child that they are a part of, where they observe adults and others engaged in activities—such as designing and assembling a bookshelf. Through being in the specific contexts, motives are generated by the activities, as important and meaningful experiences that they will one day be able to do themselves. That is, engagement potential is generated for future engaged activity.

Imitation, motives and the zone of potential development as concepts are important for theorising engagement and for explaining how children's engagement in SET may be generated and sustained. As such, an analysis of SET literature in relation to the Zone of Actual Development, the Zone of Proximal Development, and the Zone of Potential Development, are useful for realising a cultural-historical pedagogical view of engagement.

Our analysis

Our analysis of the engagement literature uses Vygotsky's zones of actual and proximal development. We expand on this work, by also using Kravtsova's (2008) zone of potential development. We present this as columns in the table. However, it should be read dialectically—that is, both as measured within the child's zone but also as the teacher's pedagogical practice for foregrounding development (actual, proximal or potential).

TABLE 2

A cultural-historical analysis of engagement in SET

	Zone of Actual Development	*Zone of Proximal Development*	*Zone of Potential Development*
Lens	Personal lens – transformational issues (Robbins & Jane, 2006, p. 7)	Interpersonal lens – relationships and collaboration (Robbins & Jane, 2006, p. 7)	Community/Contextual lens – valued experiences and cultural tools (Robbins & Jane, 2006, p. 7)
Impact	SET content relates to child's self-view / is within the child's MZPD (Pugh, 2004; Yung & Tao, 2004) Child is receptive to SET	Social situation supports and validates SET (Hall & Schaverien, 2001) SET teaching is reinforced beyond school	The teacher brings the SET vision to life in the classroom (Newman & Wehlage, 1995) SET is taught in the appropriate context
Context	Meaningful contexts (Rudduck et al., 1996 in Johnson & O'Brien, 2002; Mitchell, 1993 in Pugh, 2004; Skinner, 1994)	Social context (Pugh, 2004; Johnson & O'Brien, 2002)	Cultural context (Seemann, 2004)
Elements	Transformation of one's relationship with the world / propensity to apply knowledge / value beyond school (Pugh, 2004; Johnson & O'Brien, 2002; Newmann & Wehlage, 1995) Personal meaning / identity / view of possible selves (Skinner, 1994; Pugh, 2004, p. 192, Rudduck et al., 1996 in Johnson & O'Brien, 2002, p. 9, Zahorik, 1996 in Pugh, 2004) Aesthetic perspective (Girod, Rau & Schepige, 2003) Student voice / ownership of learning (Johnson & O'Brien, 2002, p. 9,10, Jane, 1995; Logan & Skamp, 2008; Woolnough, 2000) Prior learning / existing knowledge / Motivational zone of proximal development MZPD (Johnson & O'Brien 2002, p. 7; Yung & Tao, 2004) Goal orientation (Pugh et al., 2006), Intellectual challenge (Johnson & O'Brien, 2002, p. 9,10; QSRLS, 2000; Aubusson & Steele, 2002: 33) Continuum of engagement (Wehlage, 1989, in Johnson & O'Brien, 2002) Recognition of difference (QSRLS, 2000) Express understanding in an elaborate way (Newmann & Wehlage, 1995) Authenticity / doing science (INFOESCUELA, 1999; Shoring, 2000; Newmann & Wehlage, 1995) Clear purpose (Williams, 2004)	Connectedness / connecting with significant others (QSRLS, 2000; Johnson & O'Brien, 2002, p. 9,10) Sense of membership / belonging in the learning space (Gordon, 2006; Johnson & O'Brien, 2002, p. 9,10) Support: Social / cultural / family / community / classroom environment (Johnson & O'Brien, 2002, p. 11; QSRLS 2000) Family: recognise their children's interest / provide rich and stimulating environment (Hall & Schaverien, 2001, p. 22) Relevance and application to everyday life (Shoring, 1999) Encouraged to take risks (Jane, 1995) Teacher models a passion for the content (Pugh & Girod, 2007) Collaboration / team work (Woolnough, 2000; Noble, 2001) Continuity / integration of science learning (Hackling & Prain, 2005; Science Engagement and Education, 2003, Rennie, 2003, p. xii) Endorsement and inspiration from respected partner organisations (Aubusson & Steele, 2002) Collective enterprise towards a common goal (Johnson & O'Brien, 2002)	Vision / storytelling / history / continuous placement of learning within the big picture (Gordon, 2006) Butterfly learning / constant revisiting / multiple opportunities / varied presentation (Gordon, 2006, p. 100) Context: Novel real world contexts and stories / natural world / value beyond school (Fensham, 2006, p. 12) Family provided rich and stimulating environment in which to explore, generate and test ideas (Hall & Schaverien, 2001, p. 22) Visual imagery (Gordon, 2006) Experiential learning (Gordon, 2006) Problem solving (Johnson & O'Brien, 2002; Skinner, 1994; Jane, 1995) High teacher expectations (Johnson & O'Brien, 2002, p. 9,10) 'Stories of the constellations … connected families to the history and heritage of astronomy' (Gordon, 2006, p. 101) Community orientation to learning (Gordon, 2006)

