Cognitive Acceleration in Primary Science Teacher Education: catching-up at third level

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The Cognitive Acceleration through Science Education, i.e., CASE, or Thinking Science, i.e., TS, programme, developed originally in the mid-1980's in UK, has been shown to be effective in increasing students cognitive levels in Ireland as well as elsewhere in the anglophone world. Previous studies have focussed on implementation of CASE with particular class groups of children in primary or secondary school, the development of teachers to implement CASE in primary school with particular attention to metacognition, or the transition from primary to secondary school. In this work, the relevence of thinking skills to the primary curriculum is portrayed, and a discussion of the current emphasis in skills in general in science education by stakeholders. It is argued that skills education requires a different kind of learning, and therefore teaching, and that young adults who plan to be primary teachers are in a deficit of thinking skills as they are still channelized by a content driven school system. A CASE-based initial teacher education framework is proposed.

SCOPE AND PURPOSE

The purpose of this paper, which is part of long-term on-going work in encouraging thinking skills in children, is to cause stakeholders in primary level science education to reflect. The reflection being sought is on the preparation of primary level teachers of science, thinking about how much we should expect them to know, what kind of knowledge they should have, and how we can rectify deficits in skills and understanding. To be honest, the question is not new, but stakeholders are apt to fudge such questions in order to realize short-term goals: Wynne Harlen in a UNESCO report from 1993, and repeated in many books since, even titled a chapter on this very point (Harlen, 1993).

INTRODUCTION

The aphorism "*Teachers should know more than the children they teach*" implies that knowing is merely a matter of quantification, in which case, the better teacher would be someone who 'knows more' than others. In some areas, such as science and ICT, children often 'know' things that teachers do not as yet know thanks to the availability of various information media. In the past, when such information media were not available, it could be guaranteed that teachers adopted to role of 'sages' and *'fountains of all wisdom and knowledge'*, pillars of the community, the first to own a telephone, car, or television. The first to receive the signs that the world was changing, the last perhaps to embrace the change in their workplace. For the purpose of this paper, i) 'knowing' is simply the acquisition of facts and concepts; ii) ‘understanding’ is more complex, involving networks between concepts and varying degrees of structuralisation and complexity; iii) ‘wisdom’ is the deployment of knowledge and the employment of understanding in contexts that are different from those in which the ‘knowing’ arose, or the ‘understanding’ originally was intended.

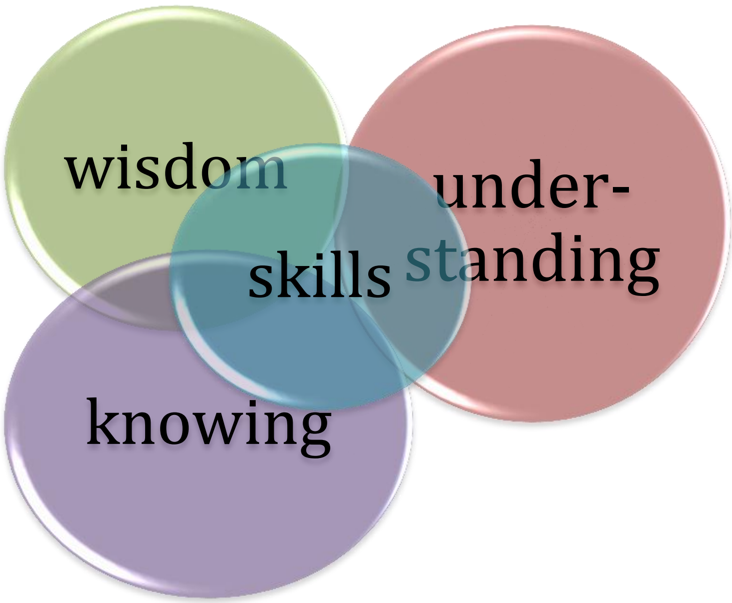

Figure 1: Over-simplified model of cognitive architecture – are any of the areas of the Venn diagram null?

