Competency-Based Education– Neither a Panacea nor a Pariah

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Introduction

It is common for Australian university academics to be critical of competency-based education systems. The values that underpin a competency-based approach and those on which traditional university education have been based are often seen to be at odds. A focus on the development of prescribed workplace skills is seen by many academics to be inconsistent with a focus on the general development of the mind. Not surprisingly, we found in an Australian study a few years ago (Bowden and Masters 1993, pp 100—102) that more than half the academics expressed negative views about a competency-based approach to university education on the grounds that such an approach is too narrow and conformist. Yet nearly 80% of those same academics indicated that they had had no experience of a competency-based approach and nearly 60% acknowledged that they had little or no knowledge of what a competency-based approach to education is about.

As this paper proceeds, those who have not paid much attention to the competency debate over recent decades will come to realise what those who have been following the debate already know, viz that the Australian finding is not unusual. Much of the debate has been based on ignorance. This does not mean that the academics' views cited above must be wrong but it does mean that they are no more telling than the similar attacks on university agendas by assertion rather than by argument, by some in the competency movement. Something more than mere assertion is needed for the debate to lead to constructive outcomes.

Anyone concerned to address these issues needs to analyse what the competency movement is about, consider what the mission of tertiary education should be in the late 20th century and attempt to discover whether there are some common purposes to be served and something to be gained by abandoning the siege mentality of many on both sides of the debate. Such a process should have two things in mind.

The first is that the quality of student learning should be at the centre of any argument

The second is that there is a need to acknowledge that both the competency movement and the nature of tertiary education have been changing over time.

This paper attempts to make a small contribution to that process. The perspectives from which competency-based education is analysed in this paper include a brief political and historical account, an analysis of the nature of a competency-based approach, consideration of the relation between competencies and competence and some attention to its basis in educational theory.

From my perspective, competency-based education is neither a unique, earth-shattering device for completely overhauling approaches to teaching and learning in post-secondary institutions, nor a self-evident blight on the educational landscape that should be eliminated, although there are many who hold one or other of those two extreme views. Historically, the competency movement has embraced some narrow, educationally suspect practices which have attracted due criticism. On the other hand, it has certain elements which are shared with other educational reform agendas and in that sense it is valuable but not unique.

Its presence in recent decades has been catalytic and has focused attention on some important educational reform issues and has been influential on educational change outside those areas that have actually adopted a competency-based approach. This applies particularly to the relation between the educational institutions and industry and also to the nature of the professions. In addition, within the competency movement, the idea of what a competency-based approach should be about has been evolving and many current practices are in stark contrast to earlier, less acceptable versions of competency-based education. Of course, in many other cases, practices have not changed much at all.

The competency debate has never been a subdued one. In most countries in which competency-based education has been on the agenda, there has been a time when the majority of commentators has appeared to have adopted either one or the other of the extreme positions mentioned earlier. My comments derive from first-hand experience in Australia during the 1990s, when I appeared on various platforms with a number of university vice-chancellors, trades union leaders, heads of government departments, members of industry training boards and leaders of professional associations. Those conferences and meetings during the early 1990s in Australia were vitriolic and political, with first one and then the other participant painting such an extreme picture of their opponent's perspective on competency-based education that all arguments were completely polarised.

It appeared that any individual had to be depicted either as opposing any preparation for work whatsoever in university degree programmes or, on the other hand, as being totally opposed to any learning not related to prescribed work performance. Nothing in between these opposite positions was recognised in such debates. For several years, educational newspapers and some parts of the Australian popular press avidly documented the polemics that emerged from those encounters. The polarised debates are reminiscent of the "behavioural objectives" debates some decades ago and have been commented on by Harris et al (1995) in a publication with the graphic title "Competency-based Education and Training: Between a Rock and a Whirlpool."

There have been unfortunate consequences. The nature of the debate has meant that political criteria have had a greater effect on decision-making within educational systems than they otherwise would if the debate had been more focused on learning. As a consequence some undesirable competency-based practices have been introduced, in Australian further education for instance, in forms that are not as educationally sound as they could or should be, to the dismay not only of commentators like myself but also of teachers in the system (see Kinsman, 1992).

Another feature of the debate has been the suggestion by some in universities that a competency-based approach is appropriate for training institutions but not for university education. I find this to be an unacceptable proposition and throughout this paper I do not make a distinction between education and training. I have difficulty in seeing training as being a different kind of activity from education when applied to the learning processes that people engage in to acquire qualifications or to develop their competence in the workplace. To the extent that training means learning to do something without understanding how or why, then it is to me merely an inferior form of education. This is unfair to students.

Worse still is to consign a particular group of students, or kind of work roles, to a learning programme which makes such an assumption. I can think of no occupation where understanding is a hindrance. The kinds of responsibilities that a plumber, a doctor, a mechanic, an engineer, a nurse, a carpenter, a teacher or an electrician each has, require judgement based on understanding of the context in which they are working and the relevance of their own knowledge and skills. To suggest that some of these obviously need to be trained while the others need to be educated seems to be without basis and not to take seriously the real nature of work. Unfortunately, the further education sector in Australia is distinguished from the higher education sector by the title VET (vocational education and training) which perpetuates this unfortunate view.

My interest in competency-based approaches has been as a researcher and as a manager of educational change in RMIT, a university of technology which provides both higher and further education programmes in integrated faculty structures. RMIT's intention is to develop a seamless system of education which embraces both sectors. I am interested in the same issues that drive the competency-based agenda but I am more interested in the conceptual and pedagogical aspects of the debate and the relation between educational experience and professional practice than I am in the political or economic aspects, let alone the economic rationalist agenda.