In Table 2 our analytical framework for examining the literature on engagement in SET for the early years is summarised.

When the SET engagement literature is examined in relation to the zone of potential development, it is evident that pedagogy affords a focus on family as well as the school context (Hall & Schaverien, 2001). That the real world is foregrounded, the relevance for everyday life is noted (Shoring, 1999), but also historical connections are featured (Gordon, 2006). The SET vision is brought to life in the classroom (Newmann & Wehlage, 1995), that valued experiences and cultural tools are considered within the pedagogy (Robbins & Jane, 2006), and a value beyond the classroom for SET is visible (Fensham, 2006). The European Pollen project focuses on the community context, also analysed in Table 2, involving the whole community including children, teachers, parents and scientist" in an attempt to bring "science closer to society through schooling." (http://www.pollen-europa.net/?page=y%2BtfLHlZSts%3D). In this zone young children are not expected to know the SET concepts, but rather, they are exposed to SET in some way – as something meaningful and valued within our Society. These pedagogical-potential learning features are focussed to the future, or as Vygotsky (1987) has argued oriented towards tomorrow.

In considering the close relations between the child and the teacher within classrooms and centres, we note that the engagement literature can also be framed in relation to the zone of proximal development. That is, when the social situation supports and validates SET (Hall & Schaverien, 2001), when the child's social context is featured in the learning situation (Pugh, 2004; Johnson & O'Brien, 2002), and when there is a real connectedness with significant others (QSRLS, 2000) and when there is collective enterprise towards a common goal (Johnson & O'Brien, 2002). When children's interests are recognised (Hall & Schaverien, 2001), when teamwork is featured (Woolnough, 2000; Nobel, 2001), and when there is integration of science learning across the curriculum and between school and out of school contexts (Hackling & Prain, 2005; Science Engagement and Education, 2003; Rennie, 2003). Importantly, when the SET taught is endorsed by respected partner organizations and inspiration is provided by them (Aubusson & Steele, 2002), high levels of engagement are noted. Community involvement (Gordon, 2006) is also an important feature of SET engagement, and also teacher modelling of passion for the content has been shown to be important (Pugh & Girod 2007). The Engineering is Elementary program developed by the Museum of Boston in the US has been shown to have some success in engaging young children meaningfully in engineering and technology (Yocom de Romera, Slater & DeCristofano, 2006), particularly children with special needs. Important elements identified by Yocom de Romera et al. (2006) can also be seen in our analysis in Table 2. They include the use of everyday objects, which caused the children to "begin looking at materials in new ways" (p. 35), acquisition of a technol-

ogy and engineering vocabulary which led to children feeling "empowered by these additions to their vocabulary" (p. 35) Foregrounding utilizing picture books created a sense of anticipation and elicited prior knowledge and experience which was found to be particularly useful in engaging the children. The use of "realia: real objects that students could see and touch" (p. 35) was an important aspect of understanding materials for the children of non-English speaking backgrounds and "the design challenge itself was introduced in the context of a problem in the children's real world that they could relate to- rabbits had invaded the fourth-graders' vegetable garden and there was clearly a need for a wall" (Yocom de Romera et al., 2006 in Fleer, March & Gunstone, 2006, p. 54).

