International Electronic Journal of Elementary Education
Vol.1, Issue 1, October 2008.

Dear reader,

It's a great pleasure for me to introduce you the Vol. 1, Nr 1 of *International Electronic Journal of Elementary Education (IEJEE).* Elementary education is an important part of the lives of every generation. It therefore deserves a special attention by researchers, policy makers, teachers and parents. There are many, and sometimes, different topics and challenges related to Elementary Education in different contexts and countries. At the same time the community of national educational researchers in every country and international researcher circles have access to an increasing amount of research based knowledge. We do more research and know more in our days than ever before about several aspects of elementary education.

Changing social, economical and technological conditions in the life of the children and the factors surrounding the schools as institutions create, however, continuously new questions and new challenges. The main aim of *International Electronic Journal of Elementary Education (IEJEE)* is to be a channel for the *academic friends* and *researchers* of Elementary Education, regardless where they are.

As a scientific journal, *IEJEE*, will be an open channels for researchers from all over the world to make their research accessible for teachers, other professionals and scholars, and decision makers.

With such ambitions *IEJEE* is committed herself to follow ethical and scientific rules of research, submission and publication.

IEJEE is a peer-reviewed electronic journal. It will come out three times a year. A group of researchers from different universities from different countries comprise *IEJEE*'s editorial team. We'll be glad to extend and renew our editorial team while we are developing *IEJEE*. We'll be glad to get more and more submissions, even though the submissions to our first issue have been overwhelming.

I want to take the opportunity to thank Dr. Turan Temur of University of Dumlupinar, who has been the primary founder and activator of *IEJEE*. I also want to express my gratitude to all of the members of the editorial team and all the authors that now have the honour of being the first scientific voices of *IEJEE.*

Sincerely,
Dr. Kamil ÖZERK, Editor
Professor of Education
University of Oslo, Norway

- *All responsibility for statements made or opinions expressed in articles lies with the author.*

International Electronic Journal of Elementary Education
Vol.1, Issue 1, October 2008.

Exploring elementary students' understanding of energy and climate change

Colin BOYLAN

Charles Sturt University, School of Education
CBoylan@csu.edu.au

Abstract

As environmental changes become a significant societal issue, elementary science curricula need to develop students' understanding about the key concepts of energy and climate change. For teachers, developing quality learning experiences involves establishing what their students' prior understanding about energy and climate change are. A survey was developed to explore what elementary students know and understand about renewable and non-renewable sources of energy and their relationship to climate change issues. The findings from this survey are reported in this paper.

Key words: *Elementary students, energy, climate change*

Introduction

One of the current challenges facing people around the world focuses on energy. In particular, issues surrounding access to continuing energy sources, the rate of usage of known non-renewable energy resources, the use of renewable energy sources, the impact that society's use of energy can have on the environment and earth's climate are regularly reported in the media.

For elementary students, these are key issues that will have a major impact on their quality of life both in the short term and in the longer term. For elementary teachers, the challenge is to teach about energy and climate change in ways that promote deep knowledge and deep understanding of these concepts. In the New South Wales education system, elementary students (K-6) engage in the study of Science and Technology through a curriculum document that brings both Science and Technology studies together. The Science and Technology K-6 syllabus

ISSN:1307-9298

www.iejee.com

(www.boardofstudies.nsw.edu.au) provides the direction and focus of developing teaching and learning experiences for elementary students.

Related Literature

Student prior knowledge

Through the research of Corney (2000), Dawson (1997), Driver (1985), Osborne and Freyberg (1985) and Tytler (2002), some recurring themes about students' prior knowledge of science related topics can be made. These themes are:

1) students bring to their studies their own ideas about science and environmental concepts;
2) these pre-conceived ideas are formed through prior experiences and they are very persistent; and,
3) the pre-conceived ideas are difficult to change.

For the classroom teacher, the underlying message from these authors draws attention to how important it is for teachers to establish what students do know, do not know, and partially know about science concepts as the first step in quality teaching practices.

These authors then suggest that elementary teachers design their teaching and learning programs in ways that build from what the students know and provide opportunities to engage in experiential learning practices that will lead to elementary students developing new and deeper understandings.

Understandings about energy

As part of the Learning in Science Project, the New Zealand researchers concluded that the concept of energy is a difficult concept to teach (Osborne and Freyberg, 1985). Kirkwood and Carr (1988) investigated the concept of energy using both elementary and secondary students. Their research found that children across the world typically perceived energy as something which:

1. Is a general kind of fuel that does work for us.
2. Is associated with living things often linked to terms including energetic, and human-centred.
3. Is associated with moving things, e.g. fire, cars, ringing telephones.
4. Can take on different forms as it travels through wires or chains of bicycles.
5. Is a source of force or activity stored in objects, for example, water has energy in it so it can turn a water wheel.
6. Is a storehouse used to make things work such as a battery.
7. Can be obtained from food, the body, sun, and soil, it is regarded as an ingredient stored in them.
8. Is a fluid-like material that flows from one body to another, as an electric current or a stream.
9. Is given off like a waste product, for example, chemicals give off heat.

From this set of observations, it is clear that students do hold a variety of ideas about the nature of energy. The diversity and reported persistence of scientific and non-scientific understandings about energy has been shown to extend beyond school (Trumper, 1997). In his study, Trumper (1997) explored the ideas that pre-service elementary teachers hold about the concept of energy. His analysis revealed a number of persistent misconceptions that pre-service teachers hold including:

1. Hold a number of different, alternative conceptual frameworks when describing physical situations involving energy, instead of the accepted scientific concept.
2. Mostly think that energy is a *concrete entity*.
3. Mostly do *not* accept the idea of energy conservation.
4. Are *ambiguous* in their recognition of different types of energy.
5. Mostly *confuse* the concepts of energy and force.

In the investigation reported in this paper, the more specific link between energy and environment related issues is the central focus. Very little research literature was found that specifically dealt with elementary students' understanding of concepts such as sources of energy, climate change, and renewable and non-renewable energy sources. Corney (2000) noted also that very little research had been conducted that sought to establish what students knew about environmental concepts.

One study by Papadimitriou (2004) reported that both students' and adults' understanding about environmental concepts, including climate change, are often incorrect as well as being very persistent to teaching interventions. In Papadmitriou's (2004) research with pre-service elementary teachers the following findings revealed a set of common misconceptions held by many of the students:

1. weather effects and climate change are often confused.
2. climate change is linked to air pollution and environmental pollution.
3. climate change is incorrectly associated with ozone layer depletion.

Through her research, the author sought to explicate the deep science conceptual understandings held by these pre-service teachers. She concluded that the concept of energy in its various forms (electromagnetic radiation, heat and chemical) was a difficult concept which these students did not fully understand.

Additionally, environmental terminology misconceptions were identified by Boyes and Stanisstreet (1997) which led to the inclusion of one question in the student survey (Appendix 1: Question 8) that sought to determine if students were able to recognise differences between these environmental terms: climate change; greenhouse effect and global warming.

The findings from Boyes and Stanisstreet (1997), Kirkwood and Carr (1988), Papadimitriou (2004) and Trumper (1997) research are reinforced by those reported by Cavanagh (2007). He acknowledged that, as public concern about global warming increases, teachers realise the significance of teaching about these environmental issues and they 'are carving out a larger place for those issues in science classes, particularly at the high school level.' However, he noted that the need to increase the teaching time devoted to these issues has not been supported by appropriate curriculum materials. Cavanagh (2007) stated that teachers faced challenges in finding accurate and student-friendly classroom resources for teaching about these environmental topics. Cavanagh (2007) identified *The Keystone Centre* (www.keystonecurriculum.org) as a useful high school curriculum resource designed to solve the problem of locating up-to-date and relevant resources. While The Keystone Centre resources are appropriate for high school students, he did not identify relevant elementary teacher resources. This omission in elementary teaching resources has been addressed through the e-learning materials that have been developed as part of the research reported in this paper.

In summary, the literature suggests that students frequently define energy as the 'ability to do work' but their understanding is superficial. Additionally, many students hold inaccurate ideas about the nature of energy which are very persistent. When energy is linked with environmental concepts such as climate change, little research has been conducted into this area. Research that has been conducted suggests that students hold views that are confused, often inaccurate, and persistent. Coupled to these topical and important concepts is that fact that teachers find that many textbooks have very little up-to-date and relevant information about energy and climate change in them. One of the goals of this paper is to identify what elementary aged students know about energy and related environmental concepts.

Energy and Climate Change

Among the many concepts that elementary students encounter as part of their education in science, energy is one of the more important. Currently society is becoming more aware of the importance of energy, the supply of energy, its continuing longevity, and its impacts on the natural and built environment. One particularly topical issue is the relationship between energy and climate change and how it is affecting our lives.

The concepts of energy, renewable and non-renewable sources of energy, and climate change are introduced in the elementary curriculum in New South Wales. These concepts are progressively extended through the New South Wales Years 7-10 junior secondary science curriculum and into a number of the Year 11/12 syllabuses in Biology, Earth and Environmental Science, and Senior Science (see www.boardofstudies.nsw.edu.au/syllabus_hsc/syllabus-a-z.html) In the elementary (K-6) curriculum, the Science and Technology syllabus introduces students to ideas about the environment, human impacts on the environment, human use of Earth's resources, and the energy needs of society.

Context for this study

The impetus for the research reported in this paper arose from a state-wide educational initiative in environmental education within the state of New South Wales Australia. This initiative focused on developing students' knowledge and understanding about energy and related environmental concepts as a priority teaching area for 2007.

Regional Environmental Education Policy

During 2007, the Riverina Region of the New South Wales Department of Education and Training implemented the Riverina Regional Environmental Education Plan for its 197 schools. The major focus in this policy was the development of a teaching program about energy that sought to promote students' understanding of the relationship between energy and key environmental concepts such as climate change, and renewable and non-renewable energy sources.

The Riverina Environmental Education Centre

Within the Riverina Region is the Riverina Environmental Education Centre (REEC) which is one of 24 environmental education centres located throughout New South Wales. The principle role of an environmental education centre is to assist schools, teachers and their students with curriculum based environmental fieldwork and to help schools become more environmentally friendly. The task of devising and implementing the region wide program about energy was allocated to the staff at the Riverina Environmental Education Centre.

At the Riverina Environmental Education Centre, this regional focus was translated into developing learning activities that were based on a theme of Energy and Climate Change specifically for elementary students. The plan involved two major initiatives:

1. a collaboratively planned program between Charles Sturt University staff, third year elementary teacher education students and REEC staff that led to a major regional Energy learning event; and,
2. the development of the e-learning resources on *Energy and Climate Change* that supported the New South Wales Science and Technology K-6 syllabus.

The first element of the regional energy plan revolved around a set of six learning activities developed by REEC staff. Participating elementary students rotated around these activities and the CSU elementary teacher education students became group leaders for specific activities. As part of the planning for this day, the author was asked to develop a short survey that would identify what the elementary students' level of knowledge and understanding about energy sources, and renewable and non-renewable sources of energy was. This survey and its analysis is the primary focus of the reminder of this paper.

This second initiative involved the development of a student self-paced, e-learning guide. Riverina teachers were encouraged to incorporate these e-learning resources and activities into their teaching programs. These e-learning materials are accessible to all teachers and students by accessing the REEC website (www.reec.nsw.edu.au). The *Energy and Climate Change* resource is accessed from the K-6 section of the REEC website as shown in figure 1 below.

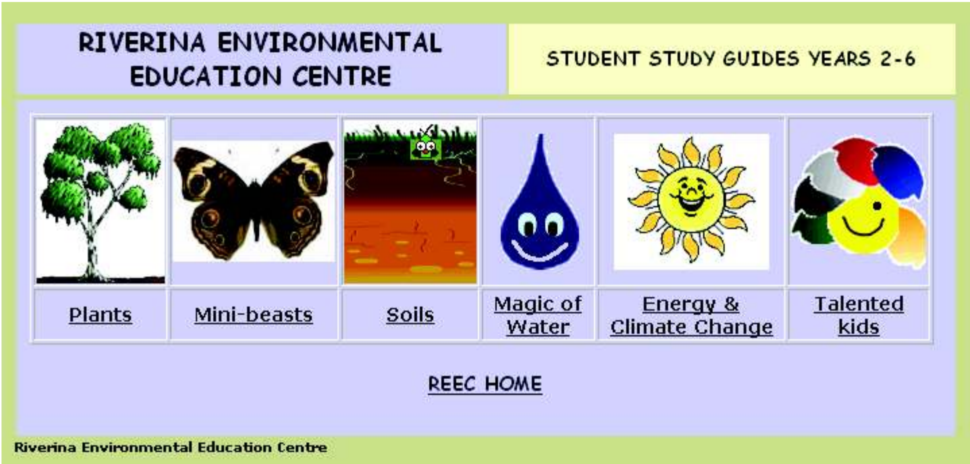


Figure 1: Available elementary e-learning activities

In the next figure a sample web page from the e-learning materials within the *Energy and Climate Change* learning resource is shown.

