YOUNG CHILDREN'S EMERGENT SELF-REGULATED LEARNING SKILLS IN A PRIMARY SCIENCE INVESTIGATION

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ABSTRACT

Research on self-regulation of children's learning is seldom set at lower primary school levels. Indeed, there are conflicting views about the ability of young children to self-regulate their learning. We have found that, with appropriate teacher support, and the use of purposefully constructed learning materials, Year 1, 2, and 3 children were able to demonstrate what we consider to be foundational aspects of self-regulated learning (SRL). This paper reports on an exploratory study of a sequence of four lessons in one Year 1–3 class.

INTRODUCTION

There has been considerable interest in self-regulated learning in recent years (see, for example, the collected essays in Zimmerman & Schunk, 2001). Learning to be self-regulating is seen as an essential skill for "life-long learning", which in turn is seen to be an important disposition for living in a post-modern "knowledge society" (Gilbert, in press). However, what this term actually means seems open to a number of interpretations. Zimmerman (2001) defines self-regulation as the degree to which students are "metacognitively, motivationally, and behaviourally active participants in their own learning processes" (p. 5). In a meta-analysis of seven different theoretical orientations to self-regulation, he suggests that differences of focus and interpretation are related to the three clusters of factors: students' purposeful use of specific learning strategies; students' monitoring of the effectiveness of their learning; and their awareness of certain motivational dimensions of their learning.

Taking a different approach, a recent meta-analysis of student engagement in schooling identifies significant overlaps between the literature on "cognitive engagement" and that on self-regulation (Fredricks, Blumenfeld, & Paris, 2004). While these researchers differentiate between cognitive, emotional (motivational), and behavioural engagement, they also suggest that more studies should explore these in a multidimensional manner. Their analysis identifies gaps in current research knowledge about young school-age children's ability to self-regulate their learning, and in particular a lack of observational studies. They found "a dearth of self-report measures for younger children" (p. 68). One reason they suggest for these gaps is that it may be seen as developmentally inappropriate to look for self-regulation in young children because metacognitive abilities are known to increase with age. The exploratory study reported here discusses our findings of emergent self-regulation in a class of Year 1, 2, and 3 children, who were supported to develop these skills in science investigations carried out over four lessons on successive days.

Fredricks et al. (2004) identify a range of specific factors as *antecedents* to cognitive engagement/self-regulation. Those of relevance to our study include teacher actions in creating a socially supportive *and* intellectually challenging environment, and in creating conditions for positive peer interactions in which students "actively discuss ideas, debate points of view, and critique each other's work" (p. 77). We think there is an alignment here with Zimmerman's (2001) *social cognitive* theoretical orientation which focuses on "interdependent contributions of personal, behavioural and environmental influences" (p. 19) on students' ability and willingness to self-regulate. Our study explores the ways in which the environment created by the teacher supported the children both academically and socially in a manner that allowed them to develop what we will identify as observable, fledgling skills of self-regulation. Fredricks et al. also identify the *characteristics of a task* as an *antecedent* to the development of self-regulation. Of particular interest for our study are the findings from one piece of elementary school research in primary science. Drawing from the work of Blumenfeld and Meece (1988), they cite "complex hands-on tasks" combined with instructional support from a teacher who "presses students for understanding" (Fredricks et al., 2004, p. 79). Characteristics of mathematics tasks found to be effective in promoting cognitive engagement included "novel tasks that have personal meaning" (p. 79).

What might effective tasks that display these types of characteristics look like for children at the very beginning of their schooling? We drew on findings of earlier research in which we had investigated the development of children's science investigative skills (Hipkins & Kenneally, 2003) to design the tasks we used in the investigation reported here. This paper then, is an exploratory study of the types of emergent self-regulation that might be recognised and observed in children who are just beginning their school learning journeys. By combining detailed planning shared with an expert teacher, relatively unstructured observations, and the use of existing theory to provide a framework for analysis, we propose a cluster of factors that we think represent emergent self-regulation skills in the context of science investigations.