My involvement relates to a project team I led and a monograph we wrote for the Australian Federal Government (Bowden and Masters 1993), on the implications of the competency movement for higher education, with the Australian further education (VET) sector having already adopted a competency-based approach. The conclusions of the study were

moderate although the term moderate should not be taken as implying any uncertainty or lack of conviction. To the contrary, our conclusions might be described as aggressively moderate as we saw the competency movement as neither a panacea nor a pariah. There are useful aspects of competency-based approaches that should cause all tertiary teachers at least to pause and question their own practices. However, there also are forms of competency-based education which do not provide adequate learning experiences for students and which should not be adopted. Hence our conclusion was that neither of the polarised perspectives described earlier was tenable and that it was inappropriate either to reject outright all ideas associated with the competency movement or to embrace any particular competency-based approach without question. (Some conclusions of our study are listed later in this paper.) It is perhaps a reflection of the polarised debate already alluded to that our findings were criticised to an equal extent by university vice-chancellors and by members of the competency movement.

History and Principles Of Competency-based Systems

The concept of a competency-based education system is both an old and an evolving idea, details of which are still being worked out, especially in relation to higher education institutions and the professions. The notion of competency-based education programmes was first introduced in the USA, beginning in teacher education in the late 1960s, and evolved through applications to other professional education programmes in the USA in the 1970s, vocational training programmes in the UK and Germany among others in the 1980s and vocational training and professional skills recognition in Australia in the 1990s.

Such approaches have been promoted as key elements in the Australian Federal Government's agenda for training reform and improved skills recognition and, in promoting it in that way, the Australian Government have followed the lead of their counterparts in the UK. Competency-based approaches have been seen to have the potential not only to influence the ways in which employment-related skills are assessed and recognised, but also to influence the structure and delivery of formal education and training programmes and to provide enhanced opportunities for articulation between sectors and for credit transfer across institutions.

In seeking the origins of the competency-based movement, some writers point to parallels with the scientific management theories of Frederick W. Taylor in the early twentieth century. While some elements of competency-based education have clear parallels with Taylorist approaches and may indeed have been influenced by Taylor's work, competency-based education is most directly descended from the behavioural objectives movement of the 1950s in the United States. Its origins are found in the thinking of educators such as Benjamin Bloom.

The behavioural objectives movement sought to focus attention on the intended outcomes of learning programmes and, in particular, to encourage teachers to express their instructional objectives as changes in observable student behaviours. Proponents of the movement advocated the specification of objectives as 'directly observable behaviours which can be reliably recorded as either present or absent' (Bloom et al. 1971, p 28). An important feature of the movement was the desire for reliability of observation and judgement. Writers of behavioural objectives were encouraged to state outcomes 'in terms which are operational, involving reliable observation, and allowing no leeway in interpretation'. In an attempt to achieve this degree of reliability, statements of educational objectives begin with verbs describing student behaviour such as 'states', 'lists,' 'names,' 'selects,' 'recognises,' matches,' and 'calculates' (Bloom, et al. 1971, p 34). It is this narrowness that has led to much of the criticism of such approaches, then and now.

The behavioural objectives movement of the late 1950s and 1960s gave rise in the 1970s to four related developments: mastery learning (Bloom 1974); criterion-referenced testing (Popham 1978); minimum competency testing (Jaeger and Tittle 1980); and competency-based education (Burke et al. 1975)

Although the imperatives for the introduction of competency-based education have been different in different countries at different times, and the ways in which this concept has been operationalised have changed over time, the basic principles and intentions of competency-based education have remained essentially unchanged since the 1960s. They are:

- a focus on outcomes

- greater workplace relevance
- outcomes as observable competencies
- assessments as judgements of competence
- improved skills recognition
- improved articulation and credit transfer

There are two themes through these. One derives from economic and social theories and is the basis for the political debate which has threatened to overwhelm the pedagogical questions. The second concerns the relation between the world of learning and the world of work and the mechanisms by which experience of one is a preparation for participation in the other.

This paper focuses on the second rather than the first of these two themes. A more complete analysis of the history of the competency movement and the principles of competency-based approaches may be found in Bowden and Masters (1993) from which this account draws and which describes developments in Australia in the 1990s. Houston (1985) describes the early movement in the USA in the 1970s while Jessup (1991) and Tuxworth (1989) deal with UK developments in the 1980s.

A focus on outcomes

A first characteristic of competency-based education is its emphasis on the specification and assessment of outcomes (referred to as competencies). This focus on outcomes is often contrasted with more traditional concerns of educational programmes with inputs such as methods of student/trainee selection, lengths of courses and training programmes, class sizes, teacher-pupil ratios and so on (Spady 1977; Johnston 1992).

Of course, competency-based education is not unique in its intention to focus more sharply on educational outcomes. This intention is central to many current initiatives in education in many countries, including the development of educational performance indicators; the setting of national educational goals; the introduction of statements and profiles for key areas of the curriculum; and the development of programmes to assess and report levels of student achievement and to monitor educational standards over time. These initiatives share an intention to clarify and to communicate educational outcomes and to establish frameworks for setting goals and monitoring progress towards the achievement of those outcomes. This kind of framework applies both to the system and the individual level.

What distinguishes competency-based education from this broader orientation towards the clearer specification and monitoring of outcomes is its concern with outcomes relevant to employment.

Greater workplace relevance

Running through the literature on competency-based education is an ongoing concern over the workplace relevance of much of the content of formal educational programmes. There is a commonly expressed belief that institution-based courses too often emphasise theoretical or ‘book’ knowledge at the expense of the ability to apply knowledge to perform practical tasks and to fulfil workplace roles (Tuxworth 1989; Jessup 1989, p 66). Recent initiatives in Australia to promote competency-based education have similarly been based on concerns over the workplace relevance of many formal educational qualifications:

> Dissatisfaction with the workplace relevance of many credentials derived in the traditional model of curriculum development based on the inputs of ‘knowledge,’ ‘understanding’ and ‘skill attainment’ has led to an emphasis on working from the outcome–increasingly referred to as a competence. A competence is the ability of the learner to put skills and knowledge into action. (Humphrey 1992, p 61)

Under competency-based approaches, the redesign of curricula to make them more relevant to workplace requirements normally begins with an analysis and identification of workplace 'competencies' which are then organised into a set of 'competency standards' for an occupation. To ensure that standards are firmly based on the needs of employment and not merely on doubtful assumptions about workplace needs, competency-based educational reforms look to industry to take the lead in developing appropriate standards and to involve persons in the workplace as widely as possible in determining and endorsing competency standards.