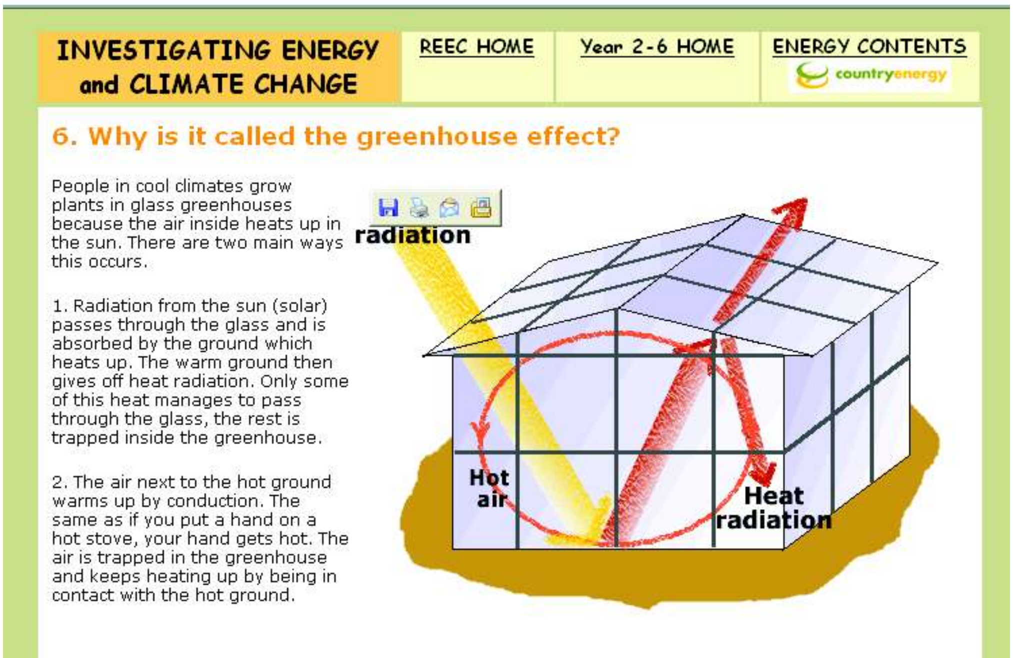


Figure 2: A sample page from the Energy and Climate Change e-learning resource

Methodology

Instrumentation

The *Energy and Climate Change* survey was designed using guidelines for establishing what prior understandings students hold based on the seminal work of Osborne and Freyberg (1985). The specific questions in the survey were developed following analysis of: a) the syllabus learning outcomes in the Science and Technology K-6 Syllabus (Board of Studies, 2006); b) misconceptions about energy and the environment identified from the literature analysis; and, c) the major ideas presented in the on-line e-learning resource on *Energy and Climate Change* contained on the REEC website (www.reec.nsw.edu.au). The instrument, see Appendix 1, included 8 questions that were designed to determine what the students' level of understanding about the following concepts was: energy, climate change, and renewable and non-renewable sources of energy.

Participants

132 elementary aged students who participated in the major regional Energy program of learning in 2007 were surveyed. 44 students were in Years 3/4 (identified as Stage 2 within the New South Wales context) and 87 students were in Years 5/6 (identified as Stage 3 within the New South Wales context). 56% of the students were boys and 44% were girls.

Overall, the response rates to individual questions on the survey were high (minimum respondents per question = 90%). No students omitted Question 1; 1 student omitted Question 2; 2 students omitted Question 3; 2 students omitted Question 4; 3 students omitted Question 5; and, 1 student omitted Question 6. For Question 7 which contained 8 different sub-parts, the number of students who omitted a response to any one energy source ranged from 7 (Hydro Electricity) to 12 (Nuclear Electricity). The average non-responses rate for this question was 9 students per energy source. For the final question, Question 8, 6 students omitted a response to this question. Statistical analyses included generating descriptive statistics and conducting Chi-square tests to determine if response pattern differences between groups were evident: namely Year 3/4 (Stage 2) vs Year 5/6 (Stage 3); and, gender (Boys vs Girls).

Results

Students' responses to Q1 to Q6 are presented in Table 1 below. Descriptive frequencies and their associated percentages are reported. Further the data were divided into: a) educational stage which is derived from how the Science and Technology K-6 syllabus is organised namely, Stage 2 (Year 3/4) and Stage 3 (Year 5/6); and, b) gender, Boys and Girls.

Questions 1 - 3 were designed to reveal what students knew about the types of energy while questions 4 – 6 asked to students about where energy comes from.

Table 1: Response about energy (Q 1 – Q 6)

Question	Response Choices	All students Number (%)	Stage 2 Number (%)	Stage 3 Number (%)	Boys Number (%)	Girls Number (%)
Is light coming from the bulb a type of energy?	Yes	112 (91)	37 (90)	76 (94)	61 (92)	47 (92)
	No	11 (9)	4 (10)	5 (6)	5 (8)	4 (8)
Is the person using energy when she runs?	Yes	121 (92)	36 (88) [a]	79 (99) [a]	65 (98) [b]	45 (90) [b]
	No	11 (8)	5 (12) [a]	1 (1) [a]	1 (2) [b]	5 (10) [b]
When the radio is turned on, is the sound coming from the speaker a form of energy?	Yes	89 (69)	19 (48) [c]	64 (80) [c]	43 (67)	35 (69)
	No	41 (31)	21 (52) [c]	16 (20) [c]	21 (33)	16 (31)
As wood burns, what type of energy is produced?	Electrical	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
	Heat	31 (24)	10 (24)	18 (23)	16 (25)	10 (20)
	Light	2 (1)	1 (2)	0 (0)	0 (0)	1 (2)
	Light and Heat	97 (75)	30 (74)	61 (77)	48 (75)	40 (78)
The energy in our bodies comes from:	Sleeping	44 (34)	15 (37)	23 (29)	25 (39)	8 (16)
	Eating food	49 (38)	11 (27)	36 (46)	29 (45)	18 (36)
	Drinking water	36 (28)	15 (37)	19 (24)	10 (16)	24 (48)
On our planet Earth, all life depends on the Sun for its energy.	Yes	109 (83)	34 (83)	66 (83)	55 (83)	40 (78)
	No	22 (17)	7 (17)	14 (17)	10 (17)	11 (22)

<u>Key</u>
a: Significant difference detected: Chi–square statistic = 6.891, df=1, p<0.01
b: Significant difference detected: Chi–square statistic = 4.176, df=1, p<0.05
c: Significant difference detected: Chi–square statistic = 13.207, df=1, p<0.001

Discussion of Table 1 results.
Types of energy (Q1 – Q3)
Overall the results suggest that elementary (Stage 2 and 3) students do know quite a deal about the different types of energy. In question 1, overall about 9 in 10 students correctly responded to this question. With question 2, the majority of students (92%) successfully recognised that when a person is running, energy is being expended / consumed. When the secondary analyses of this question were conducted it revealed that: a) more Year 5/6 (Stage 3) students correctly understood what was happening than

Year 3/4 (Stage 2) students; and, b) boys more frequently than girls correctly recognised that the person used energy while running. The third question revealed that about 2 in 3 students correctly knew that sound emanating from a radio was a form of energy. The secondary analyses conducted in this question also identified that Year 5/6 (Stage 3) students were significantly better at recognising that sound was a form of energy than the younger Year 3/4 (Stage 2) students. This finding suggests that these younger elementary students hold prior understandings about sound energy that are different to the accepted scientific explanations. This finding can also be linked back to the syllabus as sound production and energy are concepts that are first introduced in the Physical Phenomenon and Using Technology strands of the Science and Technology (K-6) syllabus for student investigation sometime during their studies over Years 3 and 4.

Origins of energy (Q4 – Q6)

The next three questions probed what students know about where does energy come from. These questions drew upon the some of misconceptions identified in the research by Kirkwood and Carr (1988) and Trumper (1997). Question 4 required the student to appreciate that both light and heat energy are produced when wood burns. It was pleasing to report that no student selected electrical energy as the product of burning wood. In fact, 3 in 4 students (75%) recognised that both light energy and heat energy are produced. Almost all of the remaining students (24%) stated that only heat energy was produced. The misconception that burning wood in a fire does not produce light energy is a topic that elementary teachers need to include when teaching about burning. Secondary analyses of the data revealed that this misconception is very persistent and consistent across both Stages and gender. Question 5 asked what students knew about where does the energy used in our bodies originate. The responses to this question revealed a surprising and unexpected set of results which were consistent across Stages and gender. About 1 in 3 students (34%) believed that sleeping was where the energy in our bodies originated. Similarly almost 1 in 3 students (31%) believed that drinking water supplied the energy our bodies needed. Just over one-third of the students (38%) correctly stated that it was through eating food that our bodies gained the energy they needed. These findings indicate that the majority of students hold alternate ideas about the origins of energy in our body. For elementary teachers, the body and food are common topics taught in elementary science classes, they need to make more explicit the links between food as a source of energy and how our body processes food to provide the necessary energy for normal cellular and bodily functioning. The final question (Q6) revealed that the majority of students (83%) knew that the Sun was the source of energy for all life on Earth. This finding was consistent across Stages 2 and 3 and by gender.

Renewable and non renewable energy sources

Students' knowledge and understanding about how they classified different sources of energy as either renewable or non-renewable were specifically explored by Question 7 of the survey. In the following table, the responses of the elementary students are reported.

Table 2: Renewable and non-renewable sources of energy

Question ***Which of the following are renewable and non-renewable energies?***	**Response choices**	**All Students Number (%)**	**Stage 2 Number (%)**	**Stage 3 Number (%)**	**Boys Number (%)**	**Girls Number (%)**
Hydro Electricity	Renewable	89 (71)	25 (71)	59 (74)	45 (70)	36 (78)
	Non-Renewable	36 (29)	10 (29)	21 (26)	19 (30)	10 (22)
Coal	Renewable	35 (28)	10 (29)	24 (30)	20 (31)	11 (26)
	Non-Renewable	88 (72)	24 (71)	55 (70)	45 (69)	32 (74)
Natural Gas	Renewable	63 (52)	20 (59)	35 (44)	35 (55)	18 (41)
	Non-Renewable	59 (48)	14 (41)	44 (56)	29 (46)	26 (59)
Nuclear Electricity	Renewable	71 (59)	27 (77) [d]	40 (53) [d]	38 (59)	24 (57)
	Non-Renewable	49 (41)	8 (23) [d]	36 (47) [d]	26 (41)	18 (43)
Food	Renewable	69 (56)	21 (62)	42 (53)	35 (54)	27 (63)
	Non-Renewable	54 (44)	13 (36)	37 (47)	30 (46)	16 (37)
Solar Electricity	Renewable	109 (89)	35 (97)	66 (86)	59 (89)	38 (88)
	Non-Renewable	13 (11)	1 (3)	11 (14)	7 (11)	5 (12)
Oil / Petrol	Renewable	41 (34)	14 (39)	25 (33)	23 (36)	15 (34)
	Non-Renewable	81 (66)	22 (61)	52 (67)	41 (64)	29 (66)
Wind Generated Electricity	Renewable	95 (77)	24 (69)	62 (78)	51 (78)	32 (73)
	Non-Renewable	29 (23)	11 (31)	17 (22)	14 (22)	12 (23)

Key

d: Significant difference detected: Chi–square statistic = 6.017, df=1, $p<0.05$

Discussion of Table 2 results

Overall many students' ideas about which energy sources are renewable and which are non-renewable revealed considerable confusion. On average, 7 in 10 students answered correctly to Hydroelectricity being a renewable source of energy. This response rate was consistent across Stage 2 and Stage 3. A very similar correct response rate was found for Coal as a non-renewable energy with 7 in 10 students being successful. The responses provided for Natural Gas were more interesting with only 5 in 10 students understanding that Natural Gas is a non-renewable source of energy. The misconception about Natural Gas being a renewable source of energy may be in part due to the word 'Natural'. Students may interpret 'Natural' as implying it must be renewable. On average 6 out of 10 students believed Nuclear Electricity was a renewable source of energy. Upon further investigation, a significant difference was found in how students in Stage 2 understood this example compared with Stage 3 students with a larger proportion of the latter group holding the correct understanding. There is a 24% increase from Stage 2 to Stage 3 in the number of students correctly identifying Nuclear Electricity as a non-renewable source of energy suggesting that this improvement may be linked to specific topics about energy contained only in the Year 5/6 (Stage 3) syllabus learning outcomes. However the elementary students' response to this example still emphasise that 5 in 10 students are unaware that Nuclear Electricity is a non-renewable source of energy. The implication for teachers when teaching about types of energy sources and whether they are renewable or non-renewable is clear. A detailed consideration about how and where nuclear electricity comes from needs to be included in the teaching sequence.

Determining if food was a renewable or non-renewable source of energy was also a question that revealed students held misconceptions. Between 5 and 6 in every 10 students correctly identified food as a renewable source of energy. This finding when linked with Question 5's responses indicated that holistically the level of understanding about food as an energy source and whether food is a renewable or non-renewable source does not align with the accepted scientific understandings. One possible explanation for the high level of misconception associated with this question could be that students do not link eating food with the food chains, energy flow and life cycles. Further, students may think that food must be non-renewable because when you eat it, it is gone. Solar electricity produced the highest successful response rate with 9 out of 10 students understanding that it is a renewable source of energy. The high response rate can be attributed to the high media focus on solar power making it a 'hot topic' at the moment. However, Oil/Petrol consumption is also a high priority media event, yet only about 2 in 3 students responded correctly that they understood that Oil/Petrol is a non-renewable source of energy. The final example revealed that 8 in every 10 students recognised wind generated electricity as a renewable source of energy. This response was consistent across both Stage and gender.

Environmental terminology

The final question (Q8) was included in the survey as the literature suggested that these environmental terms were not well understood by students. In Table 3, the responses from the elementary students are reported. This question explored whether students recognised the three selected terms as being the same or different.

Table 3: Knowledge about environmental terms

Question.	Response choices	All Students Number (%)	Stage 2 Number (%)	Stage 3 Number (%)	Boys Number (%)	Girls Number (%)
Climate change, greenhouse effect and global warming all mean different things	Yes	74 (59)	21 (53)	51 (66)	40 (63)	28 (57)
	No	52 (41)	17 (47)	26 (34)	24 (37)	21 (43)

No Significant differences found between Year 3/4 and 5/6 (Stages 2 & 3) and between boys and girls.

Discussion of Table 3 results

Only 6 in 10 students could correctly identify that climate change, greenhouse effect and global warming all mean different things. There was a slight improvement in the correct response rates from Year 3/4 (Stage 2) to Year 5/6 (Stage 3), however this change was not statistically significant. This response was surprising given the high level of current media coverage on these issues world-wide and specifically the Australian media coverage of the ongoing drought (now into its 6th year) in inland Australia which has reached crisis point.