INVESTIGATING CHILDREN'S INVESTIGATION SKILLS

In this study we worked with an experienced teacher of beginning school children. This teacher had shown a strong interest in teaching science and we had worked with her before. Because the school was nearby, we were able to visit daily during the investigative period. Before beginning the actual case study, we observed a small group of children, chosen by the teacher, who were working independently on a science investigation. We wanted to find out what self-regulated learning skills the children used spontaneously.

The scoping phase

In the scoping phase we observed four 6- and 7-year-old students (two girls and two boys) working on a science investigation set by us. One boy was identified as being particularly interested in science, and all had been involved in using materials generated by the NEMP Probe study the previous year (Hipkins & Kenneally, 2003). All members of the group were receiving extra tuition to improve their writing skills. The concept that underpinned the investigation we had planned was that internal frictional forces influence the distance cans containing different substances will roll. This was deliberately chosen for its cognitive challenge. We knew that "fair testing" of cars rolling down a ramp was something the children had been exposed to in their first year at school, but cans of the same size, one containing liquid contents and one containing solid contents would, we thought, hold some novel surprises. The students were provided with some instructions, a worksheet, and a range of materials, but otherwise there was little intervention from us.

What we observed

The four students were very motivated to begin the practical investigation and maintained their busyness for about 40 minutes, but showed little inclination to think about the concepts involved. There was little sense of sustained exploration of a single idea – rather, they jumped from one idea to another. Ostensibly they worked as a group but, in fact, apart from co-operating to perform tasks such as measuring, they paid little heed to each other's ideas. Nor did they draw on any of their previous experiences. We could perhaps describe this as "undisciplined motivation", which has more to do with playing with the context (emotional and behavioural engagement), rather than a motivation to engage at a cognitive level. Fredricks et al. (2004) suggest motivation at a cognitive level is a factor in becoming self-regulating.

In summary, what we learnt was that these very young children were very motivated to investigate, but:

- they did not connect the action of investigating to the focus concept;
- they were easily distracted by the "noise" of a complex science concept;
- they did not listen to or consider others' ideas;
- they were inconsistent with keeping things fair; and
- their conclusions were influenced by their predictions more than their observations.

There was, in fact, little evidence of any self-regulated learning behaviours.

The exploratory phase

The scoping phase reinforced for us the importance of carefully crafting a series of lessons to provide the antecedents for developing self-regulated learning skills. The teacher had already established an environment where student interactions and peer support were encouraged. For the second part of the investigation we worked with the classroom teacher to develop a series of four lessons, using the same focus as the scoping session, but providing support to develop an understanding of both the concept and the necessary investigation skills. The class included the four students from the initial session, and ranged from 5-year-olds (including one who started school the same day as we began the series of lessons) to 7-year-olds. The teacher then taught the four sessions with the students over four consecutive days, while we observed. When working independently, the students were in mixed age groups of three. The focus of this part of our research was to see what impact teacher actions and structured materials had on the students' ability to self-regulate.

The concept under investigation was frictional forces in the context of rolling. We used marbles and balls rolling on different surfaces, then matched pairs of transparent jars, one containing cotton wool and the other water to explore internal friction, and finally cans of soup and cat meat to compare which rolled further.

We drew on a NEMP Probe study (Hipkins & Kenneally, 2003) for teaching investigative strategies, because these had already been shown to be successful in supporting students to develop skills in fair testing by:

- reducing demand on children's memories by displaying more of the overall investigation simultaneously;
- making data recording quick and easy, so repeats are manageable and engaging;
- making comparisons obvious; and
- making effects of "unfair" management of variables more immediately obvious.

These investigative strategies included using coloured sticky dots to record where the marbles and cans stopped moving, and paired cards and sets of gear to support students setting up their fair test.