Outcomes as observable 'competencies'

A third intention of competency-based approaches is to express outcomes as explicit, observable workplace performances. The intention is to express outcomes in the form of clear and precise 'competencies', so that (a) the needs of employment can be better communicated; (b) the goals of educational programmes can be re-defined and communicated with greater precision; and (c) straightforward judgements can be made about the extent to which any particular competency has been attained:

> Rather than designing curricula to meet assumed needs, representative occupational bodies identify 'occupational standards' which are clear and precise statements which describe what effective performance means in distinct occupational areas. The standards are then used to develop 'new' vocational qualifications and the assessment which underpins them; plus learning programmes which deliver the achievements identified in the standards. (Mansfield, 1989, 26)

Explicitness and precision are recurring themes in discussions of competency-based outcomes. If outcomes can be expressed in precise, observable terms, it is argued, these can then be used to set clear goals for educational programmes. For Gilbert Jessup, a leading advocate of competency-based education in the UK, precision in the specification of competencies is the key to accurate communication of workplace needs:

> For accurate communication of the outcomes of competence and attainment, a precision in the use of language in such statements will need to be established, approaching that of a science. (Jessup 1991, p 134)

Again the narrowness of these representations of this principle have alienated many tertiary educators. However, it is possible to glean, from this and the other principles, some aspects which are progressive and to produce educational design which meets the needs of a range of stakeholders. Also, this interest in greater workplace relevance is not unique to the competency movement although its presence may have been catalytic in increased interest by universities in including professional and industry personnel in review of programme structures and curricula.

During the 1990s, many Australian professional associations, with government assistance, developed competency-based standards for work in their professions and used them in their interactions with universities. Academic respondents to our national study (Bowden and Masters 1993, p 98) were asked to express their views about the involvement in the design of curricula, teaching and assessment in higher education of the following groups: practising professionals, professional associations and employers. The majority of respondents were positive about the current involvement of such groups.

Further conclusions from our national study (Bowden and Masters 1993, p 152), which were derived from data and views provided by professional associations, employers of graduates, university vice-chancellors and their representatives, professional teams engaged in the development of competency standards and university academics, are listed below. The study was focused on the implications for higher education of the development of competency-based standards by the professions.

> The evidence suggests that universities, the professions, employers and the community have much to gain from the activities concerned with the development of competency-based standards by the professions. It is doubtful that these gains will be in exactly the form that some in the competency movement intended but the outcome reflects the fact that the whole process has been dynamic and developmental. However, we do not believe that a full-blown competency-based approach to education will become dominant in university courses.
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> In developing competency-based standards, one of the benefits for the professions is that they are better able to understand and articulate their professions. Most professional organisations have used the processes of standards development to improve dialogue and relations between themselves and the universities with regard to curricula.

> We believe that as a consequence, some of the fears of universities that may have originally been well-founded, can now be put aside; some of the desirable objectives intended by the professions, argued for by many employers and ultimately supported by the university representatives, should be pursued and can be attained. These include greater attention to the links between workplace performance and discipline-based knowledge, increased efforts to address more concretely the attainment of underlying capacities of a generic kind and explicit consideration of the relation among all of these in curriculum development, teaching and learning activities.
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> Progress of this kind will best take place in the context of the existing, long-standing and largely successful relationships many universities have with the professions and employer groups through course advisory committees and accreditation processes.
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> Indeed, if there is one continuing danger both to university education and to professional practice, it is the possibility of bureaucratically inspired external interference in the planning and conduct of professional education.
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> ... university education in general and professional education in particular are complex processes in which conceptual understanding and practical experience combine to enable the development of the higher order capacities that are called for by employers, governments and the community.
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> Such complex educational outcomes are likely to be jeopardised by bureaucratic imposition of narrow perspectives, both of professional practice and also of educational processes and outcomes. These are best left to the professions and the universities who can use the experience of the past few years to assist the evolution of better professional, educational programmes that meet both community and individual student needs, not only in the short term but also in the longer term, as circumstances and need change.

The Relation Between Competence and Competencies

Types of Competency-based Approaches

The history of the development of competency-based education and the hierarchy of forms of it go hand in hand. The hierarchy represented in Table 1 shows different perspectives on what represents competence, as implied by different competency-based practices.

Table 1: CBE Levels

0 **Generic**	Knowledge, skills and attitudes (what the competency-based movement has reacted against)
1 **Behaviourist**	Basic performance in the workplace
2 **Additive**	Performance plus knowledge (usually with knowledge assessment undertaken separately from performance assessment, an additive not an integrative approach)
3 **Integrative**	Performance and knowledge integrated
4 **Holistic**	Holistic competence (discussed further below)

Gonczi, Hager and Oliver (1990) point out that the analysis of professional work into roles, tasks and sub tasks, results in impractically long lists of specific tasks (Level 1 in Table 1). Attribute analysis on the other hand (Level 0) runs the risk of attempting to spell out the knowledge, skills and attitudes that underlie professional competence without considering what it is that professionals actually do in the workplace. According to Gonczi, Hager and Oliver, the Level 2 approach begins by attempting to identify those areas of professional

practice in which it is essential to demonstrate at least minimum competence and to identify the knowledge, skills and attitudes required to perform complex professional activities.

There is a need to differentiate between that additive approach and the Level 3 approach which attempts to consider knowledge in context, in relation to performance rather than separate from it, while the Level 4 approach represents the attempt to integrate as well the person's way of seeing himself/herself as a professional. It is more holistic than and subsumes the previous Levels.

