Unpacking Dispositions in the CC2020 Computing Curriculum Overview Report

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***Abstract*— Computing Curriculum models have been historically framed from a cognitive perspective. Typically, the focus has been on bodies of knowledge and increasingly the notion of supporting skills and abilities. More recent curriculum documents such as the IT2017 curriculum have moved towards a professional competency approach and have included the further important notion of dispositions.**

While these dispositions are seen as complementing and supporting the traditional elements of knowledge and skills, exactly how they are conceptualised and operationalised is still being developed. The ACM/IEEE-CS Computing Curriculum 2020 Overview Project (CC2020) has been working towards this goal, in part driven by the very practical purpose of enabling visualisation of the multiple components of the existing and differing curriculum reports, incorporating the notion of dispositions and enabling them to be mapped to clusters of knowledge and skills embodied in selected curriculum statements.

This paper reports on progress to date towards conceptualising and operationalising the notion of dispositions within the CC2020 project, reviews the research challenges faced, the models adopted and the findings to date.

Keywords—Competency Modelling, Curriculum Design, CC2020 Computing Curricula, Computing Education, Disposition

I. Introduction

Computing curriculum models have all historically had their innate limitations and perspectives. In a recent ICER conference paper [1] three perspectives on framing “computational thinking” have been put forward: 1) skill and competence building; 2) creative expression and participation; or 3) social justice and ethics. Similar framings for curriculum models have been given by Clear and Young [2]. Here, a self-assessment instrument was used to distinguish three paradigms, enabling participants to understand their own teaching approaches against each paradigm:

(i) Functional: Is set in the present. Fits what the industry or society needs now for that person to take up that job. Reproductive. Technical. Task and skills-based. Methodology often involves set lectures and teacher-directed demonstrations, workshops or laboratories.

(ii) Transactional: Based on the needs of the individual students or group who happen to be doing that course. Often transferable skills are involved. Process – rather than product - or content orientated. Negotiated objectives and criteria (for individual and/or group) evolve. Methodology often involves facilitation of group discussion. People-centred. Student-centred. Experiential learning is valued.

(iii) Critical: Based on predictions of future needs, visions of a better, fairer world. Education for the future is a focus. Learning to learn is important. Developing critical thinkers is a goal. Methodology often involves teacher asking critical questions, shaking previously held beliefs, querying current systems, acting as change agent, emancipatory. Objectives are often broad. [2].

These paradigms help define the role of competency in defining educational goals. When set against these paradigms, engineering and computing curricula can then be seen as largely “skill and competence building” [1] or “functional” in approach [2]. While acknowledging this historical focus, the CC2020 project aims to better frame curricular specifications to embrace all three paradigms by using structured competency statements to define learning goals. Most engineering and computing education utilizes a learning-outcomes approach to what the learner knows or can do that parallels the transactional approach. The inclusion of disposition embraced by CC2020 extends teaching and learning to embrace not just what the learner knows or can do, rather it embraces their agency in what the learner does with what they know and can do. Like the third approach studied by Clear and Young, the inclusion of disposition in curricular modelling offers an opportunity to broaden our perspectives on curricular goals.

II. Background

Many educational structures for tertiary degree programs make the case for a broad education. However, it does not dictate what that breadth should be or how it should be structured. It does mean, that however the curriculum is structured, it should focus on what John Henry Newman called “enlargement or expansion of mind” [3]. For Newman, enlargement like knowledge was a process through which a person obtained a philosophical disposition or wisdom. Therefore, one of the aims of higher education is to help students to enlarge their minds [4]. Recent developments in competency modelling suggest that the student development needed to connect Clear and Young’s ‘critical’ learning paradigm to the “skill and competence building” [1] can be more explicitly achieved through the inclusion of disposition as part of tertiary learning goals [5].

Implicitly or explicitly, disposition development plays a significant role in broad education. Dispositions can be defined as patterns of behaviours that are exhibited frequently and intentionally in the absence of coercion, representing a habit of mind [6]. However, identifying desirable dispositions in engineering and computing education, or more particularly developing curricula with a goal to develop, reinforce or assess such dispositions is not common in engineering or computing [5], [7].