Conclusion

This paper set out to report upon an investigation designed to establish what elementary students knew about sources of energy, climate change, and renewable and non-renewable energy sources while attending an Energy learning event at the Riverina Environmental Education Centre. The findings revealed that students' ideas about the types of energy are still developing with their understanding about sound energy revealing some persistent misconceptions. Further, most students realised that the Sun is the major energy source for all life on earth but many students held misconceptions about food as an energy source for humans. Up to half of the elementary students held specific misunderstandings about renewable and non-renewable energy sources. Finally, many students were not clear about how the key environmental concepts of climate change, greenhouse emissions and global warming are different from each other. For elementary teachers, this investigation suggests a strategy for assisting students to overtly consider their tacit ideas about energy and climate change and the need to explicitly teach these concepts within real world contexts. For these teachers, this study highlights the important pedagogical practice of establishing what ideas students already hold about a concept at the start of their teaching program and developing a responsive teaching program to promote deep understandings of the concept. The *Energy and Climate Change* survey developed and used in this study provides one easy to use strategy that teachers can implement to assist them in finding out what concepts and misconceptions students in their class hold.

References

Board of Studies (2006). *Science and Technology K-6. Outcomes and indicators.* Sydney: Office of the Board of Studies.

Boyes, J. & Stanisstreet, M. (1997). Children's Models of Understanding of Two Major Global Environmental Issues (Ozone Layer and Greenhouse Effect). *Research in Science and Technological Education, 15*(1), 19-29.

Cavanagh, S. (2007). Lessons About Climate Change Pose Many Challenges for Science Teachers. *Educational Week*, 27:10, 1 – 16. Retrieved on 1st November 2007, from http://www.edweek.org/ew/articles/2007/10/31/10warming.h27.html?print=1

Corney, G. (2000). Student geography teachers' pre-conceptions about teaching environmental topics. *Environmental Education Research*, *6*(4), 313-329.

Dawson, C. (1997). *Science teaching in the secondary schools*. Sydney: Longmans.

Driver, R. (1985). *Research into Childrens' Ideas Book 2*. London: Routledge.

The Key Stone Centre (2007). *CSI Climate Status Investigations*. Retrieved on 4th November 2007, from http://www.keystonecurriculum.org

Kirwood, V. & Carr, M. (1988). *Learning In Science Project (Energy) Final Report.* Science Education Research Unit, University of Waikato – Hamilton Teachers' College Hamilton, NZ.

Osborne, R. &Freyberg, P. (1985). *Learning in Science: The implications of children's science***.** Melbourne: Heinemann.

Papadimitriou, V. (2004). Prospective primary teachers' understanding of climate change, greenhouse effects and ozone layer depletion. *Journal of Science Education and Technology, 13*(2), 299-307.

Trumper, R. (1997). The need for change in elementary school teaching. *Educational Research*, *39*(2), 157–174.

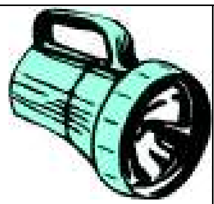
Tytler, R. (2002). Teaching for understanding in science: student conceptions research and changing views of learning. *Australian Science Teachers' Journal***,** *48*(3), 14-21.

Appendix 1

ENERGY and CLIMATE CHANGE

Please circle: I am a boy/girl in Year ______

Q1. When the torch is switched on, the light bulb glows.
Is the light coming from the bulb a type of energy?



YES NO

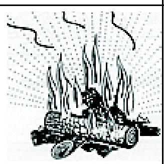
Q2. Is this person using energy when she runs?

YES NO

Q3. When the radio is turned on, is the sound coming from the speaker a form of energy?

YES NO

Q4. As the wood burns, what type of energy is produced?



a) Electrical c) Light
b) Heat d) Light and Heat

Q5. The energy in our bodies comes from:

a) sleeping b) eating food
c) drinking water

Q7. Which of the following are Renewable (R) or
Non-Renewable (NR) energies?

a) Hydro Electricity R NR
b) Coal R NR
c) Natural Gas R NR
d) Nuclear Electricity R NR
e) Food R NR
f) Solar Electricity R NR
g) Oil/Petrol R NR
h) Wind Generated Electricity R NR

Q8. Climate change, greenhouse effect and global warming all mean different things.

YES NO

Q6. On our planet Earth, all life depends on the Sun for its energy. YES  NO	

International Electronic Journal of Elementary Education
Vol.1, Issue 1, October 2008.

Teacher Variables As Predictors of Academic Achievement of Primary School Pupils Mathematics

Adedeji TELLA

Osun State University, Faculty of Education
Department of Science, Mathematics and Technology Education
dejtell@yahoo.com

ABSTRACT

This study examined the relationship between Teacher self- efficacy, interest, attitude, qualification, experience and pupils' academic achievement in primary school mathematics. The participants of the study comprises of 254 primary school teachers and 120 primary school pupils. Data collected on the study were analysed using a stepwise multiple regression analysis. The results reveals that teacher self – efficacy and interest had significant correlation with pupils achievement scores. Teacher's self-efficacy being the best predictor of pupils' academic achievement in mathematics was followed by teacher's interest. Attitude, qualification and experience were not significant correlation with pupil's achievement in mathematics. The study recommended that it is high time for primary school mathematics teachers to have a change of attitude towards the teaching of the subject so that the achievement of universal basic education will not be hindered. Furthermore, primary school educational authorities were called upon to ensure that only teachers who are qualified to teach the subject are employed. Not these alone, their attention was also drawn to the fact that they should design educational programmes that will enhance the teacher self- efficacy for a better prediction of pupils' achievement in mathematics.

Keywords: *Teacher self-efficacy, interest, attitude, qualification, experience and pupils academic achievement in mathematics.*

Introduction

The importance of mathematics in most fields of human endeavor cannot be underestimated. Its usefulness in science, mathematical and technological activities as well as commerce, economics, education and even humanities is almost at par with the importance of education as a whole. Mathematics is one of the key subjects in both the primary and secondary school education system in Nigeria. Fajemidagba (1991) was

ISSN:1307-9298

www.iejee.com

earlier of the opinion that the teaching of mathematics is very important to all human existence.

Mathematics is all about finding solutions to problems. All decisions taken are based an such questions as what and how these question is best answer by converting every statement to mathematical statement before solution is sought. The depth of mathematical knowledge an individual has dictated the level of accuracy of his/her decision. This implies the fact that before an individual can function well in the society he/she must possess or have relatively good knowledge of mathematics especially in this era of technological age. The technological development is highly rooted in the study of mathematics. Okebukola (1992) opined that mathematic is referred to as central intellectual discipline of the technological societies. Kerlinger (1985) describe mathematics as a language of science. Aminu (1990) argued that mathematics is not only the language of sciences, but essential nutrient for thought, logical reasoning and progress. Mathematics liberates the mind and also gives individuals an assessment of the intellectual abilities by pointing towards direction of improvement. He concluded by saying that mathematics is the basis of all sciences and technology and therefore of all human endevaours. Application of mathematics cut across all areas of human knowledge. Despite these wide applicability and importance of mathematics many pupils and students still not finding there feet in the subject as a result of their perennial failure in the subject.

Mathematics educators and researchers like (Ohuche 1978; Ale, 1989; Oshibodu, 1984 and 1988; Akpan, 1987; Odogwu, 1994; Edwards and Knight,, 1994; Alele –Willaims 1988; Georgewill, 1990; Tella 1998) have over the years carried out researches on factors that responsible for poor performance in mathematics at primary and secondary school. These factors ranging from shortage of qualified mathematics teachers, poor facilities, equipment and instructional materials for effective teaching, use of traditional chalk and talk methods, large pupils to teacher ration and mathematics fright/phobia to mention but a few. Just few of these studies if at all, consider Teacher's variables such as Teacher self –efficacy, interest, attitude, qualification and experience.

Several factors have generally been identified as predictor of poor academic achievement. Agyeman (1993) reported that a teacher who doesn't have both the academic and the professional teaching qualification would undoubtedly have a negative influence on the teaching and learning of his/her subject. Apart from qualification, other teachers' variables still exit which can either positively or negatively predict pupils' mathematics performance. However, research particularly in the Nigeria context is being silent about them. It is against this background that this study critically examined teacher variables as predictors of mathematics achievement in primary school. The choice of primary school culminated from the fact that it is the bedrock/foundation of any advancement in educational system. Teacher variables the study focused are teachers' self-efficacy, interest attitude, qualification and experience on pupils' achievement in primary school mathematics. In other to achieve the purpose of this study, the following research questions were answered:

1. To what extents would the teacher self-efficacy, interest, attitude, qualification and experience when taken together predict mathematics academic achievement among primary school pupils?

2. What is the relative contribution of each the factors to the prediction?

Literature Review

In recent years a numbers of researches have sought to relate two dimensions of self-efficacy to an educational setting. In this context the term "teacher efficacy" (TE) is generally accepted as analogous to Bandura's "self-efficacy". In an attempt to determine two elements which corresponded with Bandura's two factors theoretical model of self-efficacy, Gibson and Dembo (1984) developed a scale to measure the two dimensions of TE. There is results indicated that teacher efficacy consisted of at least two clearly distinguishable factors. One factor (GTE) appeared to represent a sense of whether or not a teacher's ability to bring about change is limited by factors outside his/her control. The second factor (TSE), which is relevant to the present study, seemed to represent to a teacher's sense of whether or not he/she personally has the skills and abilities necessary to enhance pupils' learning. However, the teacher efficacy scales developed by Gibson and Dembo (1984) consisted of items which, with the exception of one which related to teaching a new mathematics concept, reflected beliefs about education in a general sense, whereas Bandura(1977) maintained that self-efficacy is situation specific and cannot be identified in general terms. Raudenbush, Rowan and Cheong (1992) assumed that TE was not a "global disposition" and that perceptions of TE may be situational. Summarily, Kennedy (1990), commented that the various definitions of self-efficacy, such as " a person beliefs about their performance capabilities in a particular domain" and "judgements about their ability to accomplish certain goals or tasks by their actions is specific situations", suggested that these implied " a relatively situational or domain- specific construct rather than a global personality trait" (p.844).

Teaching preparation and procedures

Quality teaching has been defined as "teaching that maximizes learning for all students" (Glatthorn& Fox, 1996, p.1). Teaching entails engaging pupils as active learners to induce positive, comprehensive changes in their pre-existing knowledge, skills, and attitudes. Comprehensive changes (growth) are achieved by teachers who are able to build on learners' experiences, abilities, interest, motivation and skills. Therefore teachers must have mastered the basic skills of teaching and possess the ability to continuously adjust their teaching strategies to meet the diverse needs of their pupils.

Knowledge of Subject-Academic Preparation

It is intuitively obvious that teachers must possess a professional knowledge base and exhibit knowledge of the subject matter. Successful teacher have a vast repertoire of instructional strategies and techniques that reflect their knowledge of the subject. According to Slick (1995), teachers are those that consciously reflect upon, conceptualize, and apply understandings from one classroom experience to the next. Teaching of mathematics requires continuous reflection and decision making before, during, and after classroom instruction (Berliner& Biddle, 1995; Colton & Spark – Langer, 1993, Costa, 1995; Lampert& Clark, 1990; Pultorak, 1996).

Personal Characteristic and Professional Responsibility

As previously indicated teachers have the ability to evaluate their own instructional effectiveness and be professionally responsible for teaching by accepting responsibility for pupils learning and behavoiurs (Porter & Bryophyte, 1988). Further, since "the essence of teaching is human interaction" (Dwyer & Villegas, 1993, p.10), all teachers must continuously refine and enhance their skills of communication and collaboration. Personal and professional attributes that have been identified as being representative of teachers include: the ability to show a genuine interest in teaching and enthusiasm for learning., a pride one's personal appearance, Skills in adapting to change, accepting responsibility for actions both inside and outside the classroom, the desire to take a cooperative approach towards parents and school personnel, punctuality and regularity in attendance and the ability to establish a genuine rapport with pupils.

Teachers Variables / Characteristics

Teachers Qualification

Interest in student performance and teacher qualifications has intensified among education policymakers and researchers. During this time period, research has accumulated that links student achievement to the qualifications of teachers (see Ferguson 1991, 1998; Goldhaber and Brewer 2000; Mayer, Mullens, and Moore, 2000). Two central measures of elementary and secondary teacher qualifications are teachers' postsecondary education and their certification. To understand how many students are taught by teachers lacking specified levels of training, efforts have focused on mismatches between teacher qualifications and their teaching assignments (National Commission on Teaching and America's Future 1996; Ingersoll 1999). One of the main findings concerning teacher qualifications has been the relatively high incidence of teachers teaching subjects outside their areas of subject matter training and certification (see, e.g., Bobbit and McMillen, 1994; Ingersoll 1996, 1999, 2000; Neuschatz and McFarling 1999; Robinson 1985). Moreover, the incidence of out-of-field teaching has been shown to vary by subject and by grade level. Out-of-field teaching also has been shown to occur more often in the classrooms of low-income students (Ingersoll 1999). Goldhaber and Brewer's 1997 analysis of teachers' postsecondary degrees and students' mathematics performance found a positive relationship between these variables; with higher levels of performance among students whose teachers held a bachelor's or master's degree in mathematics than among students whose teachers were out-of-field. Goldhaber and Brewer (2000) examined data on the postsecondary degrees and certification status of teachers and their students' performance in mathematics and science. They observed a positive relationship between teachers' degrees and student performance in mathematics consistent with earlier findings. They also found that students whose teachers were certified in mathematics but did not hold a postsecondary degree in mathematics did not perform as well as students whose teachers held a postsecondary degree in mathematics. These findings provide a foundation for further examinations of out-of-field teaching data. One of the most significant studies in this area was also performed by Hanushek (2000) who surveyed the results of 113 *studies* on the impact of teachers' qualifications on their students' academic achievement. Eighty-five percent of the studies found *no positive correlation* between the educational performance of the students and the teacher's educational background. Although 7 percent of the studies did find a positive correlation, 5 percent found a *negative impact.*[4] Those that push for legislation requiring certain teacher qualifications for homeschoolers have no research to support the necessity of such standards. The results of these 113 studies are certainly an indictment on proponents of certain teacher standards for homeschoolers. Higher teacher qualification does not make better students.