There is a series of trends as you move from Level 1 through to Level 4. In the first place, that progression mirrors the historical development of competency-based education. The narrower, performance focused aspects represent the beginning of the movement and, over the decades, some in the movement have revised their thinking and developed practices further, although this has not been universal. The other trends from Level 1 to Level 4 include

- increasing complexity of outcome
- broader curriculum requirements
- more complex assessment requirements,
- increasing ambiguity in the relation between objectives and assessment of outcome, and
- increasing need for interpretation and professional judgement in assessment.

Level 4 for instance represents a three-way integration among the person's way of seeing his/her professional role, his/her capacity to undertake that role and the knowledge-base with which that professional identity and performance are intermeshed. The assessment of such an outcome is not simple and it is difficult to assess it directly.

It is not surprising that, initially, the competency movement focused on minimal ambiguity and greater certainty, viz Level 1. They were concerned to generate greater recognition of the role of education in preparing students for the workplace, within an educational world that they saw as focused on book-learning and theory. As a consequence their terminology and their practices focused almost entirely on the workplace connection. This may or may not have been strategically wise but, whether it was strategic at the time or not, such lower level approaches must be judged in the 1990s on their merits, not on rational motives of decades before. Hence the kinds of shifts in focus espoused by Gonczi and Hager and others are developments that would be expected to take place and some would argue, including myself, that there is even further to go. That is what the next section of this paper is about.

The Nature of Competence

What is competence and how is it related to competencies? The term competency itself has two elements to it. The first is that it appears to be linked to competence in some way and the second is that it is a diminutive, ie it refers to some part of competence. The term is not used consistently although its origins mean that it refers in some way to competence in the workplace. Is a competency the capacity adequately to do some task which, along with other tasks, represents competence in the workplace? Is a competency one of a range of underlying attributes, the possession of which will ensure competence in carrying out workplace activities. Or is the concept of competence more complex than either of these indicates?

It is argued here that the concept of competence is indeed more complex than the definitions considered above and that we must understand its complexity if we are to design educational programmes that properly prepare students for their role in the workplace. Velde and Svensson (1996) provide a review of questions such as those asked in the previous paragraph and cite Gonczi's (1994) classification of different conceptions of the nature of competence. They are the behaviourist (corresponding to Level 1 category above), the generic (equivalent to Level 0) and the holistic (equivalent to Levels 2, 3 which I have labelled additive and integrative respectively, with Level 4 as the one I label holistic). Velde and Svensson also discuss relational notions of competence:

> Gonczi (1994) adds that this (holistic) notion of competence is relational, because it brings together the abilities of individuals and the tasks that need to be performed in particular situations. Jones and Moore (1995:81) use the term 'relational' to "indicate the broader theoretical way in which it attempts to locate competence within contextually located sets of social relations and their cultures of practice..."

Jones and Moore talk about the whole being greater than the sum of the parts and put this view of competence with its cultural characteristics and associations with social practice as a contrast with one which attempts to represent competence in a technical system of prescribed behaviours.

Velde and Svensson summarise the situation thus:

> …the conception of competence needed to meet the demands of the general situation seems to be a relational, interpretative, holistic and contextual conception. Relational in the sense that it focuses on the relation between an individual (group) and a situation, seeing competence as a holistic quality in this relation. It has to be contextual both in the sense that parts of the relation are understood in relation to the whole and in the sense that the whole qualities of the relation are understood in relation to the nature of the individual and of the situation… what is needed is not only a description of performances which are according to standards but an understanding of the variation in whole characteristics of performances on specific tasks, both successful and unsuccessful performances, as a basis for understanding the relation between more general and more specific parts of competence.

Sandberg (1991, 1994) extends these views of competence by arguing for the inclusion of an intentional dimension, ie the person's conception of the work and his/her relation to it. This corresponds to Level 4 of the earlier categorisation. Sandberg's notion of intentionality is content-related. This means that the general characteristics of competence that have been described acquire their meaning only through consideration of each specific case. What it means to be a competent engineer, a competent doctor, a competent electrician or a competent teacher will be different from each other despite all being characterised by the individual's way of seeing the professional situations. Those meanings have to be learned.

Learning Theory and Competence

Learning for an Unknown Future

It is one thing to argue for the kinds of learning outcomes implied by the particular definitions of competence above which many, including myself, deem as more appropriate for describing performance in the workplace. It is quite another to suggest mechanisms by which such high level outcomes might be achieved. A theory of learning is needed which accounts for the ways in which learning experiences may be designed so that these particular learning outcomes are more likely to be achieved. Ference Marton (1996) addresses this issue in a way that reflects Sandberg's view of competence:

> Studies in higher education are supposed to enable students to deal with situations in the future which cannot be defined in advance. By means of appropriating what is known, students are expected to be equipped for dealing with the unknown. This can be achieved by forming the eyes through which students are going to see situations in their professional lives in the future.

What tertiary educators must face is that students need to experience a curriculum related to a particular area of study which will enable them to develop the capacity to perform after graduation in circumstances that can't be prescribed in advance. On the one hand, it is too difficult to reproduce the specific contexts that a particular graduate will later confront. Students need to learn in ways that help them deal with a range of contexts, many if not all unique. Secondly, the world advances every day and no preparation for experiences some years ahead can rely on the accuracy of any forecasting of such advances. So university education has to be, as Marton suggests, about learning for an unknown future.

Learning physics concepts

This section is focused on a technological learning topic, viz understanding of concepts such as force and acceleration, which has been the object of my own research in recent years. Typically in a physics course at senior secondary school or first year university, concepts of force and acceleration are exemplified through problem sets featuring, for instance, motor vehicles travelling along roads or trains on railway tracks. Students are asked to solve many problems of the kind that require calculation, say, of the acceleration of a vehicle which increases its velocity from zero to 50 kph in ten seconds. Some relevant equations (which I learned off by heart over thirty years ago) are

$v = u + at$ $s = ut + 0.5\,at^2$ $v^2 = u^2 + 2as$

with "u" being the initial velocity, "v" the final velocity, "a" the acceleration, "t" the time elapsed and "s" the displacement.

