Computing Competencies, Dispositions and the Affective Taxonomy: More work still to do?

Today's global computing curricula is seeing an increasing move towards 'competency' rather than the historically 'knowledge-based' computing curricula. "In the CC2020 Report [5] and related work [4,6,8], the notion of competency has been defined as comprising 'knowledge + skills + dispositions + task', based on a broad conception of competency as effective professional performance in a relevant setting" [7].

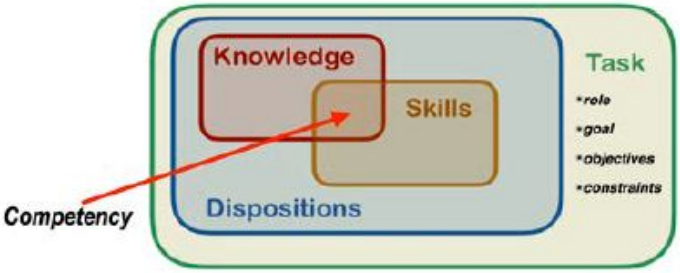

Figure. 1: Conceptual Structure of the CC2020 Competency Model [Ex. 5 Fig 4.1 p. 47]

But does adopting the notion of "skills", drawn from Bloom's cognitive taxonomy here [1,2], fully address the level of all these elements of a competency? This column aims to explore how fully the competencies of CC2020, the Bloom taxonomy of 'skills' from the cognitive domain and the notion of 'dispositions' really dovetail and what alternative conceptions might be useful?

This question has arisen for me in co-supervising with Dr Ramesh Lal our student Johnny He's Research Report towards his Master of Computer and Information Sciences. Johnny has sought to contrast how "*Skills Requirements*" *[or capabilities or competencies]* for practitioners develop in the transition from Junior Software Developer to Senior Developer. The study has been based on him reviewing job advertisements and contrasting stated junior and senior software developer expectations. In developing *competency statements* from this data source, drawing on the process for mapping the knowledge based CS2013 curriculum statements to competency statements, as adopted in the ITiCSE working report [6], two key insights were derived: 1) for *professional skills* such as "teamwork" (which did not easily fit within a cognitive taxonomy) Johnny struggled to map them to the "skills" aspect of the identified competency so rated them at level 0 of the 'skills' taxonomy; and 2) in subsequently allocating *dispositions*, distinguishing between *skills* element of the CC2020 competency model and junior and senior expectations of the degree of exhibition of a *disposition* has posed some challenges.

At this point we need to revisit the early work of Bloom and colleagues [1, 2, 3] in developing educational taxonomies. The "*original plans called for a complete taxonomy in three major parts – the cognitive, the affective, and the psychomotor domains. The cognitive domain…includes those objectives which deal with the recall or recognition of knowledge and the development of intellectual abilities and skills. This is the domain … in which most of the work in curriculum development has taken place and where the clearest definitions of objectives are to be found phrased as descriptions of student behavior.*

A second part of the taxonomy is the affective domain. It includes objectives which describe changes in interest, attitudes and values and the development of appreciations and adequate adjustment." [1: 7]

The cognitive taxonomy depicted a hierarchy of *skills* based on a vocabulary classifying levels of learning building from less to more sophisticated where, as noted in [6], "Within the cognitive domain, the six cognitive-learning levels are: knowledge, comprehension, application, analysis, synthesis and evaluation" [6].

So in addressing point 1 above: where *professional skills* such as "teamwork" did not easily fit within a cognitive taxonomy, they were not readily assessed and so rated at level 0 of the 'skills' taxonomy. In discussing more complex activities which might be evidenced through group work, Bloom made the following points:

"*It is probable that tasks involving synthesis objectives provide a wider kind of experience than those involving mainly acquisition of ideas. …pupils may work as a group defining important problems…proposing hypotheses to account for phenomena, planning simple experiments to test these ideas and actually carrying out the experiments either individually or in small groups. Such activities should foster productive thinking, some independence in approach as well as cooperativeness*"*…Synthesis objectives occur at most levels of education. Obviously the tasks corresponding to these objectives will differ in their magnitude and complexity from level to level. We would expect a progression from relatively small tasks to much larger tasks as the student moves through the educational program.* [2: 165-166]