The Predict, Observe, Explain (POE) strategy (Palmer, 1995) is another well-researched strategy that we used to encourage students to talk about what they were thinking. We also included a concept cartoon, a strategy developed and extensively researched in the United Kingdom (Keogh & Naylor, 1999) to support children's thinking about science concepts.

Because the classroom had only one floor surface, we built sturdy ramps, half of which were carpetted, and the other half left as smooth wood. We also made a recording book for each group, which contained prompt questions designed to encourage students to think about their observations.

Briefly, the structure for the four lessons was:

- Session 1: free exploration. The students were given marbles and balls and asked to investigate how different surfaces affect rolling. Before they began, the students suggested different surfaces they could investigate, and at the end they discussed what they had found out.
- Session 2: modelling. The teacher and class worked together investigating the students' ideas from the previous day. The POE strategy was used to elicit students' predictions about which would roll further, and their reasons for making this prediction. The teacher modelled thinking out loud about principles of fair testing, and introduced a strategy for measuring.
- Session 3: structured investigation. The focus for this investigation was internal frictional forces. An initial activity looked at how water inside a dirty jar could clean the jar's internal surface when shaken. They then investigated whether a jar of cotton wool or a jar of water rolled further. To help them think about how they would set up their investigation, they initially selected from three cards of paired ramp settings.
- Session 4: independent investigation. The students investigated whether a can of cat food or a can of soup would roll further. Discussing a concept cartoon about the science concept supported their predictions, but their investigations were carried out independently.

For each session class discussion time was deliberately planned for both before and/or after the practical activities. Harlen (2004) cites Barnes (1976), in describing the importance of speech as reflection, and argues that dialogic talk which is child centred "enables important goals of learning, for understanding and for learning how to learn, to be achieved" (p. 19). For most sessions there was some recording expected. Learning intentions were made clear for each session, and, importantly, the teacher kept referring back to these. Materials and strategies simplified the number of decisions students had to make about fair testing, and supported discussion in their groups. We designed questions the teacher could use to keep the discussion focused.

What we observed

In contrast to the scoping session we observed many instances of emergent aspects of self-regulated learning. These included self-efficacy, awareness of learning strategies, self-monitoring of fair testing strategies, managing distractions, drawing on previous experience, and sustaining learning. We next outline examples of how these behaviours were manifested in the 5- to 7-year-olds in this class.

Motivation and self-efficacy

As in the scoping group, all of the class was engaged at a behavioural and motivational level. Even William, the child who had just started school, while interacting very little with his group and not at all during whole class discussions, was observed to quietly try rolling different objects down a ramp. However, in contrast to the scoping group, many of the class also began showing some instances of "minds on" behaviour. This was most often obvious during teacher-led discussion after the practical activities, or when the prepared materials prompted them to think in this way.

An interesting change in behaviour was observed in Jarred, a student from the scoping group. During the scoping session, he was the least engaged of the four students, but from then on he apparently saw himself as a bit of an expert. Every day he would rush to meet us, demand to know what we were going to be doing, what we had brought with us, and, if he got a chance, look at and try out the support material. For Dewey, and other educators who have recently built on his work, *anticipation* is seen as an important disposition to foster when motivating children to learn in ways that are personally meaningful for them (Girod & Wong, 2002). Jarred took responsibility for making sure that he was ready for the focus of the day's learning. In contrast to the scoping session he was focused throughout all four teaching sessions, contributed to all discussions, and attempted to use his observations to explain his ideas about frictional forces.

Awareness of learning strategies

Children used learning strategies that had recently been modelled by the teacher. Older children, as leaders of their group, were likely to emulate the teacher. One girl in particular, Danielle, used the structured material to "be the teacher". She used the card pairs to coach the younger group members in making fair decisions, and the concept cartoon to teach her group to consider what they thought about each statement. She also reminded her group to "remember what we found out yesterday". She was unable, though, to respond to answers she knew were incorrect, and, once she began writing on behalf of the group in the recording book, she no longer asked questions or included them in any way.