Teachers Attitude

Attitudes are generally regarded as having been learnt. They predispose an individual to action that has some degree of consistency and can be evaluated as either negative or positive (Fishbein & Ajzen, 1975 in McMillen et all, 2000). Caraway's (1985) data revealed that mathematics competency and achievement were both positively correlated with attitude toward mathematics This is also true for pre-service teachers , as is reported in the study by Rech, Hartzell, and Stephens (1993) who compared the mathematical competencies and attitudes of American pre-service elementary education students against a representative college population, over three years. The results supported Caraway's findings and also showed that the pre-service students possessed significantly more negative attitudes toward mathematics than the general college sample. Davies and Savell (2000), in a study of 53 New Zealand early pre-service childhood students found they entered their teacher preparation program feeling negative about mathematics Grootenboer (2002) reported similar findings for 31 New Zealand pre-service primary teachers and there are Australian studies with similar results (e.g., Sullivan 1989). When exploring the attitudes of primary school teachers towards mathematics it is necessary not only to consider their attitudes towards mathematics but also their attitudes towards the teaching of mathematics. The significance of research involving the attitudes of primary teachers is important due to the potential influence of these people upon pupils. The experiences of teachers influence the formation of attitudes and these, in turn, influence their classroom practices. These attitudes and practices may sometimes be at variance with the main direction of their tertiary teaching methods courses. Thus it is crucial in understanding primary teachers that these attitudes are made explicit and examined in order to adapt tertiary courses to the needs of these students. Research has argued that positive teacher attitudes contribute to the formation of positive pupil attitudes (Sullivan, 1989; Relich, Way, & Martin, 1994). Other studies have shown that classroom strategies used to teach a subject are influenced by teacher attitudes which, in turn, influence pupil attitudes (Carpenter & Lubinski, 1990). Research into attitudes to mathematics has explored the influence of a range of affective variables such as anxiety and self-image. Mathematics anxiety is usually defined as a feeling of tension and anxiety that interferes with mathematics performance. There is disagreement over whether it constitutes an independent affective construct or is really a reflection of some deeper attitude. Thus while Nisbet (1991) argued that anxiety and confidence in teaching mathematics were independent factors. Relich, Way, and Martin (1994) disagreed in their study of 212 Australian undergraduate pre-service teachers.

Teachers Experience

Teacher characteristics such as years of teaching experience have been investigated to determine their effect on student outcomes (Sanders and Rivers, 1996; Wright, Horn et al., 1997). A more recent analysis by Wenglinsky (2000) used multilevel structural equation modeling to analyze data from the NAEP and found that teachers with a major or minor in the subject area that they are assigned to teach produce greater gains in student achievement in both mathematics and science. This remained true even after controlling for teacher professional development, teacher classroom practices, class size, and student demographics. Interestingly, Hawk, Coble, and Swanson (1985), found that students with mathematics teachers assigned in- field scored higher and had greater gains than students with mathematics teachers assigned out- of-field which indicates a connection of content-knowledge, but not necessarily applying pedagogical knowledge to other content areas. However, teacher experience is a topic of potential concern to policymakers, because experienced teachers often try to move to districts, schools, and classrooms with a more privileged student body and higher resources. Thus, if teacher experience is related to student achievement, and more experienced teachers are able to some extent select the schools and districts in which they teach, or even their teaching assignments within a school, poor students and students at risk of educational failure may end up being doubly disadvantaged because they are more likely to be taught by inexperienced teachers. Greenwald, Hedges, and Laine (1996) found in their meta-analytical study that teaching experience had a positive and significant effect on student achievement. Hawkins, Stancavage, and Dossey (1998) found evidence that although teaching experience appears to be related to student achievement, the relationship may not be linear; students whose teachers had fewer than 5 years of experience had lower levels of mathematics achievement as measured by the NAEP mathematics assessment, but there were no differences in mathematics achievement among students whose teachers had more than 5 years of experience. Other researchers have disagreed with these findings. Hanushek (1997) wrote that 71 percent of the studies he reviewed did not find any results to support a relationship between teaching experience and student achievement.

Teacher Self-Efficacy

Self-efficacy as a teacher, on the other hand, is a powerful predictor of how and whether a teacher will act. Self-efficacy is the belief that one is capable of exercising personal control over one's behaviour, thinking and emotions. Effective teachers believe that they can make a difference in children's lives, and they teach in ways that demonstrate this belief. What teachers believe about their capability is a strong predictor of teacher effectiveness. People who hold strong self-efficacy beliefs tend to: i; be more satisfied with their job (Trentham et al 1985); ii, demonstrate more commitment (Trentham et al 1985); and iii, have lower absenteeism (McDonald & Siegall 1993). Teachers who have high self-efficacy tend to: persist in failure situations (Gibson & Dembo 1984); take more risks with the curriculum (Guskey 1988); use new teaching approaches (Gibson & Dembo 1984); make better gains in children's achievement (Brookover et al 1979); and have more motivated students (Midgely et al 1989).

Teachers Interest

It's been noted that teachers interest in the teaching of a particular subject usually go a long way to improve the performance of their learners. Teachers interest in the teaching of Mathematics could be describe as their feeling of wanting to teach the subject and learn more about it. No wonder that literature have reveal the fact that teachers interest promote learning outcomes in Mathematics particularly among the pupils. It is hope that the result in this study will confirm this fact.

In the context of this study, the following teacher variables are operationalized thus: Teachers' qualification means the highest educational certificate possessed by a teacher to teach mathematics. Attitude refers to a complex mental state involving beliefs, feelings and values and dispositions of a mathematics teacher. Teacher experience connotes the nature of the events a mathematics teacher has undergone in the teaching of the subject. This is usually measure in terms of years. Teacher self-efficacy indicates the capability or ability a mathematics teacher has in teaching the subject; and teacher's interest refers to a sense of concern with and curiosity a mathematics teacher has about the teaching of the subject.

Though, literature seems to confirm that most of the teachers' variables/characteristics have positive relations with pupils' performance. But researches have not confirmed this as much in a population of Nigerian primary school pupils.

Methodology

Research design

This is an Ex- post facto study. In this type of research the researcher does not have direct control on the independent variables since their manifestation have already occurred. The researcher was interested in examining the phenomena under investigation and data were collected after the phenomena had taken place.

Sample: The participants is this study were 120 pupils and 254 primary school teachers selected by stratified/ simple random sampling techniques from some primary schools in Ejigbo Local Government Areas of Osun State, Nigeria. Out of the 254 teachers 129 were females and 125 males.

Instruments: A modified instrument tagged **Teachers Variables Questionnaire** was used for the collection of data on this study. This instrument is divided into two sections. The first section required the participant demographic information. These include sex, age, level, qualifications, and years of teaching experience. The second section contains the items. This is sub-divided into three parts.

Part 1- Teachers Attitude Sub-scale: This part contains items that measured teacher's attitudes towards the teaching of mathematics. It comprises of ten items of likert type scale with response range from strongly agrees to strongly disagree. Items in this part were adapted from Southwell and White (2005) teacher's mathematics attitude survey. The reliability coefficient of this sub-scale was found to be r = 0.78. Cronbach alpha.

Part 2- The teachers Self- Efficacy Subscale: This part contains items that measured teacher's self-efficacy in the teaching of mathematics. It is also contains ten items and of likert type format with responses ranges from not at all true, barely true, moderately true and exactly true. Items in this part were adapted from Schwarzer, Schmitz and Daytner (1999) Teacher Self-efficacy Scale and mathematics teaching efficacy Belief Instrument (MTEBI) by Riggs & Knochs (1990) The reliability coefficient of this sub-scale yielded an r = 0.73.

Part 3- Teachers Interest in Mathematics teaching Scale: This part measured teacher's interest in teaching mathematics. It contains ten items which are of likert type format. Response in this part range from strongly agrees to strongly disagree. Items in this part were adapted from Mitchel (1993) interest scale. The reliability of this part was found to be r = 0. 84 cronbach alpha. The overall reliability coefficient of the scale return r = 0. 88.

Mathematics Achievement Test (MAT) constructed by the researcher. This was used to gather respondent's academic achievement score in mathematics. MAT comprises of 15 items objective test based on what pupils have been taught in their various classes. MAT is meant for primary 3 to 6 where selection of teacher is done. MAT has a Cronbach Alpha reliability of 0.90 and concurrent validity of 0.76. Opinions of the teachers in primary schools were also sought concerning the test items and they confirmed that the test has content validity. In all 120 pupils were drawn to write the MAT.

Procedure

The three tests were group administered to the subjects in the schools involved in the study by the researcher with the help of some assistants who were teachers and friends from schools under studied. The researcher explained the various sections of the questionnaire to the subject who were instructed not to leave any of the items unanswered. It took them about 50 minutes to complete the questionnaires of the questionnaires that were returned 254 were valid for the study. The researcher scored the inventories according to the instructions in their manuals. Pearson's Product Movement Correlation Statistical Procedure and multiple regressions analysis (stepwise). The criterion measure or dependent variable was academic achievement in mathematics while the predictor or independent variables were Teacher Self-efficacy, interest, attitude, qualification and experience.

Results

(a) Using a combination of independent variables to predict mathematics achievement.

Table 1 : Means, standards deviations and intercorrelations among predictor and mathematics achievement for total sample (N = 254)

	Variables					
	1	2	3	4	5	6
1. Teachers' qualification	1.000					
2. Teachers' attitude	-.090	1.000				
3. Teachers' experience	.018	-.131	1.000			
4. Teachers' Self-efficacy	-.036	-.191	.267*	1.000		
5. Teachers' interest	-.127	-.071	.149	.040	1.000	
6. Mathematics achievement	.023	-.027	.179	.313*	.308	1.000
Mean	1.508	16.25	102.815	35.996	1.472	33.899
Standard deviation	.501	8.50	11.751	6.745	.500	4.094

* Significant P < .05.

The correlation matrix means and standard deviations of the measured variables are presented in Table 1. Results on Table 1 showed that only Teacher self- efficacy and Teacher interest were significantly correlated with mathematics achievement outcomes ($r = .267$ and $.313$; $P < .05$, respectively); but other variables viz: Teachers attitude, qualification and experiences had very low insignificant correlations with mathematics achievement. This indicates weak relationships.

Table 2: Summary of Regression Analysis between the predictor variables and mathematics achievement

Regression analysis	Analysis of variance				
R .42176	Source	DF	S.S	MS	F – ratio
R^2 .17789	Regression	5	754.258	150.851	
S.E 3.74912	Residual	248	3485.871	14.055	10.732*

*Significant at P < .0000

Table 2 above shows the values of the parameters of the regression analysis between the predictor variables and mathematics achievement. The results of the analysis showed that predictor variables predicted mathematics achievement of pupils in the primary school. The predictor variables taken against the criterion variable yielded a coefficient of multiple correlations (R) of .421 and adjusted multiple correlation square (R^2) pf 0.177. The R^2 value translated into 17.7% of the observed variance in the mathematics achievement scores. The analysis also gave a standard error (SE) of 3.75 and F-value of 10.732 significant at an alpha level of 0.05.

(b) Relative contributions of independent variables to the prediction.

Table 3: Relative contributions of predictor variables to the observed variance in mathematics achievement

Step	Variable	R	R^2	S.E.	F-value	Sign.	Remark
1.	Teacher Self Efficacy	.3130	.0979	30895	27.374	.0000	*
2.	Interest	.4100	.1681	3.748	25.369	.0000	*

* Significant at < .05.

Table 3 shows the relative contributions of Teacher's self-efficacy and Teacher interest to the observed variance in the interior variable (mathematics achievement) as indicated by the R and R^2 values at the various steps of the regression analysis. It was found in Table 3 that Teacher self-efficacy had R and R^2 value of .313 and 0.979 respectively. Teacher's interest entered the equation at step 2; and the cumulative R was .4100 and R^2 was .1681. The values corresponding to the two steps involved in the multiple regressions were significant at P. 05 level. The results in Table 3 confirm that Teacher self-efficacy is the best predictor of pupils' mathematics academic achievement in primary school mathematics among the studied sample followed by Teacher's interest. The other variables Teacher's attitude, experience and qualification did not enter the equation at 0.05 levels. Hence, revealing that they are weak predictors of pupils' academic performance.

Table 4: The Betas of the Predictor Variables to the Predictor of Mathematics Achievement

Variable	B	SEB	Beta	T	Sign. T.
Teachers' interest	2.1675	.4816	.2648	4.500	.0000*
Teachers' experiment	.1202	.1328	.0535	.0906	.3659
Teachers' attitude	.01107	.4772	.0013	.023	.9815
Teachers' qualification	.03184	.0209	.0914	1.522	.1293
Teachers' self-efficacy	.1575	.0371	.2596	4.245	0000
Constant	19.675	3.609	5.452	.0000*	

* Significant at 0.05 level.

Table 4 gives the prediction variables in the regression equation, the Beta values, and significant T corresponding to the variables regressed against the dependent variable. A look at Table 4 reveals that the Beta values for Teacher's interest and Teacher's self-efficacy were found to be highly significant (teachers' interest B = .2648; t = 4.500 at .05) and teachers self-efficacy (B = .2596; t = 4.245, at .05). Looking at the results in table 3, the values pulled by these two variables were higher than the ones pulled by the other three variables, as revealed in table 4. This confirm the results in table 3 where teachers' self-efficacy and teachers interest were earlier revealed to be the best predictors of pupils mathematics academic achievement.

Discussion

The results on Table 2 indicated that 17.7% of the variance in mathematics achievement was accounted for by the predictor variables taken together. The relationship between mathematics achievement and the predictor variables taken together were moderately low as shown by the coefficient of multiple correlation (R = .421). Thus, the predictor variables investigated when taken together could, to some extent predict mathematics achievement among primary school pupils involved in this study.