So we see that in defining "synthesis" as a cognitive level of learning involving larger tasks, the expected behaviours of students inherently include more socio-emotional dimensions. So in linking competencies and larger tasks we need a need arise for a partnership between both the cognitive and affective taxonomies. As an example of how the affective taxonomy may better express levels of achievement of a professional knowledge area, Lynch and colleagues have taken the professional outcome of "Teamwork" and mapped it to the five levels of the affective taxonomy [11]. This tabulation is given below:

Teamwork

1. Receiving: *describe* characteristics of effective intra- and multidisciplinary teams;
2. Responding: *participate* in intra- and multidisciplinary teams;
3. Valuing: *share* suggestions to enhance team performance;
4. Organizing/conceptualizing: *organize* the team including integrating team members and altering processes to achieve more effective results; and
5. Characterizing: *displays* team-building skills and *influences* others.

Table 1: Professional Outcome of *Teamwork* Mapped to five levels of Affective Taxonomy [Ex. 11]

A key distinction to be considered here as suggested by Lynch et al [11] in going beyond the cognitive domain, is the notion of "internalization":

Krathwohl et al. _1964_ found a great diversity of imprecise affective terminology. Terms such as interest, appreciation, attitudes, and values are commonly used to cover portions of a large range of achievement—from simple awareness to the point of absorption into internal structures guiding behavior. In response, they settled on a single continuum, internalization, as an organizing principle; and were able to construct a hierarchy of five major levels along this continuum.[ ]…Progression from Level 1 to Level 5 denotes an increasing level of internalization of interests, attitudes, and/or values. [11]

This taxonomy then enables us to address the concerns raised by Johnny's first insight and map a professional knowledge area to one of five levels, rather than, with Johnny, having to resort to defining "teamwork" at a default level 0, based solely on its absence from the cognitive taxonomy of "skills".

For Johnny's second insight: in subsequently allocating *dispositions*, and distinguishing between the cognitively framed notion of *skills* and junior and senior developer expectations of the degree of exhibition of a *disposition,* it is clear that the allocation of *skills* fails to separate the level of a disposition from the adoption of the cognitive level of learning, which is primarily derived from the size and nature of the task chosen to frame the competency. However, the adoption of the affective taxonomy may provide a way to distinguish the depth of ***internalization*** of a disposition. The affective taxonomy's core notion of *internalization* here fits well with the concept of a *disposition* as *"... a disposition "concerns not what abilities people have,* ***but how people are disposed to use those abilities****" [12].*

In his analysis Johnny applied the CC2020 competency model to a selected set of job advertisements, including tallying the knowledge areas including the professional knowledge areas, to profile the knowledge expectations. His more analytical findings are briefly reported in Table 2 below.

"For the analysis competency statements, a total of 11 job ads (5 for junior and 6 for senior) were selected, with a total of 57 statements (28 for junior and 29 for senior). Key verbs in the statements were extracted and mapped with CC2020 Skill Level Vocabulary. The six skill levels include Remembering (level 1), Understanding (Level 2), Applying (Level 3),Analysing (Level 4), Evaluating (Level 5) and Creating (Level 6)." [9: 11] *There are a total of 11 dispositions in the CC2020 Disposition Vocabulary, with no hierarchy: Proactive (D-1), Self-Directed (D-2), Passionate (D-3), Purpose-Driven (D-4), Professional (D-5), Responsible (D-6), Adaptive (D-7), Collaborative (D-8), Responsive (D-9), Meticulous (D-10) and Inventive (D-11)...The whole competency statements were evaluated and the most relevant dispositions were assigned to them. The frequency of skill levels and disposition labels were recorded, and also separated into junior and senior. [9:11]* *…the most frequently appeared skill levels are level 3(applying) and level 6 (creating); the most frequent for junior job ads is level 3, whereas the most frequent for senior job ads is level 6…The most frequent dispositions are D-8 (collaborative), D-6 (responsible) and D-4 (purpose-driven). Junior job ads focus more on being collaborative, whereas senior job ads also put emphasis on being responsible and purpose-driven on top of being collaborative. Overall, more disposition labels are assigned to competency in senior level job ads than junior level job ads. [9:21]* *A noteworthy piece of data is that mentorship appears frequently in senior level job ads, and is exclusive to senior developers. This suggests that mentorship is a desired and distinctive quality of senior software developers compared to junior developers, and is a skill that aspiring senior developers should aim to hone. Communication skill appears in 50% of all job ads, which means it is the most valued quality overall. A possible explanation is that communication skills are not only about teamwork, but can also mean communicating with clients and management, even though the task may be individual. [9:29]* *Combining the traditional analysis of hard and soft skills and the mapping of competency statements with skill levels and dispositions, a consistent theme is the frequency of communication and collaboration in job ads. This suggests that software development in companies is not an individualistic job, and it is something that developers need to actively improve. [9:30]*