What I remember doing those decades ago, unhappily in retrospect, was to ask myself which of u, v, a, t and s had numerical values provided in the problem description, which variable was needed in the answer and then to choose the equation with that complete set of variables in it. In a sense, what acceleration meant to me was "the answer to the solution of the relevant equation". Slightly more scientific than that, it also had a meaning associated with changing (usually increasing) speed. These understandings were reinforced by the large number of problems of just this kind that we did and by the fact that those problems inevitably turned up in the examination papers.

The assumptions that are required to solve problems such as those described above are that any acceleration being calculated is uniform or constant, that the vehicle is travelling on a straight, flat surface and that other forces such as wind resistance should be ignored. One of the difficulties in helping students learn about force and acceleration using this kind of curriculum is that such assumptions are unlikely to be encountered in real-life situations.

Lest you think that this minimalist approach to teaching and learning is likely to be a characteristic only of inferior educational institutions or less able students, you should know about an Australian Research Council funded research project that we undertook because later year students in a university physics course were having difficulty with advanced study despite performing very well in physics examinations in final year of school and first year at university (see Bowden et al, 1992; Dall'Alba et al. 1993; Walsh et al. 1993). The university was a prestigious one always ranked in the top group on any national ratings scale and the students entered the university with secondary school grades higher than any other cohort entering physics courses elsewhere in the region.

In our research, we asked students to solve physics problems, some of which were quantitative and others of which were qualitative problems without any numerical answers possible. Students were always asked to explain how and why. We found the anticipated result that, while there was a range in capacity to solve the quantitative problems, many students had little or no difficulty at all with numerical problems. In contrast, few students were able to deal adequately with the qualitative problems. Further, even when students were able to solve the quantitative problems, their qualitative explanations often lacked scientific rigour.

For instance, in one of the qualitative problems, we described a situation in which a parachutist jumps from an aircraft and opens the parachute after a few seconds. We asked each student to tell us what would happen from the moment the parachutist left the aircraft and to explain why.

The scientific explanation for the motion prior to the opening of the parachute is that the force due to gravity causes the parachutist to move towards the earth at an increasing velocity. However, the parachutist doesn't accelerate (increase velocity) indefinitely. In fact, a parachutist would be moving towards the ground after falling, say, two thousand metres, at the same velocity as after just one thousand metres. Why is this so? The reason is that as the parachutist falls faster and faster, the air resistance gets greater; the faster you fall through the air, the more force the air exerts on your body in a direction opposite to your movement. That force is exerted upwards, opposite to the effect of gravity. So as you get faster, the magnitude of the force of air resistance gets closer to that of gravity and your overall acceleration diminishes, ie the rate at which your velocity is increasing is slowing. Eventually the acceleration becomes zero when the force of gravity and the air resistance are equal. With your acceleration zero, your velocity remains constant. Thus you continue to fall at that constant velocity which has been given the name 'terminal velocity'.

Few students in our study were able to explain the parachutist's motion in this way despite being able to calculate answers to quantitative problems depicting similar situations. Many were aware of the influence of gravity on the parachutist's velocity and they were also aware of the effect of air resistance on velocity but they often responded as if these two aspects were not related. They tended to deal with them independently but not together.

Underlying all our results was the finding that descriptions of students' understanding of fundamental concepts such as force and acceleration cover a range of categories and that many of these understandings have much less explanatory power than the accepted scientific explanation. An important aspect of that is that many students who were unable to explain adequately the underlying scientific principles still could perform the quantitative tasks perfectly, provided they could be addressed simply by using memorised equations. So here we have an example of students being able to do something, to carry out a required task, but who are unable to cope with problems outside a narrow spectrum and unable to explain adequately why the solutions work. Some members of this particular university were among the most vocal opponents of the competency movement in Australia in the 90s and yet this particular approach to education has all the hallmarks of what I would regard as the unacceptable face of competency-based education. In a way Level 0 and Level 1 of the hierarchy described earlier are mirror images of each other. They are both concerned with performance and they are both narrow and limited, but with a different focus.

Marton's Variation Theory

Clearly most students who participated in our study didn't appear to be developing the capacity to deal with novel situations in very effective ways. They could cope with problems that were very similar to others they had learned to solve but they were able neither to explain why those solutions worked nor to deal with problems that were presented in formats they hadn't experienced before. They had not developed what Marton (1996) has referred to as a professional "way of seeing" novel situations.

What is this professional way of seeing? What is it that makes one worker more competent than another who perhaps possesses the same knowledge and skills? The question can be turned around to ask how it is that when confronted with a novel situation, the more competent person knows what aspects of their knowledge and skills are relevant to the situation.

Every phenomenon has a large number of aspects.

> The aspects and the relations between them that are discerned and simultaneously present in the individual's focal awareness define the individual's way of experiencing the phenomenon. Being focally aware of the weight of a body immersed in some fluid as compared to its weight when not immersed, of the fact that a certain volume of fluid is displaced by the act of immersion, of the weight of the fluid displaced–all at the same time–amounts to what it takes to discover, or to understand, Archimedes principle. The key aspect is the set of different aspects which are simultaneously present in focal awareness (Marton and Booth 1997)

To be competent in dealing with workplace situations, it is necessary to discern and be aware of all relevant aspects of the phenomenon and of the situation simultaneously. It is in this way that the competent worker is able to know what knowledge and skills are relevant. In the parachutist example described above, many students had awareness of both the gravity and air resistance aspects separately but not simultaneously. The next question to be asked is how that capacity to discern the relevant aspects can be developed.

