

Identifying a Taxonomy for the Emergence of Metacognition in Young Learners

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Abstract

This paper details a study of upper primary (elementary) students' thinking as they go about solving a problem, presented in an innovative computer program. Student responses to a metacognitive probe question reveal levels of responses that can be classified because of their shared quality. A thematic analysis was conducted with the initial classifications being based on theoretically derived categories from the metacognitive literature. These classifications were subsequently ordered into a taxonomy of hierarchical progression towards metacognition. Results in this instance indicated that less than 20% of these upper primary students showed they were capable of operating at a metacognitive level.

Keywords: metacognition, metacognitive development, taxonomy of metacognitive development, problem solving.

1. Introduction

An important goal of education is to develop and promote effective learning. Research has acknowledged that metacognition is a powerful predictor of learning (Wang, Haertel, & Walberg, 1990; Veenman & Elshout, 1999). More effective learning outcomes are related to a learner's ability to be metacognitive. "Metacognitive skilfulness, rather than intellectual

ability appears essential for learning when learners operate at the boundary of their knowledge” (Prins, Veenman, & Elshout, 2006, p. 374).

Early studies of metacognition (Flavell, 1979; Brown, 1978) referred to the construct of metacognition as the stable and stable knowledge the learner possesses about his or her cognitive processes (Palincsar & Brown, 1987). Flavell (1979) identified metacognition as knowledge about variables related to a person, task or strategy. Metacognition involves a learner’s awareness of his or her motives and abilities and the demands of the learning task, along with the degree of control and regulation the learner has over his or her cognitive activities. Later conceptualisations of metacognition (Baker & Brown, 1984) introduced the notion of self-regulation through mechanisms such as checking the outcome, planning, monitoring effectiveness, testing, revising, and evaluation strategies. Hence, metacognitive learners understand, analyse and control cognitive process (Klassen, Krawchuk & Rajani, 2008; Tarricone, 2011), that is, they control the processes of thinking about their thinking.

Metacognition involves what the learner knows about his or her cognitive processes (metacognitive knowledge), along with the ability to regulate those processes (metacognitive skills). Metacognitive knowledge involves reflection on the relationship between prior and new knowledge, and the beliefs that the learner has about their own nature and their own cognitive abilities (Tarricone, 2011). Metacognitive skills are those “self-regulated activities actually being performed by the learner in order to structure the problem-solving process” (Prins, Veenman & Elshout, 2006, p. 375).

The emergence of metacognitive knowledge and metacognitive skills has been related to age. Metacognitive knowledge appears to develop after 5 years of age and continues during one’s life span (Alexander, Carr, & Schwanenflugel, 1995). Metacognitive skills become apparent at about 8 to 10 years of age (Veenman, Van Hout-Wolters, & Afferbach, 2006) and subsequently continue to develop.

Research related to the developmental aspect of metacognition has been linked to the extensive and analytic work of Piaget (Fox & Riconscente, 2008; Veenman & Spaans, 2005). Flavell’s (1992) work on metacognition suggests links to Piaget’s stages of cognitive development. Piaget’s concrete operational stage (7yrs – 11yrs) describes learners who have the ability to develop logical thought about an object. It is followed by the formal operational stage (11yrs – 16yrs) where the learner is able think about his or her own thoughts (Inhelder & Piaget, 1958) thus presupposing metacognition. Flavell (1985) suggested developmental trends are evident in the emergence of metacognition in childhood and adolescence.

What is lacking in the literature on metacognition is an examination of how metacognitive thought develops and how that development can be recognised. This study seeks to define and describe examples of particular classifications of metacognitive development and as well to order those classifications into a taxonomy to illustrate the emergence of metacognition in young learners. Such information would assist teachers in their understanding of students’ metacognitive development and also enhance aspects of the curriculum that supports that development.

2. Teaching metacognition

Schools in Victoria (Australia) plan and deliver curriculum that is defined by a curriculum and standards framework (AusVELS). This framework describes what students should know and be able to do at various stages during their schooling. There was extensive literature in the 1980s and 1990s advocating that attention to metacognition should be part of the school curriculum (Costa, 1981; Baird, 1986; McGuinness, 1999; Gunstone & Northfield, 1994). This has been incorporated in the AusVELS documentation and has resulted in changes to curriculum. Most school systems have implemented a curriculum for thinking as part of the general school curriculum, one that incorporates attention to metacognition.