The F-value (10.73) of the analysis which was significant at alpha level of 0.5 lend credence to the fact that the predictor capacity of the predictor variables of this study did not occur by chance even though a large proportion of the variance in mathematics achievement was unexplained by the current data. The results have confirmed previous finding by Hone (1970), by Mechling, Hedman and Donnelley, (1982) and by Cunningham and Blakenship (1979) that teachers gravitate toward performing those tasks that they feel most competent in performing and more importantly avoid areas of lesser competence- even when these areas are prescribed by curricula (Schoenberger, 1988). It is logical, as well as supported by previously cited research, that feelings of competency would be likely to translate into positive attitude toward teaching specific subjects. Also Gusky (1988), Smylie (1988), and Midgelly et al. (1990) have all found that teacher efficacy is correlated with student motivation and with innovative teaching practices. However, these results contradict those of Gusky and Passaro (1993) who found distinction between teaching efficacy and personal or self-efficacy.

The results contained in Table 3 and 4 are quite revealing and informative. All the predictor variables investigated were found to contribute differently to the prediction of mathematics achievement. In particular, only Teacher's self-efficacy and Teacher's interest contributed significantly to the observed variance in the criterion variable in that order. Teacher self-efficacy accounted for 9.8% of the variance in mathematics achievement while Teacher's interest combined with Teacher self-efficacy accounted for 17% of the variance in mathematics achievement. This means that 83% of the variance in mathematics achievement is accounted for by other variables unexplained by the data.

Surprising are the non-significant contributions of the other variables, viz: Teacher's qualification, attitude, and experience to the prediction of mathematics achievement. These findings suggest that other latent and observable variable that lie outside the realm of the present study should be included to provide a more comprehensive conceptualization of the variables determining the mathematics achievement of Nigeria primary school pupils Tella (1998). This also indicate that less emphasis should be placed on those weak variables and more attention focused on those variable that have direct influenced on the academic achievement of pupils in this subject area (mathematics).

Conclusion

The results of this study have revealed that of all the independent variables correlated and regressed with the criterion measure of mathematics achievement, teacher's self-efficacy was the best predictor. This was followed by Teacher's interest. The least predictor was Teacher's experience; attitude and qualification were not significantly correlated with mathematics achievement.

Implications

The implication of these findings is that a large proportion of the variance in mathematics achievement was unexplained by the current data. Therefore, other observable factors that have direct effects on the performance of pupils in mathematics should be included in future research on predictor of mathematics achievement in primary school. It is reasonable to suggest that such variables as locus of control, gender, age, self esteem, and self concept could be included in order to be able to understand other factors that could also predict pupils achievement in mathematic.

It should also be stressed at this point that teachers' interest in mathematics and self-efficacy are very important variables as the study revealed. Therefore, at the teacher training institutions, the would-be teachers need to scrutinize themselves very well to see if their interest for the subject will be continuous. The perception of anything sort of this should be discouraged and should result to discontinuation by shifting over to specialized and train in another subject. This is because failure to do so will be detrimental to the teaching of the subject at the primary school. On the other hand, mathematics self-efficacy training can be introduced at the teacher training institutions. This is belief will go along way to strengthen teacher efficacy in the subject. Through such training, mathematics teachers who are self-efficacious in the subject can be easily identified and others who are not can be easily guided.

Another implication of the findings on this study is that, despite the low correlation obtained between most of other predictor variables, one cannot discountenance the importance on the achievement of pupils. Therefore, educational stakeholders should design and mount programme that considers the predictor variables that can enhance teacher's self-efficacy and teacher's interest. By so doing, they will be able to play their roles effectively in educational programmes that will eventually help the primary school pupils in mathematics. Primary schools mathematics teachers are called upon to have a change of attitude towards the teaching of the subject. When they do, it is belief that, this will go a long way to affects the performances of the pupils in the subject; bearing in mind that mathematics is important to whichever area of specialization one may think of majoring in the future. Since it is now glaring that every nation of the world are striving towards the millennium goal of achieving quality education by the year 2015, the teaching of mathematics and pupils performances in the subject should not be joke with, it must be enhanced because mathematics is the gateway to all discipline one can think of. The need to start building mathematician of the future for the achievement of quality education not to be a mirage is highly germane.

REFERENCES

Adams, P.E. & Krockover, G.H. (1997). Concerns and Perceptions of beginning Secondary Science and Mathematics Teachers. *Science Education_ 81(1), 29 – 50.*

Agyenmang, D.K. (1993). Sociology of Education for African Students.Temo: Ghana Publishing Corporation.

Akpan, A.A (1987).Correlates of Mathematical Problem-Solving Ability among Secondary School Students. Unpublished Ph.D. Thesis University of Ibadan, Ibadan.

Ale, S.O (1989). School Mathematics in the 1990's some Major Problems for Developing Countries*: International Journal of Mathematics Educational in Science and Technology 20 (5), 655-659.*

Alele- William G. (1988). Keynote Address Delivered at the Silver Jubilee meeting of mathematics Association of Nigeria (MAN) Sept. 1982. *Abacus 18 (1), 15-19.*

Aminu, J. (1990). Address by the Honourable Minister of Education. *Abacus 20 (1), 22-29.*

Bandura, A. (1997). Self-efficacy: Toward Unifying Theory of Behavioural Change. *Psychological Review 84, 191 – 215.*

Bobbitt, S.A., and McMillen, M.M. (1994). Qualifications of the Public School Teacher Workforce: 1988 and 1991(NCES 95-665). U.S. Department of Education, National Center for Education Statistics. Washington, DC: U.S. Government Printing Office.

Brookover W, Beady C, Flood P, Schweitzer J & Wisenbaker J (1979) School social systems and student achievement: schools can make a difference. New York: Bergin.

Caraway, S. D. (1985). Factors influencing competency in mathematics among entering elementary Education majors. Unpublished manuscript, Universityof SouthAlabama. (ERIC Reproduction Service Document No. ED260941).

Carpenter, T., & Lubinski, C. (1990).Teachers' attributions and beliefs about girls, boys and mathematics. *Educational Studies in Mathematics 21, 55-69.*

Davies, N., & Savell, J. (2000). "Maths is like a bag of tomatoes": Student attitudes upon entry to an Early Years teaching degree. Paper presented at the Teacher Education Forum of Aotearoa New Zealand Conference, Christchurch.

Edwards A, and Knight P. (1974). Effective Early Years Education. Teaching Young Children. Buckingham: Open University Press.

Fajemidagba, O. (1999). Trends in Mathematics Education in Nigeria: Issues and Problems *Abacus 2 (1),, 19-27.*

Ferguson, R.F. (1991). Paying for public education: New evidence on how and why money matters. *Harvard Journal of Legislation 28, 465-498*.

Fishbein, M., & Ajzen, I. (1975). Belief, attitude, intention and behavior: An introduction to theory and research. Reading, Mass.: Addison-Wesley.

Goldhaber, D. D., and Anthony, E. (2004). Can teacher quality be effectively assessed? The Urban Institute. Retrieved December12, 2006, from http://www.urban.org/url.cfm?ID=410958

Goldhaber, D. D., and Brewer, D. J. (2000). Does teacher certification matter? High school teacher certification status and student achievement. *Education Evaluation and Policy Analysis 22, 129-45*.

Georgewill, J.W. (1980).Causes of poor achievement on WAEC Mathematical Examination in River State. Secondary School Nigeria. *International Journal of Mathematical Education in Science and Technology 21 (3), 379-385.*

Gibson and Dembo, M. (1984). Teacher Efficacy: Construct Validation. *Journal of Educational Psychology 76, 569 – 582.*

Glathhorn Fox ; Slick ; Breliner & Biddle; Colton & Spark- Lager ; Costa ; Lampert & Clark; Pultorak ; Porter & Brophy; Dwyer & Villegas in Stroot, S; Keil V; Stedman , P; Lohr, L ; Faust, R; Schinn Cariol –Randall, L; Sullivan, A: Czerniak, G; Kuchcinski, J; Orel N; & Richter, M; (1998). Peer Assistant and Review Guidebook. Columbus; OH: Ohio Department of Education.

Greenwald, R., Hedges, L.V., & Laine, R.D (1996).The effect of school resources on student achievement. *Review of Educational Research, 66(3), 361-396.*

Grootenboer, P. J. (2002). Affective development in mathematics: A case of two pre- service primary school teachers. In B. Barton, K. Irwin, M.

Prankish, & M. Thomas (Eds.). Mathematics education in the South Pacific: Proceedings of the Twenty- Fifth Annual Conference of the Mathematics Education Research Group of Australasia (pp. 318-325). Sydney: MERGA.

Hanushek, E. (1990).The impact of differential expenditure on school performance. Educational Research 14, (4), 20- 25.

Hawkins, E.F., Stancavage, F.B., & Dossey, J.A. (1998). School policies and practices affecting instruction in mathematics. (NCES 98495). Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Hawk, P. P., Coble, C. R., & Swanson, M. (1985). Certification: It does matter. *Journal of Teacher Education 36 (3), 13-15.*

Hone; Mechling, Stedmen; & Donnelley; Cunningham & Blacenship; Schoenberger, Gusky, Smylie, Mitgelly et al and Gusky and Passaro in George Wenner. (2001); Science and Mathematics Efficacy Beliefs Held by Practicing and Prospective Teachers; A 5 – years Perspective. *Journal of Science Education and Technology 10 (2), 181-187.* .

Ingersoll, R. (1996). Out-of-Field Teaching and Educational Equality (NCES 96–040). U.S. Department of Education, National Center for Education Statistics. Washington, DC: U.S. Government Printing Office.

Ingersoll, R. (1999). The Problem of Underqualified Teachers in American Secondary Schools. *Educational Researcher*, *28(2): 26–37.*

Ingersoll, R. (2000). Rejoinder: Misunderstanding the Problem of Out-of-Field Teaching. Educational Researcher 30 (1), 21–22.

Kennedy (1990) & Raudenbush, Rowan & cheong (1992): Retrieved October 10, 2006, from http://deo,murdoch.edu.au/gem/iier/iiers/welch.htm

Kerlinger, F.N. (1985). Foundation of Behavioural Research. Rinehart Holt and Winston.

Mayer, D.P., Mullens, J.E., and Moore, M.T. (2000). Monitoring School Quality: An Indicators Report (NCES 2001-030). U.S. Department of Education, National Center for Education Statistics. Washington, DC: U.S. Government Printing Office.

McDonald T & Siegall M (1992).The effects of technological self-efficacy and job focus on job performance, attitudes, and withdrawal behaviors. *Journal of Psychology,126, 465–475.*

McMillen, M; Seastrom, K.J; Gruber, R.H.; McGrath, D.J.; &. Cohen, B.A. (2000).Qualification of the public school teacher workforce: Prevalence of out-of-field teaching 1987-88-1999-2000. *Education Statistics Quarterly*. Retrieved December 29, 2006 from http://www.nces.ed.gov/programs/quarterly/vol4/4_3/2_2asp

Mitchell, M. (1993).Situational interest: Its multifaceted structure in the secondary school mathematics classroom. *Journal of Educational Psychology 88, 3, 408- 422.*

Midgely C, Feldlaufer H & Eccles JS (1989) Change in teacher efficacy and student self-and task-related beliefs in mathematics during the transition to junior high school. *Journal of Educational Psychology l 81 (2), pp 247–258.*

Monk, D. (1994). Subject area preparation of secondary mathematics and science teachers and student achievement. *Economics of Education Review,13(2);125-145.*

National Commission on Teaching & America's Future. (1996). What Matters Most: Teaching for America's Future. Report of the National Commission on Teaching & America's Future. Summary Report. New York: Author.

Neuschatz, M., and McFarling, M. (1999). Maintaining Momentum: High School Physics for a New Millennium. College Park, MD: American Institute of Physics. Retrieved December 29, 2006, from http//: www.aip.org/statistics

Robinson, V. (1985). Making Do in the Classroom: A Report on the Misassignment of Teachers. Washington, DC: The Council for Basic Education.

Nisbet, S. (1991). A new instrument to measure pre-service primary teachers' attitudes to teaching mathematics. *Mathematics Education Research Journal, 3, 34-56.*

Odogwu, H.N (1994) Primary school Teachers and the Teaching of Time Concept in Schools" *Education Today 7, (21), 24-30.*

Ohuche, R.O (1978). Recent attempts at Mathematics Curriculum Renewal in English Speaking West Africa" *Abacus 12, (1), 17-26.*

Oshibodu, B.M (1984). An Investigation of Teacher's Instrumental problems in Mathematics. *Benin Journal of Educational Studies. 11(3), 43-54.*

Oshibodu, B.M. (1988). Mathematics at Primary level'. Abacus 18, (1) 13 – 20.

Rech, J., Hartzell, J, & Stephens, L. (1993). Comparisons of mathematical competencies and attitudes of elementary education majors with established norms of a general college population. *School Science and Mathematics,93(3), 141-44.*

Relich, J., Way, J., & Martin, A. (1994) Attitudes to teaching mathematics: Further development of a measurement instrument. Mathematics *EducationResearch Journal, 6 (1), 56-69.*

Riggs, I. and Knochs, L. (1990).Towards the Development of an Elementary Efficacy Belief Instrument. Science Education, 74, 625 – 637. Retrieved December 29, 2006, from http://deo,murdoch.edu.au/gem/iier/iiers/welch.htm

Sanders, W. L. and J. C. Rivers (1996).Cumulative and residual effects of teachers on future student academic achievement. Knoxville, TN: University of Tennessee Value-Added Research and Assessment Center.

Skott, J. (2001). Emerging Practices of a Novice Teacher. *Journal of Mathematics Teacher Education, 4, (1), 3-28.*

Southwell, B., & White, A.L.(2005).Attitude versus achievement in pre-service Mathematics teacherEducation.Retrieved December 29, 2006, from: http://www.aare.edu.au/05papsou05705.pdf

Sullivan, P. (1989). The impact of a pre-service mathematics education on beginning primary teachers. *Research in Mathematics Education in Australia, August, 1-9.*

Swarzer, R., Schmitz, G.S. &. Daytner, G.T. (1999).The teacher self-efficacy scale. Retrieved December 29, 2006, from http://www.fu-berlin.de/gessund/skalen/t_se.htm

Tella, A.(1998). An Investigation into Poor Performance and Attitude of Secondary School Students towards Mathematics in Oyo State, Nigeria. Unpublished B.Ed. Project University of Ibadan, Ibadan.