It is important to note that although this three-fold list appears to be a hierarchy, it does not presume that one leads to another in a linear fashion. In fact, the three ‘spheres’, namely: knowledge, understanding, wisdom, involve manifold feedback mechanisms cutting across various domains. Furthermore, one can have knowing or understanding with/without wisdom and skills can cut across the three spheres as a floating entity as required. Skills acquisition could involve acquiring specific knowledge, and knowledge requires ‘skills’ in order to develop. What has been outlined thus far is a rather over-simplified cognitive architecture; however, the problem this work attempts to address is the emphasis on knowing without understanding or wisdom that is encouraged in the Irish education system today. Of all the interventions that developed out of the science education revolution of 1970s, the Cognitive Acceleration through Science Education, i.e., CASE, (Adey, Nagey, Robertson, Serret, & Wadsworth, 2003; Adey, Robertson, & Venville, 2001, 2002; Adey, Shayer, & Yates, 2001) or Thinking Science, i.e., TS, programme, developed originally in the mid-1980’s in the UK stands up as one which goes beyond seeking to have children merely ‘know more’. In Ireland, a body of research is underway to

Table 1: Previous / current research in Ireland in cognitive acceleration in science education

Researcher	Institution	Focus
Maume (1998)	TCD	CASE 11-14 in Transition year only
Gallagher (2008)	DCU	LTEY Infants (4 – 5 years) in the three schemata of classification, seriation, and causality
McCormack (2009)	DCU	CASE 11-14 across 1' – 2' transition
Ryan (2014)	DCU	CASE 11-14 – metacognition in the primary school
McCloughlin (1997 – date)	DCU	adapting existing lessons to the CASE "pillars" at three levels (secondary, and from 2000 primary and tertiary)(Gash, McCloughlin, & O'Reilly, 2008; T. McCloughlin, Gash, & O'Reilly, 2008; T. McCloughlin, O'Reilly, & Gash, 2009)

Maume (1998) and McCormack (2009) examined the feasibility of transferring the CASE 11-14 programme to the Irish context, and the results were very promising. Gallagher (2008) and Ryan (2014) on the other hand examined contrasting aspects of the cognitive acceleration / thinking skills programme in primary school specifically . Gallagher (Gallagher) looked at specific schemata for 4-5 year olds, and Ryan (Ryan) looked at specific pillars such as metacognition, all the more impressive as metacognition was seen as a difficult entity to investigate.

DISCUSSION

If stakeholders assert, and many do, that primary teachers should know the basics, fundamentals or primitives of science in order to teach science to children, leaving aside a definition of 'knowing', then the same stakeholders need to qualify their assertion by a definition of 'knowing' and a quantification of what is known. There is a reluctance to do this, and even where a broad scope of objectives are intended for children to learn science i.e., the 'curriculum', specially the 'revised' curriculum of 1999 (Assessment, 1999), there is little guidance in the matter of the two points of qualification of knowing and quantification of what is known. This leads to a number of fundamental "thoughtful questions" for teacher educators which will be briefly examined in turn.

Thoughtful question 1, how much should a primary teacher know?