Language Acquisition

It is interesting to speculate on the ways in which, on the one hand, a baby learns to speak and to understand language and, on the other, the ways graduates learn to be professionally competent. It would be useful to be able to explain both forms of human learning without having to describe a separate theory for each. Let me explore that a little.

Consider the way a baby learns to understand and use language (this example is an adaptation of an analysis by Ference Marton [in press]). The experiences a baby has with language are frequent and one would expect bewildering. Some people around the baby talk to each other in ways that ignore the infant. Most at some time speak to the infant and, especially when the speaker is the mother or other family members, language is often accompanied by other behaviours such as touching or providing food, many of which are positive but some of which are negative.

However, the aural experiences a baby has are not consistent or uniform. When a mother utters certain words, they may be linked with a happy frame of mind and associated behaviour. When a father or sibling utters the same words, their utterances will certainly have different aural characteristics and they may or may not be associated with the same behaviours. Further, different people are likely to utter different words even when engaged in the same behaviour; they speak to the baby from different distances, with varying

loudness. So how does the baby manage to acquire language?

It could be said that with all that variation, all that inconsistency, it is a wonder that a baby learns to speak at all. Marton argues that, in fact, it is the variation itself in the experience a baby has which enables it to understand and use language.

Marton has devised a thought experiment to illustrate this point. Close your eyes for a moment and imagine the unthinkable–a new-born baby being cared for by robots. These robots can look after the physical needs of the baby but they also have speech recognition capacity and are fitted with speech synthesisers. Spoken words accompany all of their actions. Imagine, say after twelve or eighteen months, that the baby's parents enter the room and begin to speak to the baby using only the vocabulary which was available to the robots–i.e. no new words. Would the baby be able to understand what its parents are saying?

Well, the baby would not understand its parents very well in such circumstances. And the reason it would not is related to the uniformity of the baby's experience with the robots. What happens in normal circumstances is that the variation in a baby's experience is just what enables it to differentiate the common, essential features of language structure from the idiosyncratic aspects associated with each individual's speech. It is what enables babies to experiment with language and to infer rules. It is what enables babies to hear something with different aural characteristics but nevertheless interpret it within the inferred structure. The baby reared by robots would have a language of a kind but it would not be anywhere near as robust, as differentiated or as useful as a baby raised normally would possess.

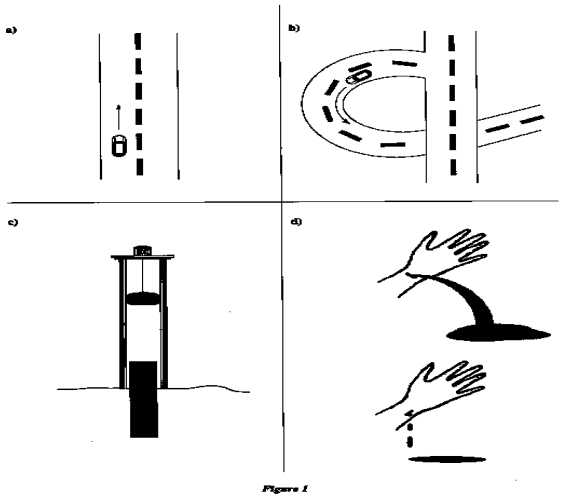
Variation theory applied to technological learning

What is the relevance of this account of language acquisition? Marton (in press) suggests that the way we learn in order to be able to cope with the unknown future is to learn variation:

> We learn to know people, mother tongue, phenomena, situations through variation in appearance, sound-pattern, perspectives, important parameters. As we learn the variation, we also learn about situations that we have never encountered and about phenomena in ways we have never seen them–they can be made sense of in terms of the variation that we have learned as not as yet realised potentialities. …the more narrow the range of situations, problems, appearances of phenomena, points of view, perspectives that we have encountered in our studies are, the less likely we will be capable of dealing with novel situations, new appearances, other points of view, other perspectives.

Marton's variation theory would suggest that students' understanding of scientific principles and capacity to explain a variety of real-life contexts would be enhanced by including well designed contextual variation in the learning experience. Far better to expose students to a variety of situations (see Figure 1) which are designed to develop the capacity to discern the relevant aspects of the situation.

Figure 1(a) depicts the idealised context for consideration of force and acceleration that is the subject of so many textbook treatments, a vehicle moving on a flat, straight surface. This is almost an invariant context. The normal variations we experience in real life are artificially removed. The difficulty for students is that if the artificiality of this context is not made visible by consideration of the same concepts in more real-life contexts, then the capacity to deal with novel contexts will not be developed. And this is what we found in our research study.



There are contexts which are more commonly encountered and which can be used to develop students' understandings of force and acceleration. These are shown in Figure 1(b), (c) and (d). The diagrams and contexts they depict are schematic and it is not suggested that they represent an appropriate curriculum. However, they do demonstrate the idea of variation and its contribution to the development of discernment of the relevant aspects of a phenomenon and are used here only for that purpose.

Figure 1(b) depicts a car driving on a ramp leading to a freeway. This context raises a number of questions:

- why do some drivers cause their cars to become slower and slower as they move down and around the ramp?
- is the car easier or harder to control if the accelerator pedal is depressed a little more as the car moves around the ramp?
- what is the relation between acceleration and the changing of direction, with or without constant speed?

In fact, the concepts of force and acceleration are not related only to changes in speed. The term velocity is used in physics rather than the term speed to denote the inclusion of the directional aspect. Not only does it take force to increase the speed of a body but it also requires force to change its direction, with the speed held constant. Hence if the accelerator pedal of the car moving around the ramp in Figure 1(b) is pressed down a little further, there can be sufficient force to bring about a change in direction without affecting the speed. However, if the pedal is not pressed down further, the speed will decrease as the direction of the motion changes around the curving ramp; the car slows down. (Even this is a simplification because transverse motion and road-tyre friction can also come into play. Nevertheless, the essential argument above stands.)