Research into the links between metacognition and effective learning has implications for teachers in the way they develop their teaching approaches. Downing, Kwong, Chan, Lam and Downing (2009) argue that metacognition and self reflection must be first developed as a skill before it can be used as consciously controlled strategies. Students can learn to articulate what they know about their own cognitive processes and develop the ability to regulate those processes for more effective learning. Teachers must also be aware of the relationship between metacognition, motivation and student self-efficacy (Zimmerman & Schunk, 2001; Efklides, 2011). Developing metacognitive skills requires the learner to be motivated and to believe that they are able to do so (Winne & Nesbit, 2009).

The curriculum guidelines for all schools in Victoria (Australia), detail standards for assessing and reporting on student achievement for ‘Thinking Processes’. According to the AusVELS (Australian Curriculum in Victoria) website -

“An explicit focus on thinking and the teaching of thinking skills aims to develop students' thinking to a qualitatively higher level. Students need to be supported to move beyond the lower-order cognitive skills of recall and comprehension to the development of higher-order processes required for creative problem solving, decision making and conceptualising. In addition, they need to develop the capacity for metacognition - the capacity to reflect on and manage their own thinking” (AusVELS).

Included in the guidelines are a series of thinking tools to be taught to students that align with the learning focus for this area.

The foundations for reporting on student achievement in ‘Reflection, Evaluation and Metacognition’ are introduced at Year 3 and Year 4. Here the learning goals are achieved through learners being able to identify strategies to organise ideas, use appropriate language to explain thinking, express points of view and justify changes in thinking. At Year 5 and Year 6 the goals are achieved through learners being able to use a range of thinking tools and strategies in a variety of contexts, reflect on their thinking and thinking processes, evaluate and justify their use of thinking strategies.

While the curriculum guidelines give teachers an awareness for the need to introduce activities to develop their students’ metacognitive thinking and to report on that development, there appears little information to assist teachers to recognise how that development occurs

and the processes that a student might go through in order to meet the identified learning goals. As teachers present their students with problems to solve it would be helpful for those teachers if there was information available in order to assess the progress their students are making toward being metacognitive, that is toward being effective problem solvers.

3. The Study

In order to examine how metacognitive thought develops, this study investigates what learners report about their thinking as they go about problem solving. The study also examines learners' developing ability in effective problem solving and details a possible taxonomy for the emergence of metacognition in learners.

The study reported here was part of a much wider research collaboration that investigated students' developing capacity to apply thinking skills to novel problems and to identify how a range of self-regulatory processes, including metacognitive and motivational components, contribute to students' performance (M. Ainley & S. Ainley, 2006). Ethical approval to conduct the larger study was obtained from the University of Melbourne, the Department of Education and the participating schools.

For the larger study, students participated in a problem task called *The Planet of Zork* developed by a research team in collaboration with teachers from the participating schools. The task was administered using specially designed interactive software (M. Ainley & S. Ainley, 2006). The scenario described how the planet of Zork was dying. The student was asked to take the role of the person charged with deciding which of three planets the Zorkians should choose for their new home. Further into the program features of life on Zork were described in detail in terms of the climate, food and recreation. After receiving preliminary information (see below) the program required students to answer the question "*Which planet would you choose and why?*"

In this larger study students proceeded through the problem during which aspects of motivation, self-efficacy and engagement were monitored and recorded. Students' time spent on resources, self-reflective thoughts and final answers to the problem question were also recorded.

For the study reported here only one small section of the data was used, that of the students response to the initial posing of the problem solving prompt question "*Which planet would you choose and why?*"

These data were used to investigate the emergence of students' metacognitive development.

4. Method

Thematic analysis, a frequently used qualitative method, was selected as the appropriate way of examining the students' responses generated by the probe question. In using this method the researchers set out to encode qualitative differences found in the responses.

4.1 Participants

Three hundred and sixty-three (363) Year 5 and Year 6 students (44% girls and 56% boys)

participated in the study. Ages ranged between 9 years and 6 months to 12 years and 10 months with a median age of 11 years and 6 months. The students who participated were drawn from three schools in the Melbourne metropolitan area and could best be described as middle-class.

The researchers established that the schools involved followed the Victorian Government guidelines where the students had been exposed to “strategies to develop the capacity for metacognition” as outlined in the AusVELS curriculum document.

4.2 Measures and Procedure

Through the expectations of the defined curriculum (AusVELS) they had been exposed to, it would be expected that these students would have experiences with the concept of metacognition and that given the research into the developmental nature of metacognition (Fox & Riconscente, 2008; Veenman & Spaans, 2005), the ability to be metacognitive should be emerging in their responses.