Notwithstanding the successes embedded in such programs, as has been shown in this paper, very little theoretical and pedagogical work has been directed to SET engagement for children in their early years. In addition, the traditional developmental theories guiding early childhood teachers and curriculum developers have been shown to be totally inadequate for taking account of the available research literature. The zone of proximal development foregrounds those features of engagement that are undertaken between the child and another teaching and learning partner. This collaboration can be located within the classroom or in out of school settings, or in collaborations between centres/schools and the community/family.

Finally, engagement in SET can also be viewed in relation to the child's actual level of development. We note that a child's transformation of his or her relationship with the world and their propensity to apply knowledge occurs through successful engagement in SET (Pugh, 2004; Johnson & O'Brien, 2002; Newman & Wehlage, 1995). Personal meaning, identity and viewing self as being connected to SET are also attributes noted in the literature of an engaged student (Skinner, 1994; Pugh, 2004; Rudduck et al., 1996 in Johnson & O'Brien, 2002; Zahorik, 1996 in Pugh, 2004). An aesthetic perspective is evident when children are engaged in SET (Girod, Rau & Schepige, 2003). Engagement has been shown to occur when ownership of learning and "student voice" features within learning contexts (Johnson & O'Brien, 2002; Jane, 1995; Logan & Skamp, 2008; Woolnough, 2000). The engagement literature also shows that intellectual challenge (Johnson & O'Brien, 2002; QSRLS, 2000; Aubusson & Steele, 2002), recognition of difference (QSRLS, 2000), elaborate expressions of understanding (Newmann & Wehlage, 1995) and goal oriented behaviour (Pugh, 2006) are evident and engagement is has been noted as occurring on a continuum (Wehlage, 1989 in Johnson & O'Brien, 2002) for individual children who are already engaged in SET. In the zone of actual development, the child is engaged.

In this section it was shown that when a cultural-historical analysis of the engagement literature was undertaken, that it was possible to include a broader range of literature on engagement. A more dynamic and expansive view of engagement was pos-

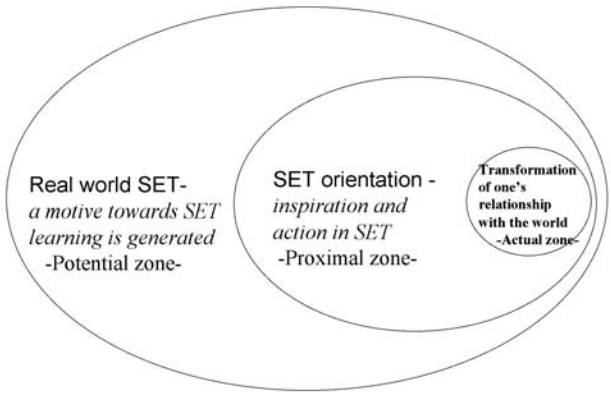
sible. In the next section we discuss this literature analysis and theorisation in relation to engagement in early childhood SET.

Conclusion: A Cultural-Historical Theory of Engagement in Early Childhood SET

A traditional developmental view of teaching and learning in early childhood has tended to ignore the value of SET for young learners (Fleer & Robbins, 2003; Fleer & March, 2008; Metz, 1995; Robbins, 2005). The limited pool of research directed to this area (see Kallery & Psillos, 2004; Lowe & Fisher, 2000; Tytler & Peterson, 2003) has made it difficult for teachers to know how to productively and meaningfully engage young children in SET. Only in recent times have we progressively seen more research devoted to this area (e.g. Christidou & Hatzinikita, 2005; Cumming, 2003; Mawson, 2003; Pantidos, 2008; Ravanis, Koliopoulos & Boilevin, 2008; Rennie, 2003) and more resources designed specifically for young children to support SET (e.g. Wings of Discovery, Canada, La Main à la Pâte, France, Pollen 'Seed City' project, Europe, Tool Kit for Early Childhood Science Education, US, The Design and Making Centre, UK and Engineering is Elementary, US).

In this paper it was also shown that most of the research findings on engagement could not be categorised into the developmental categories of social/emotional development, cognitive development or physical behavioural development. Thus making it difficult for early childhood teachers and curriculum developers to actively work with research findings related to engagement in SET. However, a cultural-historical analysis was much more fruitful, suggesting that this theory can support the early childhood field to work with SET in a more engaged way—both for children and for teachers.