What this context does is to encourage a more sophisticated understanding of acceleration and force to develop - one whose relevance structure is more complex so that it includes the direction of motion as well as the speed.

Figure 1(c) shows the use of a pile-driver. This diagram is merely a schematic one and a real pile driver is more complex. Nevertheless this provides sufficient aspects to illustrate the points being made. Basically a pile driver consists of a frame supporting a weight held some distance above a pile which is wedged in the ground. The weight is released and it falls

towards the pile. When it hits the pile the two move down together and the pile is wedged further into the ground until the pile and weight come to rest.

This context raises questions which test the useful limits of the concept of acceleration:

- is the motion of the descending weight the same as or different from that of the parachutist in free fall described earlier?
- what forces are affecting the motion of the descending weight in free flight and what is its acceleration?
- when the weight hits the pile, they appear to move instantaneously together at a velocity much less than that of the weight before impact; can this be a case of infinite acceleration or have we reached the limits of applicability of the concept?
- is there some other explanation involving new concepts such as impulse and conservation of momentum that is more appropriate?

Most of the relevant issues are found in the questions above. Indeed, the answer to the first two questions is that the motion of the falling weight and the parachutist in free flight can be explained by the same scientific principles. And yes, there is a need to use new concepts to describe the motion of the combined weight and pile.

What needs to be explained is how it is that the pile is sitting at rest and, then, instantaneously, it is moving. A relevant aspect of acceleration not yet dealt with is that it is concerned with the rate of change of velocity, ie not just with the amount of change in velocity but also how quickly the velocity changes. The average acceleration is the change in velocity divided by the time taken for the change to occur. With the pile driver, it appears that the pile instantaneously goes from rest to some finite velocity. This implies infinite acceleration; some other way of dealing with this context is necessary. The concept of impulse and conservation of momentum principles are introduced to provide a full explanation of this phenomenon. So this context both introduces a new aspect and also demonstrates some limits to the usefulness of the concepts of force and acceleration as explanations of such motion. In that way, the understanding of these concepts is enhanced and their relation to the new concepts developed. The expectation would be that the learner would develop a greater capacity to discern the relevant aspects of this and other situations.

Figure 1(d) merely depicts the different way that blood flows from a punctured vein and a punctured artery in the human body. When the blood from the artery spurts out it is moving faster than the blood which oozes more slowly from a vein. The motion of drops of blood falling to the ground from the puncture in each of the two cases can be explained in the terms already described for the parachutist. But what about the motion of blood circulating around the body in unpunctured arteries and veins? Does the behaviour of the blood coming from the punctured blood vessels reveal different motion within the closed systems? In particular,

- does the blood flow more slowly in a vein than in an artery?
- does the blood flow more rapidly down the body than up the body due to the influence of gravity?
- are the concepts of acceleration as applied to falling bodies like parachutists and pile drivers relevant when the object is a fluid?

Well, this is an even more complex situation than any of the others so far and the fact that the blood flow is not constant (related to the pumping of the heart), that there are valves in the system and that it is a closed fluid system (think of the effect of the opening of a household tap on the level of water in a reservoir many miles away) make simple analysis using the concepts of force and acceleration impossible. Again this points to the need to deal with new concepts such as pressure and adds to the understanding of force and acceleration through their relationship to such new concepts.

You will note that most of the questions that have been posed invite qualitative answers. Our research showed that the ability to provide the right answer to quantitative questions often masks the understanding of the underlying concepts and students are not challenged or encouraged by such questions to reflect on and modify their understandings. Qualitative questions and discussion are essential for conceptual development.

It should be pointed out that the context depicted in Figure 1(b) involves the idea of circular motion and the context depicted in Figure 1(d) involves fluid motion. Now some physicists who are reading this account will say, quite correctly, that in physics subjects, circular motion or rotational mechanics is often taught; so too is fluid mechanics. The trouble is that those topics are usually taught as separate idealised systems, separate from each other and from basic mechanics. Students who can solve the basic mechanics problems described earlier often also become adept at solving the quantitative problems involving rotational mechanics, using yet another set of memorised equations. But they commonly fail to integrate the experiences in a way which enriches their understanding of force and acceleration or develops their capacity to discern the relevant aspects of novel situations involving those concepts.

Figure 2 illustrates this point. In Figure 2 (a), the real life phenomenon P, as depicted, is less likely to be understood if each of the contextual variations is treated in the curriculum as a special case with lots of contemporary experiences being required which focus on that one aspect. So clumps of specialised knowledge or skill are acquired and the way of solving a problem is to see if it fits one of the clumps. When it doesn't, there is difficulty in solving the problem.

However if the changing context, the variation in experience described earlier, is treated as part of the problem solution, then the contextual differences associated with phenomenon P, become merely one aspect of the problem which students have become used to including and dealing with. It is part of their way of seeing themselves as scientists.

It should be emphasised that what is being argued here is not simply that there should be a wide range of relevant examples provided which in some way capture the range of student interest. It is not being argued that basic physics subjects should be made relevant for students of nursing, say, by replacing some of the standard "motor cars on a straight flat road" type problems with problems concerned with "wheelchairs moving down a hospital corridor" or the like. Rather, the different contexts should be chosen so that different aspects of, say in this case force and acceleration, come into focus from one context to the other. The contexts in Figure 1 provide that kind of variation and in doing so assist the student to develop a more comprehensive and differentiated understanding of the concept and the contexts in which different aspects are more or less relevant. Perhaps more importantly, they can lead students to the conclusion that there are contexts in which other concepts become more relevant and can facilitate an even broader understanding of the whole subject in a relational way. As Dall'Alba and Sandberg (1992) express it

> …students learn skills and knowledge in accordance with their developing conception of the content related to the profession. Hence, in order that students master the necessary knowledge and skills, they must learn to conceptualise the content in ways that are appropriate to the aims of education and to the profession.