Managing distractions

Maintaining a conceptual focus

In the initial scoping session, the challenging concept and the complexity of the context not unexpectedly left the four students unable to decide what they needed to focus on. While they had lots of ideas, they either did not sustain any investigation long enough to collect any worthwhile evidence, or unwittingly rigged their results to fit what they predicted would happen. When planning the four lessons, we began with a relatively simple concept, and unstructured exploration, and gradually introduced more complex science ideas and strategies for fair testing. The level of complexity of thinking that some of the children were able to engage with when supported in this way surprised us. One girl, Bea, when thinking about whether the can of cat food or soup would roll further, said, "The cat food is like the cotton wool and the soup is like the water", and identified which was solid and which liquid. She then clearly used the analogy to correctly predict that the can of cat's meat would roll further. Brad, who had been at school for only three weeks, had an intuitive grasp of the interaction of variables. He discussed how both the surface on which the object was rolling and the surface of the object itself could affect the rolling distance, and then also considered the size and weight of the object.

Sharing their theories with the class during a teacher-led discussion was an important strategy for encouraging children to consider those complexities, and to "think about their thinking". The role of the teacher in leading these discussions was a crucial factor in getting students to engage at both a cognitive and a metacognitive level, as was the willingness of children to think aloud (not all of them did).

Managing physical distractions

A class of children rolling objects and sticking dots on the floor created a noisy and challenging environment in which to investigate. Gradually over the four teaching sessions, the students realised that they needed to create a space where their investigation was not affected by the actions of other groups. By the fourth day (and some before then), groups were thinking about where they would set up their investigation so the patterns of dots did not merge with another group’s pattern, and where their rolling objects would not hit others’ objects or the wall. Most children were able to attend to their own investigation and not be distracted by what was happening near them.

Self-monitoring of fair testing strategies

The structured materials and the teacher's modelling provided the students with support that allowed them to manage, for the most part, the variables of the investigation. Compared to the scoping group, when working independently of the teacher the students spent more time in discussion about the management of variables and keeping their investigations "fair". For example, the scoping group totally disregarded the fact that cans hit the wall when considering which rolled further, yet one girl from this original group commented during the first teaching session, "They always hit something", and reorganised the group's equipment until this problem was overcome.

One boy displayed a clear understanding of variables. The students were asked to select from a set of cards the correct way to organise their equipment, and then replicate it. The chosen card showed both ramps with carpet, but he chose two smooth ramps. When asked about this, he conceded that this was different from the card, and then said, "But it doesn't matter because they are still both the same."

Drawing on previous experience

During the scoping session it was difficult to know whether students were using their past experiences because they did not make any reference to these when talking amongst themselves. We do know that they didn't use the dot strategy for measuring distance, even though the dots were included in the equipment we gave them. We also knew they had been taught this strategy the previous year, and had not experienced it since.

In the second teaching session the teacher modelled the use of coloured sticky dots to record the distance rolled. The visual pattern created when using this strategy makes it possible to hold the variability of individual test runs in children’s memory space whilst carrying out repeat runs in rapid succession. This strategy was enthusiastically picked up by the children the next day. A 5-year-old from one group was heard to announce that "We need to get some dots." So, in the short term, students did independently use a strategy modelled by the teacher. However, if the use of this strategy is not practised in a number of contexts over a period of time, it seems likely, based on the scoping group's actions, that they will not retain the strategy in the long term.

Class discussions provided an opportunity for children to talk about their theories and justify these in terms of previous experiences. For instance, one child talked at length about water affecting the slipperiness of marbles, and therefore that wet marbles would go further. He knew about this, he told the class, because they had done this at kindergarten. Interestingly, the teacher did not talk about the significance of variations in the data collected from individual trials, and so the creation of dot patterns became simply a fun part of the overall process. Indeed some children began to speak of individual runs as “winning” runs when the object rolled went further, as if each trial was of a separate object rather than a repeat of rolling the same object. When we subsequently discussed this observation with the teacher, she agreed that she herself was not clear about the conceptual learning that potentially underpinned the use of the dots.