As previously noted only one section of the larger study was used for data collection. For the study reported here students’ responses to a metacognitive probe question early in the program were recorded. After the task had been explained to the students but prior to being able to access any of the resource information, participants were required to input reactions to the task by responding to a prompt question designed to assess students’ interpretation of the structure of the task (“*What questions would you ask to help you decide?*”).

Students had seen the 4 screens listed below before responding to the prompt question.

Screengrab 1:

In this program you will be given a problem to solve. To help you solve the problem you will be given some resources which will include written information, pictures and graphs. You will also be given a notepad so you can record any things that you think are important for solving problems.

Screengrab 2:

Far, far away is the planet of Zork. The Zorkians love when it is wet weather, they love to work and play outside in the rain all year round. Zorkians like to eat bananas and apples. When they have finished their work, Zorkians like to go skateboarding. This is their favourite activity.

Screengrab 3:

Sadly, the planet of Zork is dying. The Zorkians have to find a new planet to live on. The Zorkians have sent out a scout to find a new planet that will be suitable for them. The scout has found three planets that might be suitable. These planets are Sef, Gog and Hilo. The scout has sent back to the Zorkians some information about each planet. You are the leader of the Zorkians. Which planet would you choose and why?

Screengrab 4:

Before you start:

What questions would you ask to help you decide?

Students' responses to the metacognitive probe question in Screengrab 4 were collected from the electronically stored data. Using these data we sought to ascertain students' ability to be metacognitive. At this stage it was clear that responses to the prompt question indicated aspects of procedural metacognition (Tarricone, 2011) that is, knowledge of self, e.g. "*I don't quite know what to do yet, I don't really get the problem*" (student no. 4051); knowledge of task, e.g. "*I don't know anything about the three planets, I need to know more*" (student no. 5094) and knowledge of strategy, e.g. "*What information do we have*" (student no. 5054).

Each sentence written by the student was coded into one of these categories by the research team. As we continued to review the coded data it became clear that there were differing levels of sophistication in the students' responses. We identified that there was some order emerging from those responses where the student seemed a long way from a solution ranging to those responses where the student indicated a level of metacognition that would allow an immediate solution.

5. Emergence and Construction of a Taxonomy

The students' responses that shared similar qualities or characteristics were grouped together. Four identifiable clusters emerged from the data. The inter-rater reliability between the researchers' coding was .95. The differences were discussed and consensus was reached for all responses.

The four identified clusters appeared to contain responses that could be described as

1: Uncertainty, 2: Attempting Actions, 3: Attention to Task, 4: Strategy Control

This left some responses that fell short of being included in the four main clusters. Their nature indicated that they were more sophisticated than their related group but not yet fully developed to be included in the next cluster. We deemed these particular responses as forming a transition from one level to the next.

Arranging these clusters and transitions led us to think there was an order (a natural progression) toward metacognition thus forming a taxonomy of metacognitive development

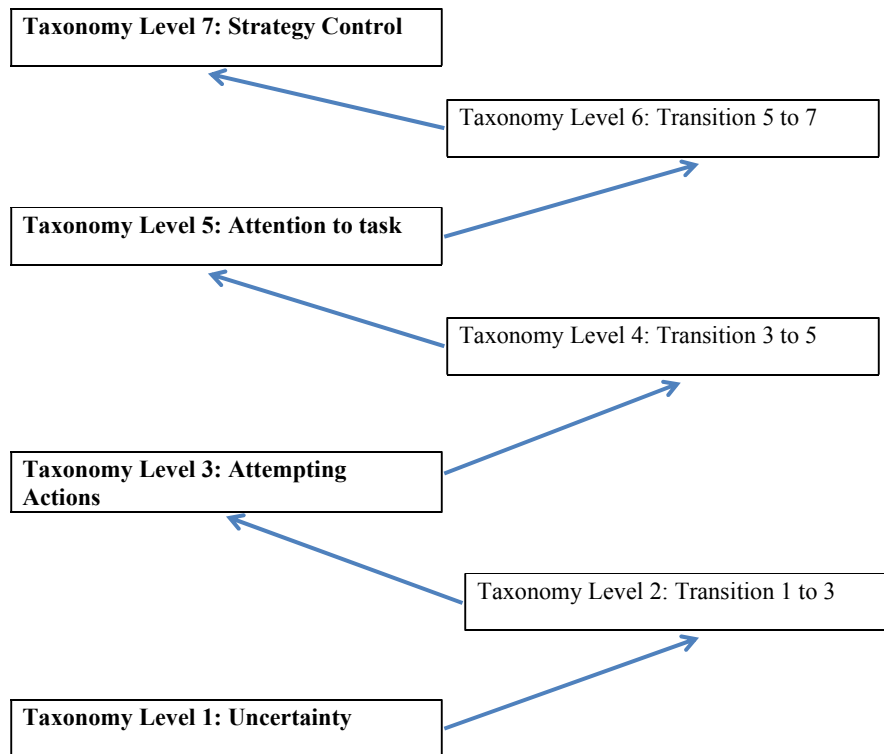


Figure 1. Taxonomy of metacognitive development

Figure 1 details the development of the seven levels that form the taxonomy. Below are listed the descriptors for each level of development.