As mentioned above, there is a lack of consensus as to how much a primary teacher should know. Of course, in order to answer the 'how much' question, one first needs to ask and answer the point as to what kind of knowledge and understandings should a teacher have? This will in turn depend on the stakeholders' views of what knowledge is and what learning is? One of the issues, the CASE project attempted to address was the issue of whether there is a central processing unit and how it might benefit an overarching view of intelligence. Notwithstanding the findings of researchers on multiple 'intelligences' (Kincheloe, 2004), the main argument appears to be no more than an attempt to explain how different people have different expertise or skills – preferable terms than 'intelligences' – and that the argument is political i.e., to assure the masses that everyone is valued for their own especial expertise and that everyone has a speciality of some sort. All this is very well, commendable even, but there is a lack in explaining how intelligence works from an epistemological viewpoint. No such lack exists with respect to the CASE project, furthermore, whereas 'multiple intelligences' can say little about the Flynn Effect; CASE researchers have noted an anti-Flynn effect (Shayer, Ginsburg, & Coe, 2007) over the last 30 years which counters the argument that CASE focuses on a simplistic view of intelligence or is merely a motivational exercise. It is much more, seeking to make explicit and apply Jean Piaget's and Lev Vygotsky's (Shayer, 2003) observations and theories of learning which are summed up in the Five Pillars of CASE, Table 2., in effect, methodologies to learning – not facts – but 'ways of thinking'. 'Ways of thinking' are the *schèmes* of Jean Piaget (Piaget, 1928). Piaget defined a *schème* as the mental representation of an associated set of perceptions, ideas, and/or actions. Piaget considered *schèmes* to be the basic building blocks of thinking, which could be 'discrete and specific', or 'sequential and elaborate'. Finally, certain *schèmes* were considered age-appropriate developing when a state of 'readiness' had been achieved, and Piaget suggested a model of stages which could be indicative of such a state of 'readiness'. 'Readiness' is, of course, a key concept in literacy and numeracy.

Table 2: The Five Pillars of CASE: an Cúig philéar de CASE

Pillar *Piléar*	Essence
Cognitive conflict *Coimhlint chognaíoch*	thinking about a problem in a way that challenges prior knowledge
Social Construction *Tógála sóisialta*	sharing explanations and under-standings of a problem and potential solutions.
Bridging *Droicheadú*	working together to apply ideas 'generated' in the lesson to problems in the real world
Concrete preparation *Ullmhú coincréiteach*	introducing a problem and helping with any new vocabulary or ways of doing
Metacognition *Meiteachognaíocht*	reflecting on thinking and articulating approaches to solving the problem

In addition to a teacher having proficiency in the five pillars or methodologies of CASE, the specific content of a teacher education course would focus on the *schèmes* and content would be channelised to meet goals that involved proficiency in each *schème*, Table 3.The assessment of such a programme would not be in content acquisition but rather in direct measurement of cognitive level which is a function of integration of *schèmes.*

Table 3: *Schèmes* and their essence

Schème	Essence
Classification	Categorising objects or an array according to sensory similarities or dissimilarities
Seriation	Linear classification
Time sequencing	Linear classification in time
Causality	Understanding "cause and effect"
Conservation	Understanding that the number, weight or volume of physical entities remains constant despite changes in physical arrangement
Proportionality	Understanding the likelihood or chance of an event happening
Correlation	Understanding possible relationships between two or more variables
Combinatorial thinking	Understanding possible combinations of objects yields a new result
Equilibrium	Understanding that changing two or more variables until they balance
Control of variables	Understanding that changing one variable affects another

Assessment of student teachers in terms of their cognitive level raises a second question, namely:

Thoughtful question 2, would you expect a 5th class child to have a higher cognitive level than an undergraduate student teacher?

It would be expected that the answer to this would be in the affirmative, but the reality is not so simple. In a typical set of 3 samples, Figure 2., 5th class boys and 3rd year – final year - Bachelor of Education students completed assessments of cognitive level SRT II Volume and Heaviness - range 1-3A based on Piaget's "child's construction of quantities"(Piaget & Inhelder, 1974). My initial hypothesis was that the undergraduates would be bunched up around the scores of 7 – 8, and certainly there would be no overlap, however this is in fact not the case. I also tested 2nd year Junior Certificate level students in secondary school – SRT III Pendulum - range 2B - 3B based on Piaget's "the growth of logical thinking" (Inhelder & Piaget, 1958) – and it was noteworthy that no student achieved the 3B score. These results are consistent with the findings of Shayer et al. (2007). This is somewhat disturbing as, cognitively speaking, graduates from the Bachelor of Education programme who are scoring much lower in cognitive scales than 5th class boys or even secondary school students will inevitably lead to lessons devised as too simple for the boys leading to disenchantment in education. Whereas the *schèmes* outlined in Table 3. begin at specific ages in children; it is often assumed that they should be only addressed at that age. This is in fact a fallacy, as all the *schèmes* benefit from 'enrichment' through further development from work designed to promote a particular *schème* throughout life.