Sustaining learning

We looked for evidence of children continuing to investigate their own ideas separate to the formal teaching session. Because we were only in the classroom during the teaching time, it is possible we missed examples of this occurring. However, we did observe some instances. The boy who had just started school collected some small teddy bears, and spent some time sliding them down a ramp. As this was done without any comment to anyone else, we have no way of knowing whether he was trying to find out something, or whether it was just play. A more purposeful investigation was carried out by an older boy who, towards the end of the last session, used two smooth ramps and compared the rolling of two jars of water. He then went looking for two different cans of cat food. Again, this was done alone, and he discussed neither his intentions nor what he found out with others. A more overt example was when one of the boys introduced the word “'force” during a discussion time. When the teacher asked him where he had learnt this word, he said he had seen it on the cover of the recording book and when he went home he had looked it up in the dictionary to find out what it meant. He was able to share a clear explanation of what a force was, and other children then were able to add to this. "I know something about forces. The magnet on the fridge forces the door to close."

These three examples demonstrate that at least some children in this class were sufficiently motivated to independently use learning strategies they had been taught in class to further their learning.

Managing the observational data – a framework for analysis

We originally drew up an observation schedule, but found that it restricted our thinking rather than organising it. Instead we carried out unstructured observations, using the literature about self-regulated learning as our "thinking framework" to collect interesting vignettes of observed behaviour. Retrospectively we realised that the observations demonstrated what could be better described as "foundations" for self-regulated learning.

When we looked at the observations we had collected over the four teaching sessions, they seemed to indicate that there were more instances of students taking some deliberate responsibility for their learning than we had been aware of in the busy classroom moment. We realised we needed a framework that captured the **developing** aspects of SRL. A paper written by Zimmerman and Kitsantas (1997) provided the catalyst that we needed. In their paper, a study involving high school students learning a skill, they referred to four stages to acquiring the skill. These stages are:

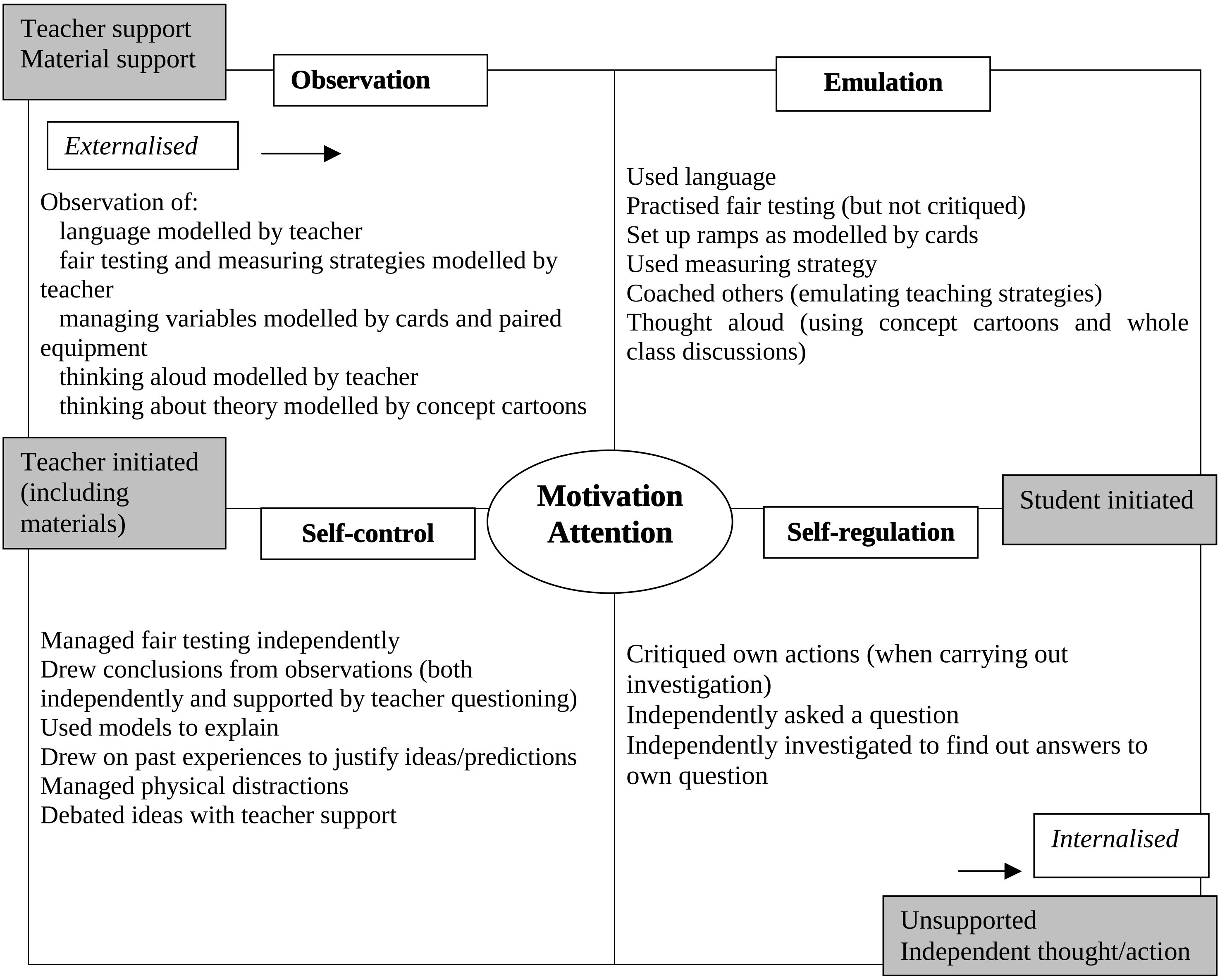
- observation, where the skill is modelled so the learner gains an "image of the skill" (Zimmerman & Kitsantas, 1997, p. 29);
- imitation, when the learner emulates the model, often receiving feedback from the teacher;
- self-control, at which stage the learner no longer has to rely directly on the model, but becomes proficient in the skill; and
- self-regulation, when the learner is able to adapt to a changing environment.

We wondered if these stages could also be applied more generally to indicate the developmental stages of moving towards self-regulation.

We began by writing on post-its all the actions that seemed to indicate some level of taking ownership of learning. Through a series of recursive stages of analysis as we rearranged the post-its, we arrived at the arrangement of ideas shown in Diagram 1. The stages we worked through were:

- Together we worked to place the "episodes" we had observed across the four sessions on a continuum that illustrated developing aspects of self-regulation. As we did this we identified a gradual progression from use of externalised to internalised learning "prompts". We also noticed a second continuum in action, related to the roles played by the teacher and students respectively. At one end of the continuum the teacher instigated the action, while, at the other end, action was instigated by the students.
- As part of our process of analysis we investigated patterns in the distribution of vignettes when we set these two continua at right angles to each other. We quickly realised that the four quadrants we had created closely approximated the four stages of self-regulation described by Zimmerman.
- Originally we had placed Teacher/Material Support in the middle at the top of the diagram, and Unsupported/Independent Thought/Action in the middle of the bottom. We repositioned these at the top left and bottom right to represent the gradual process of students taking fewer cues from both the teacher and structured material.
- It then became possible to capture the "essence" of the characteristics of each cluster of vignettes. These essences became the summary statements in each quadrant of Diagram 1.
- From the beginning of the analysis process we kept in mind the importance of motivation and attention in supporting children to engage with their learning. Zimmerman (2001) identified

these as key elements in any definition of self-regulated learning. For this reason we placed motivation and attention at the centre, to signal that a readiness to engage with learning is a prerequisite for self-regulated learning, and needs to be demonstrated at all four stages.