Trentham L, Silvern S & Brogdon R (1985) Teacher efficacy and teacher competency ratings. Psychology in the Schools, 22, (3), 343–349.

Wenglinsky, H. (2000). Teaching the teachers: Different settings, different results. Princeton, NJ: Educational Testing Service.

Wright, S. P., S. P. Horn, et al. (1997). Teacher and classroom context effects on student achievement: Implications for teacher evaluation. *Journal of Personnel Evaluation in Education:11, 57-67*

International Electronic Journal of Elementary Education
Vol.1, Issue 1, October 2008.

Justifying the design and selection of literacy and thinking tools

David Whitehead

University of Waikato, School of Education
davidw@waikato.ac.nz

Abstract

Criteria for the design and selection of literacy and thinking tools that allow educators to justify what they do are described within a wider framework of learning theory and research into best practice. Based on a meta-analysis of best practice, results from a three year project designed to evaluate the effectiveness of a secondary school literacy initiative in New Zealand, together with recent research from cognitive and neuro-psychologists, it is argued that the design and selection of literacy and thinking tools used in elementary schools should be consistent with (i) teaching focused (ii) learner focused, (iii) thought linked (iv) neurologically consistent, (v) subject specific, (vi) text linked, (vii) developmentally appropriate, and (viii) assessment linked criteria.

Key words: Literacy, thinking, tools, justifying criteria.

Most of the literacy and thinking tools I used as a beginning elementary school teacher were copied from my colleagues. When de Bono (1976) and his CoRT thinking program was published we were caught up in the hype, but we failed to apply our knowledge of learning theories, let along any criteria specific to the design of his tools, to justify why we were using PMI (positive, minus, interesting) or CAF (consider all factors), other than they struck us as clever. Likewise, data from interviews, observations and questionnaire (Wright, May, Whitehead, & Smyth, 2005, 2006) suggests that school teachers in New Zealand who use Concept Frames and other literacy and thinking tools (Whitehead, 2001) (see Figure 1) are hard pressed to justify their use of those tools. This article suggests that it is important to establish criteria for the design of literacy and thinking tools because, as professionals, elementary school teachers need to justify what they do (Whitehead, 2006).

ISSN:1307-9298

www.iejee.com

What is a literacy and thinking tool?

The intermediate Concept Frame is a literacy and thinking tool. This formative tool provides a four sector frame with a heading in each sector that prompts learners to think about what a specified concept can do, attributes and examples of that concept, and to what class of things the concept belongs. Additionally, the tool prompts learners to order what they record as an indication of how this information might be used in a report. The Concept Frame will be used to exemplify the design and selection criteria described in this article.

Links to learning theory

The design of literacy and thinking tools are related to particular learning theories and unrelated to others. For example, there is little evidence that behaviourism can provide either justification for the design of, or explanation for the effects of using literacy and thinking tools. In contrast, cognitive theories (Ashcraft, 2007) that seek to explain learning as information processing dependent on memory, attention, and task, provide useful explanatory frameworks for justifying the use of these tools. These theories explain the effects of tools designed to engage working and longer term memory, and assist learners to attend to tasks that present more or fewer degrees of challenge. Similarly, theories of social cognition (Vygotsky, 1978) provide an explanation for the effect of using literacy and thinking tools. These theories foreground the role of culture in providing the content for thinking (the ‘what to think’), the tools of intellectual adaptation (the ‘how to think’), and the dialogic setting in which literacy and thinking tools are used to solve problems. Further, the use of these tools as *teaching tools* is consistent with Vygotsky’s zone of proximal development, and the formative structure of tools that are described at three levels of challenge is consistent with understandings about how we learn. Likewise, constructivist theories which seek to explain learning in terms of the active construction of ideas or concepts based upon current and past knowledge are consistent with the use of literacy and thinking tools, because they accept that a teachers’ role is to help learners construct knowledge by working together.

Identifying design criteria

In addition to this broad explanatory framework are more specific criteria that can be applied to justify the design and selection of literacy and thinking tools. These criteria, described in this article, were identify from reviews of research describing the characteristics of effective pedagogy (Hipkins et al., 2002; National Institute of Child Health and Human Development, 2000), together with recent research about learning from educational and cognitive psychologists (Hattie, 2003; Sadoski & Paivio, 2001), and neuroscientists (Shaywitz & Shaywitz, 2007; Willis, 2007a, 2007b; Wolfe, 2001).

These criteria emerged, in particular, from a meta-analysis of significant New Zealand and international research published as the *Curriculum, learning and effective pedagogy: A literature review in science education* (Hipkins et al., 2002). The selection of studies for inclusion in this analysis were based on five characteristics including whether the research indicated (i) quantitative evidence of increases in learner understanding and performance on authentic tasks, and (ii) qualitative evidence of improved learner understanding, and attitudes in the classroom.

Finally, the criteria emerged from an analysis of data obtained from a three year evaluation of the New Zealand Secondary School Literacy Initiative (SSLI) (see a special issue of *Language and Education* edited by May and Smyth, 2007; Wright, Whitehead, May and Smyth, 2007) that involved a group of 60 pilot secondary schools. A quasi-ethnographic, multi-locale methodology was employ for this evaluation which involved detailed case studies in four schools a year, together with visits to classrooms and interviews with teachers and administrators in non-case study schools. The methodology engaged school principals, Heads of Department and Heads of Faculty, literacy leaders, and teachers, in semi structured interviews. These ‘conversations with a purpose’ (Burgess, 1988) were transcribed an analysed thematically. Additionally the researchers administered and analysed responses to a questionnaire designed to gauge the impact of the SSLI, and analysed artefacts (resources provided to teachers, memorandums and language policy statements) that provided some indication of cross-curricular sharing of literacy and thinking tools, the embeddedness of literacy principles and practices in departmental/faculty programmes, policies and professional goals.

A key outcome of this research was that schools that benefited most and sustained the initiative were characterised by literacy leaders and regional facilitators who lead learning (rather than just adopting the role of literacy ‘master teacher’). They provided what Schoenbach et al. (1999) describe as ‘highly-designed’ professional development and mentoring sessions that focused on theoretical understandings about teaching and learning, or what one respondent called ‘the head space stuff up front’. This focus provided staff with a theoretical basis for justifying their use of literacy and thinking tools.

Criteria for the design of literacy and thinking tools

The eight research-based design criteria that emerged from these analyses and research projects were that tools should be consistent with 1) teaching and 2) learner focused criteria, connected by virtue of their pedagogical focus; 3) thought linked and 4) mind compatible criteria, connected by virtue of their cognitive focus; 5) subject specific and 6) text linked criteria, connected by virtue of their literacy and epistemological focus; and 7) developmentally appropriate and 8) assessment linked criteria, connected by virtue of their formative focus. Justification for the inclusion of the teaching focused, learner focused, developmentally appropriate and assessment linked criteria stem, primarily, from the research of educational and developmental psychologists (Alton Lee, 2003; Hattie, 2003; Hipkins et al., 2002; Neisser, 1976). Research by functional systemic and critical linguists (Gee, 1990; Halliday, 1985; Martin, 1985) and psychologists (Pinker, 2002) provide justification for the text linked and subject specific criteria. The thought linked and mind compatible criterion reflect recent research from cognitive and neuro-psychologists (Ashcraft, 2007; Gazzaniga, Irvy & Mangun, 2002; McComas, 1998; Willis, 2007a; Wolfe, 2001). Each of these criterions will now be detailed.

1) The teaching focused criterion

According to a meta-analysis of research describing the characteristics of best practice conducted by Hattie (2003), teachers account for about 30% of the variance in learner achievement. What elementary teachers know, their pedagogical content knowledge, is crucial to learner achievement. In addition, what they do, such as provide feedback and quality instruction including direct instruction, and what they care about, for instance that learners should have high expectations, is crucial to learner achievement.

Tools, including the intermediate Concept Frame, that align with this criterion are consistent with the characteristics of best practice. It can be used as a teaching tool 'at the board' or through a data show when adopting direct instruction or transmission approaches. It allows teachers to scaffold learners (Alton Lee, 2003; Hattie, 2003) from dependence on them to independent literate thinkers. The tool acknowledges prior learning by eliciting first lesson recordings on the frame, and provides teachers with opportunities to model different types of questions associated with conceptual inquiry (Alvermann & Hayes, 1989; Brooks & Brooks, 1993; Goldenberg, 1993; Hipkins et al., 2002; Martin, Sexton, Wagner & Gerlovich, 1997; Ruddell, 2002).

The use of a teaching focused criterion ensures that the design and selection of literacy and thinking tools used by elementary school teachers is consistent with the characteristics of best teaching practice.

2) The learner focused criterion

The difference between tools consistent with the teaching focused criterion and tools consistent with the learner focused criterion is like the Chinese proverb: 'Give a family a fish and they will eat for a day; give them a fishing line and they will eat for a lifetime'. Tools consistent with the teaching focused criterion are like fish; tools consistent with the learner focused criterion are like the fishing line because they equip learners with a means of becoming life-long, literate thinkers. The reason why elementary school teachers need to use tools consistent with a learner focused criterion is because democratic societies need literate critical thinkers who can use a range of literacy and thinking tools independently.

The Concept Frame can be used by learners, independently, to record and then critique information from a report text, or as a note making frame prior to writing a report text.

3) The thought linked criterion

One general reason for proposing a thought linked criterion is because learning evoked through the use of literacy and thinking tools is an active cognitive process. Given the focus on the teaching of thinking in curriculums internationally a second reason is that literacy and thinking tools are designed to differentially evoke different types of thinking. It is important that teachers identify those different types of thinking. And it is important that they are able to align those types of thinking with the way disciplines construct knowledge (Paul, 1987). A third reason for proposing a thought linked criterion aligns with the claim that elementary school teachers should reconstruct knowledge as a verb (Gilbert, 2005, Lyotard, 1984). Literacy and thinking tools consistent with the thought linked criterion assist learners do something with what they know.

A fourth reason for proposing a thought link criterion aligns with another claim that elementary teachers and students need a language to objectify thinking. Teachers need a range of (i) generic labels such as creative, critical, reflective and caring, and (ii) taxonomic thinking labels such as remembering, understanding, applying, analyzing, evaluating and creating, and labels that stem from an information processing perspective such as (iii) conceptual thinking (associated with the representation of concepts about objects, animals, events and ideas) and (iv) episodic thinking (that help us think about information that has a temporal dimension). These four types of thinking will be outlined below. In essence, the thought linked criterion is premised on the supposition that elementary school teachers should identify the types of thinking evoked by the tools they use.

(i) Generic types of thinking (creative, critical, reflective and caring)

Labels objectifying generic types of thinking are well established in the literature about teaching and learning. For example, the [Australian] Curriculum Council (1998) notes that when students' plan science investigations, (although this clearly applies to other subjects), they engage in critical, creative and metacognitive (reflective) types of generic thinking. Others highlight the role of caring (and ethical) thinking (Lipman, 1977; Millett, 2003; Pohl, 2000) and memory thinking (Whitehead, 2004). These types of thinking are also explicitly stated in the Victoria (Australia) and New Zealand Curriculum documents.

More specifically, creative thinking is listed in the Hong Kong curriculum and defined as the ability to generate *original* ideas and solve problems in *appropriate* contexts. Others see creative thinking as offering new perspectives, generating novel and meaningful ideas, raising new questions, and proposing solutions to problems (Sternberg & Lubart, 1999).

Critical thinking, listed in most curriculum documents, is fundamental to philosophical inquiry. It is a type of thinking that results in 'deeper' and 'broader' thinking, abstract thinking (stemming from concrete examples), and higher order thinking about 'big issues' (Wilks, 1992). Other research notes that critical thinking in authentic contexts results in learners '...asking questions, trying to answer those questions by reasoning them out and believing the results of their reasoning' (Nosich, 2005, p. 5). The intermediate Concept Frame engages students in critical thinking by prompting them to ask and answer four or more questions (implied in the subheadings) about a concept.

Likewise, reflective or metacognitive thinking is listed in most curriculum documents internationally. In Dewey's (1933) view the development of reflective thinking is the most important goal of education because it enables learners to take responsibility for their learning. This type of thinking is significantly associated with learner achievement (Scott, Asoko, & Driver, 1992). Indeed, literacy and thinking tools that evoke reflective thinking have, arguably, the largest impact on learner achievement (Donovan, Bransford, & Pelligrino, 1999; Georghiades, 2000). The independent and appropriate use of a Concept Frame implies learners can think metacognitively.

Caring thinking, often disguised as values, has affective and ethical dimensions. Together they help us establish value systems from which to make compassionate value judgments. Affective thinking is about being mindful of self and others, about appreciating the intrinsic worth, beauty or value of objects such as the sensory/aesthetic appeal of a painting, or an idea, or a person's attitude. According to Goleman (1995) affective thinking encompasses and strengthens what he calls emotional intelligence and includes self-awareness, self regulation, resilience, empathy and social skills.

Haidt (2007) sees moral intuitions and emotions as the foundation of ethical behaviour. Traditionally, ethical thinking has been seen as helping us decide what is 'right' and 'wrong'. There are at least five types of ethical thinking that inform the design of ethical thinking tools and that support the inclusion of a thought linked criterion. These are (i) ends-based, (ii) fair and just, (iii) rule based, (iv) care based, and (v) common good thinking.

i. Ends-based thinking helps learners select actions that result in the greatest good for the greatest number (a utilitarian principle).
ii. Fair and just thinking helps learners select actions that favour or discriminate against others, that is, assists them to decide how fair an action is, whether it treats everyone the same way or whether it favours some people without justifiable cause.
iii. Rule based thinking helps learners decide what to do based on a rule. These rules may be legal, religious, or particular to a social group or personal.
iv. Care based thinking helps learners decide what to do based on the idea that this is what they would want others to do to them.
v. Common good thinking is consistent with the belief that actions should be linked to the common good of society.