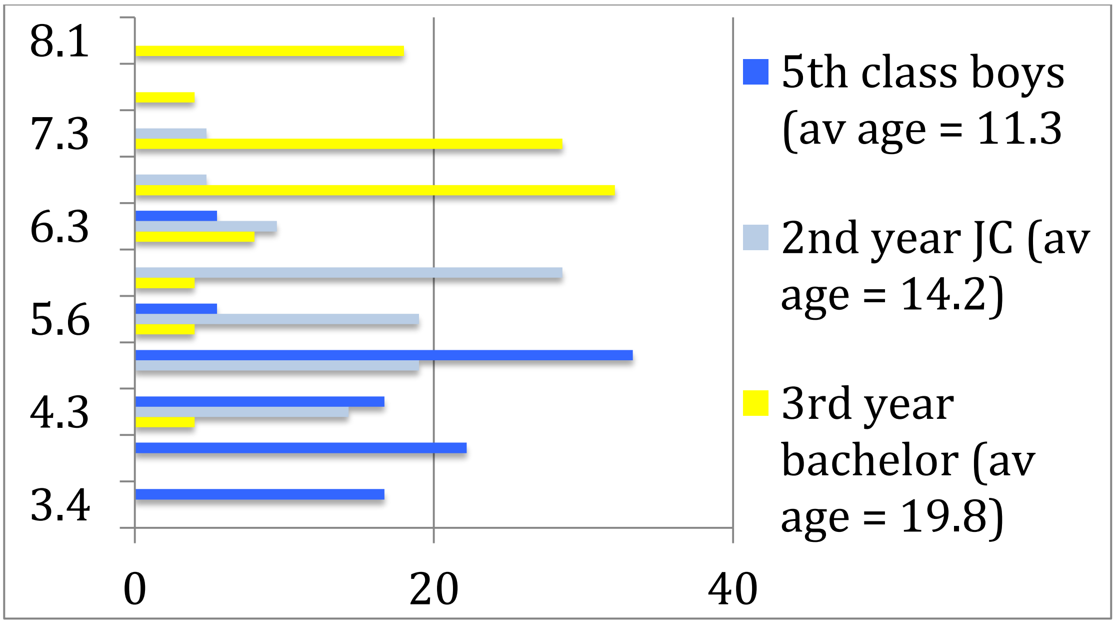

Figure 2: Piagetian Levels in three typical samples

Finally, in one approach final year Bachelor of Education Students on an elective course, n=74, did show a general (proportion of students achieving 3A or 3B) 'improvement' of cognitive level after 'engaging' with CASE, in effect a remediation of the downward shift below 6.5. This approach involved:

- Experiencing 36 hours of CASE 11-14 lessons, plus reflections, and
- teaching 3 CASE lessons, plus evaluations, on teaching practice, and
- writing and researching an essay on the CASE methodology (T. J. J. McCloughlin, forthcoming).

Thus, it can be said that these students were best prepared to teach science in way that does not focus on content without context or doing hands-on practical sessions without a thinking or 'minds-on' component.

CONCLUSIONS

- Student teachers have too great a spread of cognitive levels, including alarmingly low cognitive levels, given their educational background.
- It is recognised that some student teachers have a deficit in content and/or skills. However, science methods courses do not often seek to remediate knowledge deficits or skills deficits in science – they usually try to provide 'experiences' for students to become 'confident' in science in order to develop science pedagogy. But, science content and skills deficits can be addressed by engaging in a CASE-informed ITT course.
- The general principle of 'improvement' or 'acceleration' (a higher level sooner) is mediated through a different way of teaching (invoking the 5 pillars: concrete preparation, social construction, bridging, metacognition, cognitive conflict) rather than just teaching / transmitting more content ("the one big thing").

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