Level 1. Uncertainty

These responses indicate that the student is uncertain and not sure what to do to approach the task. Several of these responses were self-referenced and personal in nature e.g.

“ I don’t quite know what to do yet, I don’t really understand it to get the problem” (student no. 4052)

“I need help to decide which planet to move to” (student no. 3034)

“I don’t know anything about the three planets and I think I need to know more” (student no. 5115)

“I don’t know yet” (student no. 4017)

Level 2. Transition between Level 1 and Level 3

This set of responses indicates a willingness to try something to solve the problem, but show a lack of confidence. Responses at this stage would not necessarily lead to a solution to the problem as they often focus on irrelevant information rather than the information already provided, e.g.

“How far away from the planet Sun do you want to be?” (student no. 5031)

“If they (the planets) are good or not” (student no. 3141)

“Do they love or like the planet?” (student no. 3127)

“What are the Zorkians like? (student no. 5055)

Level 3 Attempting Actions

The responses at this level show an attempt to focus on the task elements, but the students' attempts show they are not clearly attending to the task criteria. While they may be sensible questions in themselves in a general context, they may not lead directly to a solution to the problem, e.g.

“Does it (the planet) meet their needs?” (student no. 3147)

“What do the three planets look like? “ (student no. 3105)

“Do Zorkians need oxygen?” (student no. 3031)

“What planet looks best for you?” (student no. 4002)

Level 4. Transition between Level 3 and Level 5

Responses indicate a more focused approach is emerging, looking more carefully at the task elements. The responses tend to be specific, picking up one or two of the elements of the problem, e.g.

“Does it rain a lot on the planets?” (student no. 3032)

“What are the weather conditions on the three planets?” (student no. 3122)

“Will they (the planets) die out soon? (student no. 3139)

“Does the planet have water and soil good enough to grow apples and bananas?” (student no. 5026)

Level 5. Attention to Task

In these responses the task demands are carefully attended to, students are responding to the criteria of the stated problem e.g.

“How many skateboard ramps are there?” (student no. 3026)

“Is the terrain smooth so we can skateboard?” (student no. 6026)

“What is on each of the three different planets? “ (student no. 3074)

“I would like to know if those planets were wet and if they had paths to skateboard on.” (student no. 5107)

Level 6. Transition between Level 5 and Level 7

The responses show the first appearance of some strategies and tactics to aid the solution. There is some re-phrasing and evaluation of the information already provided in order to seek a solution. Responses appear to be more analytic in the questions asked than at lower levels e.g.

“Which one is most suitable? Which planet can grow lots of fruit and has enough space for skateboarding?” (student no.6031)

“Which of the three planets would the Zorkians want to move to?” (student no. 5067)

“Which planet has the most rain on it? What planet do we want to live on the most?” (student no.4051)

“What would be the best planet for them to live on?” (student no. 5007)

Level 7. Strategy Control

The responses show an emergence of defined strategies to assist in the problem’s solution. Metacognitive knowledge and/or skills are often made explicit. These students’ responses indicate an analytic approach needed to process the information.

“What information did the scout send back to planet Zork about the other planets?” (student no. 5087)

“What are the benefits to the Zorkians of each planet?” (student no. 5102)

“Do the planets meet the criteria? Are the planets suitable?” (student no. 3016)

“What will they need and what will each planet provide them with?” (student no. 5001)

6. Results

Each student’s response was re-coded according to taxonomy level. Where a student gave a number or responses that fell into several categories, the responses were allocated to which ever was the higher category level. Only two (2) students made no response at all. These were coded at Level 1. Responses were graphed to show numbers at each level.