Table 2: Contrasting Competencies for Junior and Senior Software Developers

So returning to Johnny's second insight, if we allocate *skills* from the cognitive taxonomy as outlined in table 5 of the ITiCSE WG report [6] and based on the CC2020 Competency model [5] we need to do so at the overall level of competency as exhibited in the context of the *task*. But that fails to fully unpack the level of a specific chosen *disposition*, e.g. does being *collaborative* as a junior developer pose the same demands as being *collaborative* as a senior developer, although it is a disposition required in both roles at their differing levels of seniority?

While Lynch et. Al., [11] assert that:

"there is overlap of the cognitive and affective domains, especially at the lower levels of achievement...But beginning at affective Level 3 _ "valuing"_ we find the most obvious departure from cognitive categories and beyond Level 3, increasing affective achievement is uniquely described in terms not relevant in the cognitive domain.
In addition to overlap at lower levels of achievement, there is synergy among the two domains throughout all levels. Both domains may express concern about different aspects of the same thing. But clearly, knowledge about something is different than internalization of a value related to it, and expressing that value in professional action."

Lynch et al., represent the evolution of the process of internalization, through an *"Example profile of BOK2 outcomes showing suggested affective levels of achievement through formal education*" [11] for a Body of Knowledge for Civil Engineering of selected professional outcomes. The professional outcome of *Teamwor*k as tabulated in Table 1 above provides one example. The first three levels of :*1) Receiving, 2) Responding, 3) Valuing* - are positioned at the undergraduate level of achievement. Level *4) Organizing/conceptualizing* – is positioned at the Postgraduate level of achievement, and level *5) Characterizing by a value complex is deemed to apply* at the senior professional level beyond the formal education stage of a professional engineer's career.

Thus, while the combination of cognitive and affective taxonomies discussed here is complex, they may provide a way in which to more accurately capture the complexity of competencies and the evolution of each of their discrete elements. So while this is early work, perhaps we have a potential strategy for augmenting the CC2020 Competency Model and remain true to the goal of identifying competencies transcending knowledge based curricula and encompassing the realities of learning combining both cognition and affect.

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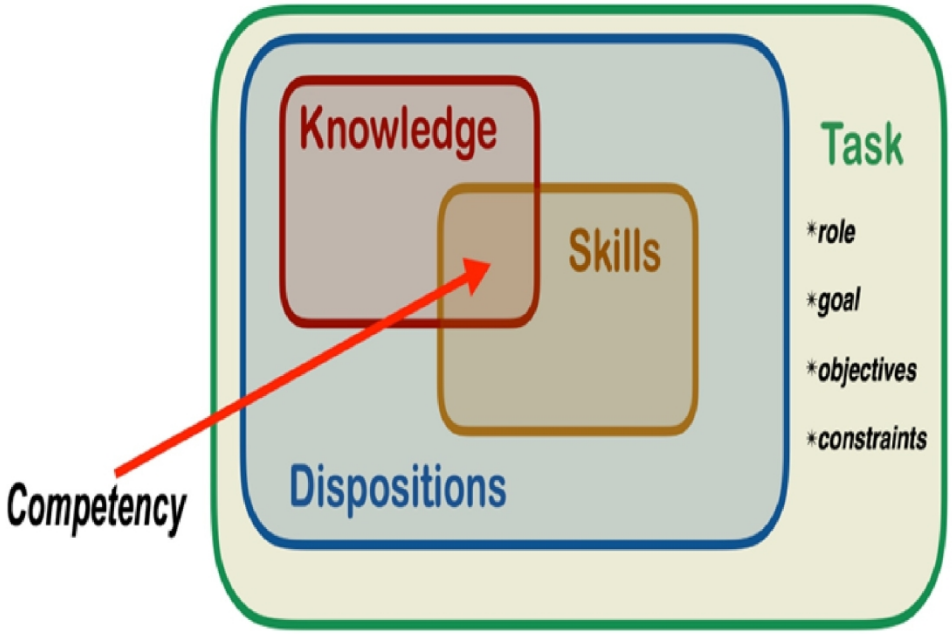

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