Examples of emergent self-regulating behaviours during teaching sessions

Our completed diagram demonstrates that, in contrast to the scoping group, we observed many examples of emergent self-regulated behaviours during the four teaching sessions. (We did attempt putting actions from the scoping group into the diagram, but not one of them fitted the descriptions.) The diagram also illustrates the relationship between the support provided by the teacher and the learning materials, and developing student autonomy. When the teacher was modelling, she was central to the action, and the students mostly observed and emulated. However, as the teacher handed more control over their investigations to the students we saw more examples of self-control (although the structured materials did support them in their decision making). The classroom environment, in which students were actively encouraged to work together and share their ideas, would also seem to provide support integral to the development of emergent self-regulation skills.

We noticed something else from our diagram, that it is not till the last stage, self-regulated learning, that the "self" emerges from the social interaction of the group. The three examples we observed were all undertaken independent of the teacher or the group they were working with. We concur with Zimmerman and Kitsantas (1997) that social interactions are an important factor in students learning the emergent skills. However, for children to take that last step to become self-regulating, they need to have set themselves a **personal** goal. Zimmerman (2002) describes this as "personal initiative, perseverance, and adoptive skill" (p. 70).

SO WHAT DOES THIS MEAN FOR TEACHERS?

Much of the literature about SRL claims that young children cannot self-regulate. Zimmerman and Kinsantas' earlier work was helpful for us when identifying that, like most learning, even young children can, with support, begin taking responsibility for their own learning. While it cannot be claimed that these 5-, 6-, and 7- year-olds were totally and independently self-regulating, many of them certainly took some responsibility for their learning to varying degrees of sophistication and consistency.

We found instances of emergent SRL behaviour when the teacher provided a structure for students to learn and practise these behaviours. Actions that supported students were:

- pre-activity class discussion;
- post-activity class discussion;
- making learning focus clear, and referring back to this;
- modelling thinking out loud;
- teacher questioning;
- teacher introducing and modelling the use of appropriate language;
- visual prompts; for example, cards to select which set of variables would be fair;
- simplifying management of variables; for example, by providing pre-prepared equipment; and
- encouraging cognitive engagement by presenting alternative possibilities, using such strategies as concept cartoons.

As the series of lessons progressed, and as the teacher handed over more control to the students, students demonstrated more aspects of self-control and, to a lesser extent, self-regulation. Teacher action seemed to be an important factor. The teacher in this class was very skilful at modelling and questioning the students, so they were practising thinking about aspects of their investigation. Over the four days they were able to adapt what they had been doing with her support to working in independent groups carrying out a more cognitively challenging investigation.

Two of the strategies we planned appeared to be unhelpful in encouraging children of this age to be self-regulating. One was asking the groups to reflect on their ideas in writing. The act of writing took so much effort, even for the 7-year-olds, that it overrode their ability to reflect on their learning, or even to engage with others in the group. Students were more concerned with completing the task, the spelling of the words, and their handwriting. This is in contrast to other studies of older students that we have read, which indicate that writing does help students to reflect on their learning.

The second ineffective strategy was asking the students to reflect on their learning by choosing from a continuum of happy and sad faces. They were given a series of statements and asked whether they had used the described activity, for example, "We thought about the water in the jar", when they were thinking about the cans of cat food and soup. The younger children in the group did not engage in the task at all, and the older ones simply ticked all the smiliest faces. However, when they were asked to **talk** about the statements, they were able to share some quite sophisticated thinking about which learning episodes they had used effectively.