Implicit in the adoption of the thought linked criterion is the need for teachers to understand different types of generic thinking, and the need, ultimately to decide whether these types of thinking have a place in their programmes, and if so, when and to what extent.

(ii) Taxonomic types of thinking

Of all the types of thinking consistent with the thought linked criterion, taxonomic classifications are perhaps the most significant. They have driven the design of educational documents and teacher planning for many years. Most notable is the classification provided by Bloom and subsequently revised by Anderson & Krathwohl (2001).

(iii) Conceptual thinking

Concepts include our knowledge about objects, events and ideas/beliefs. Humans appear to have an innate ability to represent direct experiences as concepts. Indeed, every human society classifies plants and animals into species-like conceptual groups represented in the brain as connected attribute and classification ‘meaning nodes’ (Blaut, Stea, Spencer & Blades, 2003; Farah & McClelland, 1991). Tools, such as the Concept Frame that differentially evoke conceptual thinking are designed to reflect the way evolutionary and cognitive psychologists think concepts are stored in memory and the way we use these representations (Collins & Loftus, 1975; Pinker, 2002).

(iv) Episodic thinking

Episodic thinking is associated with the comprehension of events/episodes that occur over time. Tools that support the composition of narrative and recount texts are thought linked because they differentially evoke episodic thinking. Indeed, tools that evoke narrative thinking seem to be consistent with the default setting of the mind to construct reality through narrative (Tulving, 2002). Other researchers claim that ‘…narrative is universally basic to conversation and meaning making’, and that ‘...humans appear to have a readiness, from the beginning of life, to hear and understand stories’ (Read & Miller, 1995, p. 143). Their argument here is that reality is narrative linked.

The thought linked criterion reflects the ability of literacy and thinking tools to differentially evoke generic, taxonomic, conceptual, and episodic types of thinking and prompt teachers to identify the types of thinking evoked by the tools they use. However, it would be unwise to apply this criterion as a means of defining types of thinking as mutually exclusive. Likewise, despite the imperative implied by this criterion, it would be unwise to assume any single association between a specific tool and a specific type of thinking. The potential for tools to evoke multiple types of thinking render popular classifications such as ‘creative thinking’ or ‘creative thinking’ as problematic. But the fact that tools evoke different types of thinking should neither deter elementary school teachers from the professional responsibility to understand these types of thinking, nor be used to dismiss the thought linked criterion as a means of justifying the design and selection of literacy and thinking tools.

4) The mind compatible criterion

Types of thinking associated with the thought linked criterion have their genesis in the mind (which is what the brain does). It is reasonable, therefore, that the design of literacy and thinking tools should be consistent with a mind compatible criterion; that they should be brain-friendly (Gazzaniga, Irvy & Mangun, 2002; Willis, 2007a, 2007b; Wolfe, 2001). But given the development of understanding about the brain, and brain-to-practice links, we should proceed with caution. Clearly, if the brain were so simple we could understand it, we would be so simple that we couldn't.

The mind compatible criterion should serve to remind us that when we teach we operate on learners' brains as assuredly as neurosurgeons. The neural circuitry of the brain is re-structured or pruned every time we teach; the very structure of our brain, the relative size of different regions, the strength of connections between them, even their functions reflects the way we teach. Like sand on a beach, the brain bears the footprints of the decisions we have made, the tools we have used, and the instructional conversations we have conducted.

Some links between this criterion and types of thinking described under the thought linked criterion are used below to provide further justification for the inclusion of this criterion.

Creative (metaphoric) thinking

There are functionally specialised and connected systems that engage, bilaterally, in the brain when we construct or comprehend novel metaphors like 'The doctor was a butcher'. These include an area in the temporal lobe (Brodmann area 37) which is also implicated in verbal creativity, and areas in the pre-frontal lobes (Brodmann areas 44/45 and area 46) involved in thinking (Mashala, Fausta, Hendlerc & Jung-Beemane, 2007).

Critical thinking

There is ample evidence that areas of the left pre-frontal lobes (Brodmann areas 45 /46 / 9) are crucial to critical thinking and problem solving. However, given that a major component of reasoning seems to be nonverbal, it is unsurprising that the right side of the brain should play a significant part (Whitaker et al., 1991). This seems to be true in respect to our ability to comprehend the theme of a story, generate inferences and establish story coherence.

Caring thinking (affective and ethical thinking)

The saying ‘I was so mad I couldn’t think straight’ is true, and universal. Emotions interrupt thought. The primary function of an area above the eye balls (Brodmann area 47), and the amygdala, a small walnut shaped body at the top of the brain stem, is to process emotion. These areas form a key part of the system that turns emotion into feelings and allow readers to form factual memories that have an emotional content.

There are also systems in the brain linked to moral/ethical thinking. These involve pre-frontal areas (Brodmann areas 9, 45, 46, and 10). The front part of area 9 is especially active when we think about impersonal moral dilemmas, and an area in the upper back section of the temporal lobe (Brodmann area 39) is active when we make personal moral judgments such as recognising a sad face or an aggressive gesture.

Reflective thinking

Reflective thinking refers to any process that involves planning, monitoring, regulating or evaluating the way we think. Reflective thinking includes knowledge we have about our cognitive abilities (‘I have a bad memory’), about our cognitive strategies (‘to remember a phone number I should rehearse it’), and about tasks (‘categorized items are easier to recall’). A review of brain imaging studies focused on reflective (meta cognitive) thinking reveals that the brain circuitry associated with attention, monitoring, and regulating behaviour is located in the upper front sections of the brain, (Brodmann areas 8 and 9), and the middle and lower pre-frontal areas, (Brodmann areas 46 and 47) (Fernandez, Baird & Posner, 2000; Shimamura, 2000).

Episodic thinking

There is research suggesting that our brains have a pre-wired default setting that pre-disposes them to construct understandings about the world in narrative form, which explains why story telling is found in every culture (Troiani, Ash, Reilly & Grossman, 2006). It appears that there is no single area or circuit responsible for episodic narrative thinking, however, several studies indicate it is associated with an area in the upper back part of the parietal lobe (Brodmann area 7) which is key to recalling events, along with upper frontal areas (Brodmann areas 8 and 9) which help us to organize information into connected narrative form and think about what has been recalled (Ash et al., 2006; Rugg, Otten &Henson, 2007).

A key component of episodic narrative thinking is the ability to infer the feelings and predict the intentions of characters. This ability is called ‘theory of mind’. Most of us have an innate ability to deceive, cooperate, empathize, and read the body language of others. These abilities operate out of the prefrontal sections of the brain (areas 45, 46 and 9) (Baron-Cohen et al., 1985; Geary, 2005; Gallagher & Frith, 2003; Rizzlatti et al., 2001; Siegal & Varley, 2002).

Conceptual thinking

Concepts or facts about objects, events and ideas are stored in many different and connected parts of the brain. Concepts seemed to be stored in systems along the middle and lower parts of the temporal lobe (Brodmann areas 37, 38, 20, 21 and 22). Conceptual categories such as objects, peoples' names, verbs, and animals are stored in separate areas. For example, it seems our concepts for people (autobiographical memories) are stored in Brodmann area 38, animals in Brodmann area 20, and tools at the bottom of Brodmann area 37. A small area at the top of the brain stem called the amygdale has a specific role in memory for emotionally disturbing concepts. Together, these are the areas differentially engaged when learners use an intermediate Concept Frame.

5) The subject specific criterion

The subject specific criterion and the following text linked criterion are relevant because they are both concerned with literacy and with how language facilitates the construction of knowledge. The intermediate Concept Frame can be used across curriculum areas. In contrast, Flow Diagram tools align with the subject specific criterion because they are well suited to the explanatory discourse of science.

National curriculum documents are typically divided into subject domains. What we know about each subject is the outcome of subject specific, disciplined types of thinking. For example, the American Association for the Advancement of Science (1996) has identified three types of subject specific 'scientific thinking': systemic, temporal-causal, and model thinking. Systemic thinking helps learners comprehend how a water cycle (a system) works, or how actual or fictional social systems work. The two components of temporal-causal thinking are change and scale. Science involves thinking about how things change over time and how much they change. This type of thinking also applies to the comprehension of narrative plots or historical recounts. Model thinking allows us to represent ideas, objects and events, often unavailable to direct inspection, as metaphor, analogies, and visual mental images (Coll, 2005; Gilbert & Boulter, 2000; Taylor, 2000). Clearly model thinking also has a place in English, mathematics, and other subjects.

Together, these arguments give support for the inclusion of a subject specific criterion that might be applied to justify teachers' use of literacy and thinking tools.

6) The text linked criterion

Support for a text linked criterion is based on the claim that specific subjects evoke certain types of thinking, and the key additional claim for links between types of thinking and text types. Indeed, Pontecorvo (1993) suggests that 'forms of discourse become forms of thinking' (p.191). For example, the thinking associated with writing a report, is both a response to subject specific ways of knowing, and to the type of text linked thinking evoked by subjects that use report texts. Writing a report about birds is both a response to science specific or ornithological ways of knowing about birds, and a response to the type of thinking evoked by the form and function of report texts. As, Lemke (1990) notes, a hallmark of engaging in learning is the opportunity to acquire subject specific discourse. This position is consistent with that of functional systemic linguists (Halliday, 1985; Martin, 1985) who make links between the social construction of knowledge and text forms. Literacy and thinking tools that evoke types of thinking similar to that evoked by a text learners are required to read, write, or talk are probably best used when they read, write, or talk those texts.

The subject specific and text linked criteria assist teachers to justify the literacy dimension of literacy and thinking tools.

7) The developmentally appropriate criterion

One reason for designing tools consistent with a developmentally appropriate criterion is linked to the professional responsibility of teachers to meet the needs of diverse learners. A second reason is linked to a principle that signals the need to scaffold students' learning. A further reason is that tools should provide a challenge to learners. This justification, consistent with research by Locke & Latham (1992), suggests achievement is enhanced to the degree that learners are set challenging goals; the greater the challenge the higher the probability of learners seeking, receiving, and assimilating feedback information.

Curriculum documents internationally, with the notable exception of the [Australian] Victorian curriculum, rarely include a developmental dimension in their description of literacy and thinking tools. In addition to the reasons outlined above, the inclusion of a developmentally appropriate criterion appears warranted because it is consistent with calls from educational psychologists for differentiated instruction (Brophy, 2001). Tools consistent with a developmentally appropriate criterion are designed to meet the needs of students at different levels of social, academic, and cognitive maturity. Thus this criterion reflects beliefs about variation in students' attention spans, ability to work in groups, motivation, learning styles, and in the types of text-related intellectual tasks they encounter in classrooms.

The developmentally appropriate criterion does not signal that tools should be age linked. If eight-year-old learners are capable of using an intermediate level Concept Frame rather than a simple level Concept Frame, they should be encouraged to do so. However, the more abstract thinking evoked by some 'complex level' tools might signal the need to scaffold their use, that is, to use them in ways consistent with the teaching focus criterion rather than the learner focus criterion. Teachers can plan to use tools at an appropriate level, but bear in mind that levels should never deny learners opportunities to think.

8) The assessment linked criterion

One reason for the inclusion of an assessment linked criterion is the need to recursively, monitor, plan, and teach when using tools. Another reason relates to the observation that forms of assessment have a powerful influence on the kinds of instruction learners' encounter, and the kind of learning they can accomplish. A further reason is based around the belief that there is nothing inherently wrong with assessing the content we teach, as long as we concurrently and regularly assess in ways that reflect how that content was taught. The assessment linked criterion is, therefore, consistent with the use of literacy and thinking tools that engage learners' in formative assessment (Black & Wiliam, 1998). The Concept Frame can be used as an assessment tool, thus enabling teachers to test as they taught, that is, in an ecologically valid way.

Conclusion

The importance of research linked criteria for the design and selection of literacy and thinking tools lays in the responsibility of elementary school teachers to justify what they do. These criteria described and justified in detail in this paper, provide guidance and understanding; guidance when it comes to selecting tools appropriate to learners needs and task demands, and understanding in respect to the impact of these tools on learning.

References

Alton-Lee, A. (2003). *Quality teaching for diverse students in schooling: best evidence synthesis*. Wellington: Ministry of Education.

Alvermann, D., & Hayes, D.A. (1989). Classroom discussion of content areas reading assignments: An intervention study. *Reading Research Quarterly*, *24*, 305-335.

Anderson, L., & Krathwohl, D. A. (2001). *Taxonomy for learning, teaching and assessing: A revision of Bloom's Taxonomy of Educational Objectives*. New York: Longman.

Ash, S., Moore, P., Antani, S., McCawley, G., & Work, M. (2006). Trying to tell a tale: Discourse impairments in progressive aphasia and frontotemporal dementia. *Neurology, 66*:1405-1413.

Ashcraft, M. (2007). *Cognition*. New York: Pearson.

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a "theory of mind"? *Cognition, 21*, 37–46.

Blagg, N. (1991). *Can we teach intelligence*? Hillsdale, N.J.: Erlbaum.

Black, P.J., & Wiliam, D. (1998). Assessment and classroom learning. Assessment in Classroom learning. *Principles, Policy and Practice*, *5*(1), 7-74.

Blaut J.M., Stea D., Spencer C., & Blades, M. (2003) Mapping as a cultural and cognitive universal. *Annals of the Association of American Geographers, 93*(1), 165-185.

Brooks, J.G., & Brooks, M.G. (1993). *In Search of Understanding: The Case for Constructivist Classrooms.* Alexandria, VA: Association for Supervision and Curriculum Development.

Brophy, J. (Ed.). (2001). *Subject-specific instructional methods and activities. Advances in research on teaching, Vol. 8.* New York: Elsevier.

Burgess, G.G. (1988). *Conducting qualitative research*. London: JAI Press.