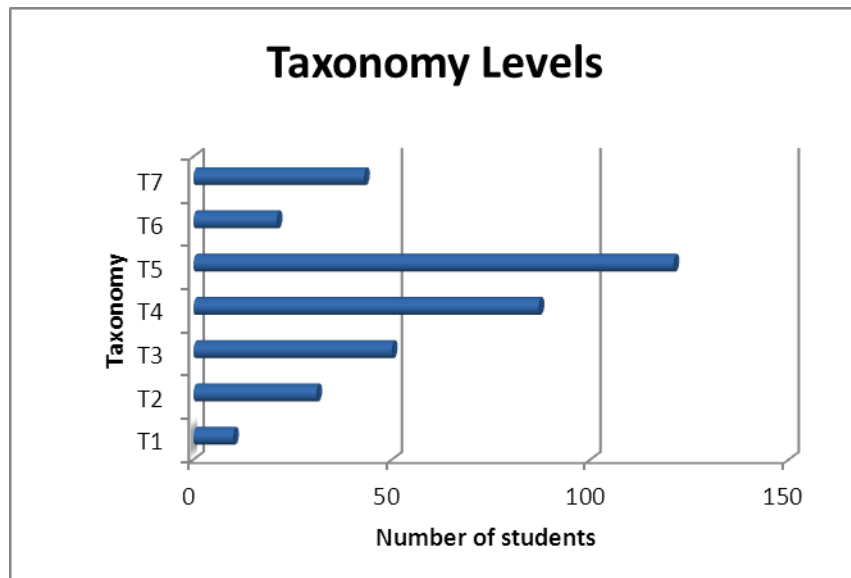


Figure 2. Taxonomy (T) levels

Figure 2 shows that the first five levels (Levels 1 to 5) show an incremental pattern suggesting that there may be hierarchical progression in the quality of the students' responses. Level 6 and Level 7 indicate that relatively few students are able to 'think about their thinking', that is are making recognisable metacognitive responses. The most usual (modal) response category is at Level 5 where the students are making a general response that attends to the criteria of the task.

Figure 2 also shows that approximately 18% of the responses were categorized at Level 6 and Level 7, indicating that relatively few students are working at a higher order level of metacognition. A chi square test was conducted on the percentages of students categorised at Levels 1 to 7. The result indicated that it was very unlikely that the distribution was due to chance factors: $\chi^2(6, N=363)=177.98, p<.001$.

7. Discussion

In this study we have been able to use the student responses to a prompt question to construct a taxonomy that would identify the emergence of metacognition in young learners. Responses reveal that students show the ability to 'think' about the task. Even at Level 1 there is evidence of responses that students are motivated to explore further (e.g. I don't know, I don't know yet). At Level 7 there is evidence of 'taught' planning techniques, that is those strategies that appear in the curriculum as appropriate for problem solving (Costa, 1981) e.g. "*Memorising the key parts of the problem I think are important*" (student no. 3168), "*First I'll check is it hard or easy, I would look at the question carefully*" (student no. 3159).

Although the ability to be metacognitive is emerging, only a minority of the students in this study appears to be able to think about their own thoughts or indicate the use of metacognitive strategies that they are able to use in problem solving.

Responses classified by the odd numbers (1, 3, 5 and 7) show a clear qualitative difference from each other and the growing sophistication of approach seems to be hierarchical.

Responses coded at the transition levels (2, 4 and 6) also show a difference from each other and from each of the corresponding named levels. Responses indicate that these students would, with extra information, be able to reach a more analytical level but as yet are inadequate to provide a solution.

The value of this taxonomy is that it charts a possible developmental sequence to which teachers could adapt their program and activities related to the curriculum for thinking for students in Years 5 and 6 in primary education. The taxonomy also demonstrates that when confronted with a problem there are varying responses to the process of solving that problem effectively. Using this taxonomy as a guide when reviewing students' responses to problem solving, will help teachers not only to become aware of differences in students' metacognitive ability but also assist in the development of the provision of appropriate activities to encourage students to move up the taxonomy to more effective problem solving.

8. Limitations

The present study features an innovative use of a computer program, and this study is limited to students' responses to the probe question embedded in that program. In Australia, the conduct of research using students is subject to a number of constraints. Ethical approval by the University is allied with approval from education authorities and the schools taking part. The preservation of privacy is a key component and studies are limited in the data that may be used and reported. Consequently data about students' academic performance was not made available to the researchers, even though these data might have been useful in interpreting student responses.

However, the subsequent steps taken by students in their problem solving as part of the computer program are available and will be used to follow up how students at different levels of the taxonomy continued to ask questions and present their solutions. This will be the subject of a further report.

9. Conclusion

A further study is needed to match these initial responses to the metacognitive probe question with the students' final answer (these data are available from the larger research study). This matching would allow further examination of the role metacognition has on problem solving.

This cross-sectional study clearly demonstrates a range of differences in students' ability to be metacognitive. A longitudinal study is needed to chart to progress of an individual in becoming metacognitive thus confirming the validity of the taxonomy. The taxonomy presented here could be used as a predictive device in assessing the development of an individuals' thinking.

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