Figure 2



A cultural-historical model of SET engagement

If we accept this argument, then it is possible to use the concepts of motives, imitation and the zones of actual, proximal and potential development for building a theory of SET engagement for early childhood education. In Figure 2 below, a model is presented which brings together the findings from the literature shown in Table 2 and reviewed in the first part of this paper.

Real world SET

In the first elliptical circle we see a disproportionate space devoted to a potential zone for SET. That is, we would expect that children would be exposed to many SET experiences within their social world. In an early childhood context, this would mean saturating the environment with SET. However, this would mean SET experiences that represented the children's real world. Rather than considering box construction, block play, construction kits such as Lego, a computer, and a science table with items from nature, to represent the children's SET experience, the engagement literature suggests that the real world of children's experiences should be brought into the preschool centre. Do children have access to and use digital cameras, the photocopier, and have design software on the computer, or visit industry and learn about, and gather different types of materials, tools, and processes? Do the staff or parents in the centre model to the children using real tools and do real scientific, technological and engineering activities in the centre (e.g. test the acidity of the soil, examine the compost for decomposition), or in the community (visit industry, do field work with specialists)? Is the centre filled with specimens, tools for examining and recording the outdoor insect life, and steeped in stories and historical accounts of technological and scientific inventions, as the engagement literature suggests is needed.

In the model of engagement in early childhood SET, staff, parents and community actively model to children real world SET, and have accessible (bought, borrowed, or through visitation program in the community) real SET tools. Adults do SET in the centre. The centre has SET as a visible dimension to the program. SET in society is shown in the centre as something to be valued. But it is not decontextualised, it is SET in action for a real life purpose, such as the example above of building a wall to keep the rabbits out, (Yocom de Romera et al., 2006). In this engagement model, the preschool context generates *a motive towards SET learning*.

SET orientation and inspiration

The second elliptical circle is smaller in size, as it is an active and focused space. In the SET engagement literature, the role of the adult was emphasised as important for orienting children to SET. The adult creates a learning space that the child feels they belong in—a member of a SET learning community. Where interest in SET was generated through real world participation (Zone of potential development), this curiosity is satisfied through supported/collaborative experimentation, construction, designing, and investigation. Children work together with community scientists, engineers, technologists, and their teachers and families, to do SET, as emphasised in the European Pollen project. The adult's role in orienting children to the SET that surrounds them is very important: teachers must be, and be seen to be, confident and passionate about the content they are teaching. Making conscious to them the wonders associated with the

everydayness of living in their world, provides children with different ways of thinking about and acting in their environment. That is, the child has a changing relationship to reality, and this constitutes a cultural-historical view of development. The social situation supports and validates SET for the children. There is a connectedness with the learning organised by the teacher, a sense of teamwork or collaboration with others in SET, and the adults inspire and endorse SET for children. The focus is on supported learning through a range of pedagogical features which make visible or conscious to children curious elements of SET for adult supported investigating, construction work or designing. That is, *SET orientation, inspiration and action* are generated in preschools.

Transformation of one's relationship with the world

The actual zone of development represents what an engaged learner actually can do. The engagement literature suggests that an engaged child shows a propensity to apply knowledge beyond the classroom, has developed personal meaning of SET, demonstrates an aesthetic perspective, connects new knowledge to prior learning, shows they are intellectually inspired by SET challenges they meet, and are goal oriented. The child is alert to SET possibilities and opportunities. In summary, the child has a *transformed relationship to the real world and is alert to SET possibilities*.

A cultural-historical model of SET engagement foregrounds the dialectical relations between the child's material world and their psychological functioning. Engagement when theorised as motives generated through activity that is socially primed for SET possibilities, places great responsibility upon teachers because engagement is socially and culturally constructed within the early childhood program. That is, the teacher in the preschool context, generates a motive towards SET learning, gives inspiration, supports action and orients children to SET, and through this, children's relationship to the real world is transformed, and thereafter they are alert to SET possibilities. The model shown in Figure 2 exemplifies this cultural-historical theorisation of SET engagement, and the new role this affords for preschool teachers.

SET engagement does not begin at school, it begins from the moment the child enters the world. The engagement model is one way of theorising how early childhood teachers can conceptualise and support engagement in SET for young children. Clearly, this is an important area in need of further research and theorisation.

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