Coll, R.K. (2005). The role of models, mental models and analogies in chemistry teaching. In P. Aubusson, & A.G. Harrison (Eds.) *Metaphor and analogy in science education*. Dordrecht: Kluwer.

Collins, A., & Loftus, E. (1975). A spreading activation theory of semantic processing. *Psychological Review, 82*, 407-428.

Curriculum Council (1998). *Curriculum framework for Kindergarten to Year 12 Education in Western Australia*. Osborne Park, WA: Author.

de Bono, E. (1976). *Teaching thinking*. London: Maurice Temple Smith.

Donovan, M.S., Bransford, J.D., & Pellegrino, J.W. (Eds.). (1999). *How people learn: Bridging research*. National Academy Press.

Farah, M.J., & McClelland, J.L. (1991). A computational model of semantic memory impairment: Modality specificity and emergent category specificity. *Journal of Experimental Psychology: General, 120*, 339-357.

Fernandez, D., Baird, J.A., & Posner, M.I. (2000). Executive attention and metacognitive regulation. *Consciousness and Cognition*, 9(2), 288-307.

Forehand, M., & Fisher, D (2005). Bloom's taxonomy. Retrieved January 15, 2008, from http://projects.coe.uga.edu/epltt/index.php?title=Bloom%27s_Taxonomy

Gallagher, H.L., & Frith, C.D. (2003). Functional imaging of 'theory of mind', *Trends in Cognitive Sciences, 7*(2), 77–83.

Gazzaniga, M.S., Irvy, R.B., & Mangun, G.R. (2002). *Cognitive neuroscience*. (2nd edition). New York: Norton.

Geary, D. C. (2005). *The origin of mind: evolution of brain, cognition, and general intelligence*. Washington, DC: American Psychological Association.

Gee. J. (1991). *Social linguistics and literacies*. London: Falmer Press.

Georghiades, P. (2000). Beyond conceptual change learning in science education: Focusing on durability, transfer and metacognition. *Educational Research, 42*, 119-139.

Gilbert, J. (2005). *Catching the knowledge wave? The knowledge society and the future of education.* Wellington: New Zealand Council for Educational Research.

Gilbert, J., & Boulter, C. (2000). *Developing models in science education*. Dordrecht: Kluwer.

Goldenberg, C. (1993). Instructional conversations: Promoting comprehension through discussion. *Reading Teacher, 46*(4), 316-326.

Goleman, D. (1995). *Emotional intelligence: Why it can matter more than IQ*. New York: Bantam Books.

Greene, J., & Haidt, J. (2002). How (and where) does moral judgment work? *Trends in Cognitive Sciences, 6*(12), 517-523.

Haidt, J. (2007). The new synthesis in moral psychology. *Science 316*, 998-1002.

Hattie, J. (2003). Teachers make a difference: What is the research evidence? Retrieved 20 July, 2007, from http://www.decs.sa.gov.au/limestonecoast/files/pages/new%20page/PLC/teachers_make_a_difference.pdf.

Halliday, M.A.K. (1985). *An introduction to functional grammar*. London: Edward Arnold.

Hipkins, R., Bolstad, R., Baker, R., Jones, A., Barker, M., Bell, B., Coll, R., Cooper, B., Forret, M., Harlow, A, Talyor, I., France, B., & Haigh, M. (2002). *Curriculum learning and effective pedagogy: a literature review in science education*. Report to the Ministry of Education. University of Waikato.

Lipman, M. (1977). *Philosophy in the classroom*. Montclair State College, Upper Montclair, N.J: Institute for the Advancement of Philosophy for Children.

Lipman, M. (1995). Caring as thinking. *Critical Thinking Across the Disciplines*, *15*(1), 1-13.

Locke, E. A., & Latham, G. P. (1992). Comments on McLeod, Liker & Lobel. Journ*al of Applied Behavioral Science*, *28*, 42-45.

Lyotard, J. F. (1984). *The postmodern condition: A report on knowledge.* Manchester: Manchester University Press.

Martin, J. (1985). *Factual writing: Exploring and challenging social reality*. Geelong: Deakin University Press.

Martin, R., Sexton, C., Wagner, K., & Gerlovich, J. (1997). *Teaching science for all children* (2nd ed.). Boston: Allyn & Bacon.

Mashala, N., Fausta, M., Hendlerc, T., & Jung-Beemane, M. (2007). Is metaphor unique? Neural correlates of nonliteral language. *Brain and Language, 100*(2), 115-126.

May, S., & Smyth, J. (Eds.). (2007). Addressing literacy in secondary schools [Special Issue]. *Language and Education, 21*(5).

McComas, W. F. (1998). The *nature of science in science education*. Dordrecht: Kluwer.

Millett, S. (2003). Thinking tools for teaching ethics across the curriculum. *Critical and Creative Thinking, March*, 2-13.

National Institute of Child Health and Human Development (2000). *Report of the National Reading Panel. Teaching children to read: An evidence-based assessment of the scientific research literature on reading and its implications for reading instruction*. Washington: Author.

Neisser, U. (1976). *Cognitive psychology*. New York: Appleton-Century-Crofts.

Nosich, G. (2005). *Thinking across the curriculum*. New York: Sage Publications.

Paul, R. (1987). *Critical thinking: What every person needs to survive in a rapidly changing world*. Rohnert Park, Calif.: Foundation for Critical Thinking.

Pohl, M. (2000). *Learning to think, thinking to learn: models and strategies to develop a classroom culture of thinking*. Highett, Victoria, Australia: Hawker Brownlow Education.

Pontecorvo, C. (1993). Forms of discourse and shared thinking. *Cognition and Instruction, 11*(3 & 4), 189-196.

Pinker, S. (2002). *The blank slate*. New York: Penguin.

Read, S. J., & Miller, L. C. (1995). Stories are fundamental to meaning and memory: for social creatures, could it be otherwise? In R. S. Wyer, (Ed.), *Knowledge and memory: The real story* (pp.139-152). Hillsdale, New Jersey: Lawrence Erlbaum Associates.

Rizzolatti, G., Fogassi, L., & Gallese, V. (2001). Neurophysiological mechanisms underlying the understanding and imitation of action. *Neuroscience, 2*, 661- 670

Ruddell, M. (2002). *Teaching content reading and writing*. New York: Wiley.

Rugg, M.D., Otten, L.J., & Henson, R.N.A. (2007). The neural basis of episodic memory: Evidence from functional neuroimaging. *Journal of Neuroscience, 27*, 14365-14374.

Sadoski, M., & Paivio, A. (2001). *Imagery and text*. Mahwah, N.J.: Lawrence Erlbaum.

Schoenbach, R., Greenleaf, C., Cziko, C., & Hurwitz, L. (1999). *Reading for understanding: A guide to improving reading in middle and high school classrooms*. San Francisco: Jossey-Bass and West-Ed.

Scott, P., Asoko, H., & Driver, R. (1992). Teaching for conceptual change: A review of strategies. In R. Duit, F. Goldberg, & H. Niederer (Eds.), Res*earch in physics learning: Theoretical issues and empirical studies* (pp.310-329). Kiel: Institute for Science Education at University of Kiel.

Siegal, M. & Varley, R. (2002). Neural systems involved in theory of mind. *Nat. Rev. Neurosci. 3*, 462–471.

Shaywitz, S.E., & Shaywitz, B.A. (2007). What neuroscience really tells us about reading instruction. *Educational Leadership, 64*(5), 74-76.

Shimamura, A. P. (2000). Toward a cognitive neuroscience of metacognition. *Consciousness and Cognition, 9,* 313-323.

Sternberg, R.J., & Lubart, T.I. (1999). Investing in creativity. *American Psychologist, 51*(7), 677-688.

Taylor, I. J. (2000). *Promoting mental model-building in astronomy education*. Unpublished Ph.D. Thesis, University of Waikato, Hamilton.

Troiani, V., Ash, S., Reilly, J., & Grossman, M. (2006). The neural correlates of narrative discourse: An investigation using arterial spin-labelling. *Brain and Language*, *99*(1), 191-192

Tulving E (2002). Episodic memory: from mind to brain. *Annual Review of Psychology 53*, 1-25.

Vygotsky, L.S. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Whitaker, H. A., F., Savary, H., Markovits, C., Grou, C., &. Braun, M.J. (1991). *Inference deficits after brain damage*. Paper presented at the annual INS meeting, San Antonio, Texas.

Whitehead, D. (2001). *Top tools for literacy and learning*. Auckland: Pearson Education.

Whitehead, D. (2004). *Top tools for teaching thinking*. Auckland: Pearson Education.

Whitehead, D. (2006). Justifying what we do. *English in Aoteraroa, 57,* 3-12.

Wilks, S. (1992). *An evaluation of Lipman's Philosophy for Children curriculum*. Masters thesis University of Melbourne.

Willis, J. (2007a). The gully in the 'brain glitch' theory. *Educational Leadership, 64*(5), 68-73.

Willis, J. (2007b). Toward a neuro-logical reading instruction. *Educational Leadership, 64*(6), 80-82.

Wolfe, P. (2001). *Brain matters: Translating the research to classroom practice*. Alexandria, VA.: Association for Supervision and Curriculum Development.

Wright, N., May, S., Whitehead, D., Smyth, J. (2005). *Secondary Schools Literacy Initiative Research Evaluation. Sustaining Literacy initiatives in Secondary Schools*. Hamilton: Wilf Malcolm Institute for Educational Research, University of Waikato.

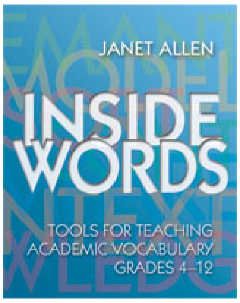
Wright, N., May, S., Whitehead, D., Smyth, J. (2006 June). *Secondary Schools Literacy Initiative Research Evaluation. Case Studies of Secondary Schools Literacy Clusters 2005*. Hamilton: Wilf Malcolm Institute for Educational Research, University of Waikato.

Wright, N., Whitehead, D., May, S., & Smyth, J. (2007*). Secondary Literacy Project Evaluation Report on 2006 Case Study Schools*. Hamilton, NZ: Wilf Malcolm Institute for Educational Research, University of Waikato.

International Electronic Journal of Elementary Education
Vol.1, Issue 1, October 2008.

Book review

Inside Words: Tools for Teaching Academic Vocabulary Grades 4-12
Janet Allen.
Portland, ME: Stenhouse Publishers, 2007.
163 pp. ISBN: 978-1-57110-399-4.



Lee Corey

Cypress Creek High School
Orlando, Florida
Leec721@aol.com

One of my favorite new professional books is *Inside Words: Tools for Teaching Academic Vocabulary Grades 4-12* by Dr. Janet Allen. Allen has shared her years of experience in teaching English and reading through books like *It's Never Too Late* and *On the Same Page.* In *Words, Words, Words* she focused on vocabulary instruction in her classroom and the classrooms of teachers she has mentored. But the teaching of reading and literacy needs to extend beyond the English classroom, which means the teaching of vocabulary does as well. *Inside Words* responds to that need.

According to the National Institute for Literacy "Readers cannot understand what they are reading without knowing what most of the words mean. As students learn to read more advanced texts, they must learn the meaning of new words that are not part of their oral vocabulary" (2001, p. 34). As teachers of English, we must not only focus on reading and writing, but on vocabulary development that supports that reading and writing. *Inside Words* is a book of practical strategies for teaching vocabulary in any content area.

As always, Allen's instruction is grounded in research. In *Inside Words* she begins with a research base for teaching vocabulary. She even has a one-page summary of the research indicating a main idea for the teaching of vocabulary and the source of the research. For example, "Students learn words through wide reading" comes from Nagy and Herman, 1987 and Fielding, Wilson, and Anderson, 1986. In fact, the research base is one of the most impressive aspects of this book. After each individual strategy, there is a list of research and references for further reading.

ISSN:1307-9298

www.iejee.com

Unlike most of her other books, once you get past the introduction, there are no stories about life in a classroom full of struggling readers. This is a book of strategy lessons for any teacher to use with any students. The strategies are organized in alphabetical order. Each strategy includes a definition and citation, directions for using the strategy, when the strategy might be used and ideas for adaptation, blank graphic organizers and student examples. In other words, a teacher can take five minutes, read 4-5 pages of the book and have something to use in class the next day. It is arranged in a clear, concise, teacher-friendly format.

Although the book is formatted with the strategies in alphabetical order, a second table of contents lists specific purposes for building content-area vocabulary paired with appropriate instructional strategies. For example, if you need to build background knowledge, Allen suggests you use a Concept Ladder, Dictoglos, a Focused Cloze, the Frayer Model, a List-Group-Label, Possible Questions, Possible Sentences, a Vocab-o-gram and/or a Word Sort. The categories of instructional strategies are “Teaches Words That Are Critical to Comprehension,” “Provides Support During Reading and Writing,” “Develops Conceptual Framework for Themes, Topics, and Units of Study,” and “Assess Students’ Understanding of Words and Concepts.” This second table of contents makes it easy to find a vocabulary strategy for any teacher’s specific purpose.

I have tried many of these lessons in my own classroom. One of my favorites is Concept Circles (Vacca, Vacca and Gove 1987). A Concept Circle is divided into 3 or 4 sections with a different word in each section. The teacher can fill in all of the sections with words and ask students to make connections between the words in writing or the teacher can fill in 1 or 2 words and ask students to add words that are connected to the words already in the circle. Students can also be given a concept and find 3-4 words related to that concept to put in the circle. Because the strategy is so flexible, it can be used to allow students to find words, to practice using words they already have, to verbalize their thinking about words and/or to assess their word knowledge.

There are two other resources that make this book a must-have for any teacher. The appendix in the back of the book has full-page copies of the graphic organizers for each strategy in English and Spanish. In addition, the book comes with a CD that has a printable version of each of the graphic organizers.

Whether you teach elementary, middle or high school, *Inside Words* has practical ideas that can be put to use immediately. This book is an excellent resource for any teacher in any discipline who wants to use research-based strategies to improve vocabulary instruction.