So it matters what kinds of learning experiences students have and the responsibility of teaching goes beyond simple specification of topics to be covered. Attention needs to be given to the ways that students see the content, ie Marton's "forming the eyes" through which students will be dealing with the future, and the example given above of contexts demonstrating aspects of force and acceleration is just that, one example. Course teams need to devise appropriate variations in learning experiences in their programmes so that students develop in ways that enable them to become competent professionals who can discern the relevant aspects of novel situations.

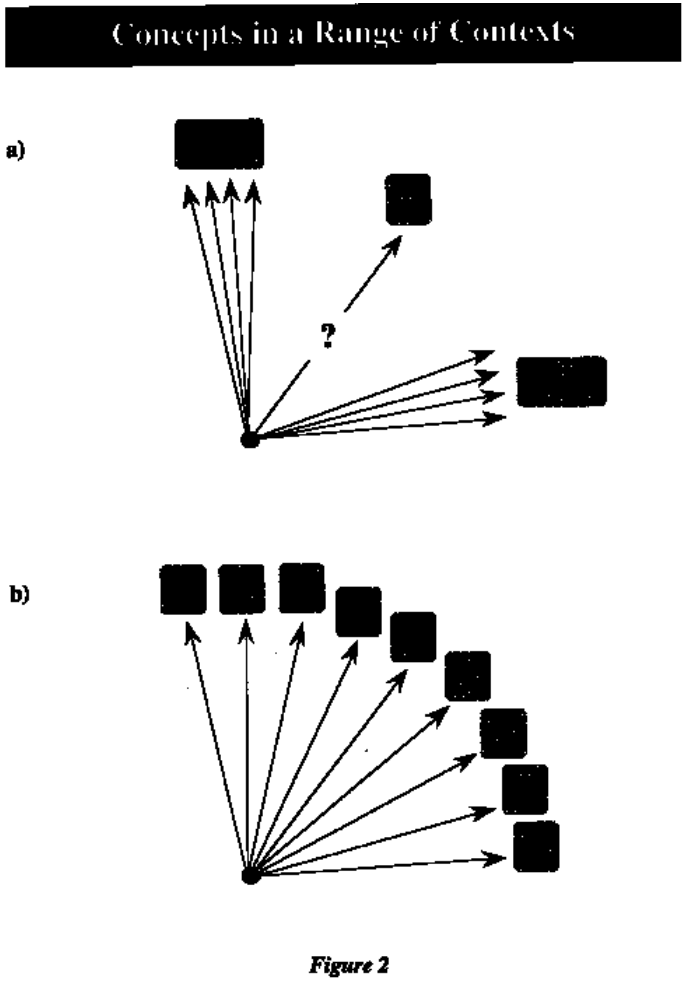


Figure 2

Some Consequences

While the explanation of such an approach based on Marton's variation theory may be new, I am not suggesting that such practices do not already exist in some educational programmes. The value placed by the competency movement on work-based learning and the widespread interest by university educators in providing learning experiences focused on field work, projects and work placement are all explicable in terms of the theoretical argument above. However the variation has to be experienced. The example above of basic mechanics, circular motion and fluid mechanics being dealt with in a curriculum as isolated issues does not represent experienced variation.

So too can Marton's variation theory account for (as of course can novice-expert theories) the fact that "experience" is so important in developing expertise and why we tend in real life to devalue the "narrow" expert. The experts we value can readily home in on the most important aspects of any situation they confront. Their expertise is based on growth through integration of a range of experiences of different contexts with each helping to build an increasing capacity to understand various situations and form professional judgements. This links to Figure 2(b). On the other hand, experts in a narrow field or fields whose understandings have been developed in isolation as depicted in Figure 2(a), will not develop such judgement. They see their role differently; they act differently. I would suggest that these two types of experience lead to different levels of competence and that the former is related more with Level 4 described earlier and the latter with the inferior Levels 1 and 2.

Another concern I have is about the notion of transfer or application of knowledge. The meaning normally ascribed to those terms, that students learn all about a concept in one context and then apply it to a different context, is a doubtful one. Rather, learning about the concept should transcend a range of relevant contexts so that students develop knowledge-in-context. They see the knowledge as relational, ie context-dependent, and they become comfortable with dealing with the concept in a range of contexts because they have developed the capacity to judge what aspects of the concept are relevant to the particular context.

Now for universities which oppose all ideas associated with competency-based education, there is a salutary lesson. The relation between theoretical concepts and their real-life representations is an essential feature of this "variation" approach. By the same token, for advocates of competency-based approaches, the "learning a hundred skills" Level 1 format should be questioned. How do you arrange competency-based learning so that students become prepared for an unknown world? The answer lies not at, but somewhere between, the extremes. It must involve a concern for workplace performance outcomes, but not exclusively nor in isolation.

Concluding Summary

This paper has provided a brief history of the competency movement and has argued that a rational analysis of the principles underpinning a competency-based approach to education should be undertaken so that the valuable aspects can contribute to our understanding of tertiary education in the 1990s.

The notion of competence in the workplace has been explored and it has been concluded that a key aspect of competence is the person's way of seeing particular situations that confront them in their workplace role. It is through these ways of seeing that the person can call on relevant aspects of the integrated knowledge and skills they have learned to deal with the variation in their work situation.

It has been argued that, since the future work situations that today's students will be dealing with cannot be prescribed, students need to learn in ways which develop their capacity to discern the relevant aspects of relatively novel situations. It is suggested that this is best achieved by including contextual variation as part of the learning experience. As Marton (in press) states: "In order to become capable of dealing with a varying future we must have met a varying past".

Competency-based approaches must therefore be adapted to deal with this unpredictable future by moving away from the prescriptiveness of earlier and less helpful versions and by embracing the principles of variation argued for in this paper. Further detail on these matters and on the crucial issue of assessment which has not been dealt with here, will be provided in a forthcoming publication by Bowden and Marton.

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