To summarise, we believe that the teacher in our study played a crucial role in developing the foundations that will lead to the development of self-regulated learning. She modelled elements of self-regulation to the students, and she provided the social environment in which students could support one another when practising copying her behaviours. She kept returning to the purpose of the investigations to encourage engagement at a cognitive level, and she knew when to hand over to the children so they could start making decisions for themselves.

CONCLUSION

So what do we think self-regulated learning in the context of science investigations looks like in the first years of schooling?

Firstly, we would see a role model – primarily the teacher, but sometimes another student – who demonstrates strategies to use, introduces the language that enables students to discuss their ideas, and talks out loud about their thinking. Further, students will be interacting with the model, and identifying and debating the key elements of the strategies in order to prepare to replicate these strategies.

Secondly, students will be practising "doing what the teacher does". Initially, this will be within a structured task, initiated by or in partnership with the teacher, and then, as children learn the processes, they will apply these in another context. Some children may begin using these processes independently to investigate questions they are interested in answering themselves.

Students will be sharing their ideas. They will be able to link these with things they have observed and/or experiences they have had. They will know why they are carrying out an investigation, and will be able to use their investigations to inform personal theories. Some children may not be willing to talk about their ideas, but their actions may indicate that they are thinking; for example, extending a teacher-instigated investigation without comment.

Students will manage physical distractions, and begin to critique their management of variables, with either teacher support or the support of structured materials.

Most of their emergent skills will be supported by social interactions with others. At times, some children may step out of scenarios directed by the group to follow up on things they want to learn about, and use appropriate strategies to do so.

Self-regulated learning skills, even at emergent levels, are likely to be applied haphazardly, and are influenced by both the learning context and the environment.

To conclude, our small study provides some evidence that, even at a young age, students are able to begin developing emergent skills of self-regulation in the context of science investigations. We found that teacher action, the structure of lessons, structured materials, and social interactions were all influential in prompting students to monitor their skills in fair testing and to engage cognitively with the science concept under investigation.

REFERENCES

Blumenfeld, P., & Meece, J. (1988). Task factors, teacher behaviour, and students' involvement and use of learning strategies in science. *Elementary School Journal, 88*, 235–250.

Fredricks, J., Blumenfeld, P., & Paris, A. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research, 74* (1), 59–109.

Gilbert, J. (in press). *Catching the knowledge wave? The knowledge society and the future of education in New Zealand.* Wellington: NZCER Press.

Girod, M., & Wong, D. (2002). An aesthetic (Deweyan) perspective on science learning: Case studies of three fourth graders. *The Elementary School Journal, 102* (3), 219–224.

Harlen, W. (2004). Talking and writing: Have we got the balance right? *Primary Science Review, 8*, 17–19.

Hipkins, R., & Kenneally, N. (2003). *Using NEMP to inform the teaching of scientifc skills*. Wellington: New Zealand Council for Educational Research.

Keogh, B., & Naylor, S. (1999). Concept Cartoons, teaching and learning in science: An evaluation. *International Journal of Science Education, 21* (4), 431–446.

Palmer, D. (1995). The POE in the primary school: An evaluation. *Research in Science Education, 25* (3), 323–332.

Zimmerman, B. (2001). Theories of self-regulated learning and academic achievement: An overview and analysis. In D. Schunk (Ed.), *Self-regulated learning and academic achievement: theoretical perspectives (2nd edition)*. New Jersey: Lawrence Erlbaum Associates.

Zimmerman, B. (2002). Becoming a self-regulated learner: An overview. *Theory into Practice, 41* (2), 64–70.

Zimmerman, B., & Schunk, D. (2001). *Self-regulated learning and academic achievement: theoretical perspectives (2nd edition)*. New Jersey: Lawrence Erlbaum Associates.

Zimmermann, B., & Kitsantas, A. (1997). Developmental phases in self-regulation: Shifting from process to outcome goals. *Journal of Educational Psychology, 89* (1), 29–36.