A. Critical Thinking Disposition Inventory

The concept that a student's disposition is critical to their education is not new. One of the more seminal works was the development of the California Critical Thinking Disposition Inventory (CCTDI) [8] first published in 1994. This and subsequent work laid out a means for assessing seven significant dispositions related to critical thinking [9]–[11]. The CCTDI inventory has been in use since its publication and illustrates how dispositions play a critical role in professional competency related to critical thinking. An overview of the CCTDI for Occupational Therapists is outlined in Table I.

TABLE I. CRITICAL THINKING INVENTORY AND SAMPLE FACTORS

CCTDI [11]	***CCTDI Factors Analysis [10]***
Truth seeking: The tendency to seek the best knowledge in a situation even when one's personal belief system may be challenged; continually evaluate new knowledge and information. **Maturity of judgment**: The ability to suspend or revise personal judgment about issues and the awareness that various solutions may be acceptable. The knowledge that individual behavior is the result of a complex set of factors, e.g., person, environment, etc.	**Objectivity**: or Respect for objectivity in the present study as it had previously, called Objectivity/Maturity and Non relativism; renamed Objectivity to streamline the factor name. Maturity was already entailed in the notion of objectivity and so was redundant as part of the factor name.
Open mindedness: Tolerance toward the opinions of others; sensitivity to the possibility of bias, e.g., considering diversity (cultural, sexual orientation, etc.) encountered in practice. **Inquisitiveness**: Curious and eager to acquire new knowledge. Deficits in this area might hinder a student's potential to develop expert knowledge and his or her practice ability as an occupational therapist.	**Receptivity**: Receptivity: open-mindedness in this study as they had in the previous studies, called Receptivity/ Open-mindedness and Open-mindedness; renamed Receptivity. Open-mindedness was already entailed in receptivity and was therefore redundant as part of the factor name.
Systematicity: The ability to approach problems in a disciplined, orderly, and focused manner; involves consideration of the best ways to approach the evaluation and treatment of clients.	**Systematicity**: Name was retained because the items loading on this factor reflected focus and orderliness, attributes entailed in systematicity.
Critical thinking self-confidence: The ability to trust one's reasoning and reflective abilities. Some persons might underestimate their ability in this area, and some may overrate their critical thinking.	**Intellectual Prowess**: Perspicacity/Confidence and Intellectual Diligence; renamed Intellectual Prowess because items loading on this factor reflected both confidence in intellectual abilities and pride in being perceived as intellectually competent and logical.

This table shows the mapping of established, understood disposition categories into repeatable categories via a careful factor analysis of the well-established CCTDI instrument [10]. The merging of CCTDI categories (e.g., 'open mindedness' and 'inquisitiveness' into the 'receptivity' factor) illustrates some of the difficulties of naming and assessing disposition.

B. Distinguishing Dispositions

Dispositions play a significant, but often contested aspect of engineering and computing education. In an educational context, they serve as a filter through which knowledge and skills are framed, and from which student behaviour emanates [6] [12, p. 1]. The concept of competency in educational statements is described as:

$$\textit{Competency} = \textit{Knowledge} + \textit{Skill(s)} + \textit{Disposition(s)} \text{ performed in a context} \tag{1}$$

Knowledge is the "know what", skills are the "know how" of a task. Dispositions describe the "know-why" and "know-yourself" of knowledge [13], and in a professional setting are observed in relation to conceptual and procedural knowledge. They typically are affective in nature, encompassing attitudinal, behavioural, and socio-emotional qualities of how disposed people are to apply knowledge and skills to solve problems [12] and the sensitivity to know when and how to engage in those tasks [14], [15]. So, they imply a tendency or an inclination to act in certain ways as determined to be appropriate in the situation. In this context, they represent enacted values, a student's values demonstrated through the observed behaviour or otherwise reflected in their work. They can thus be identified by how they moderate other aspects of knowledge, particularly conceptual or procedural knowledge.

From a learning perspective, disposition is that affective component which puts skill and knowledge into correct action in a specific context. Disposition is observable when there is a 'right' or 'better' application of knowledge and skill in a particular context. From this perspective, dispositions are both the result of and influence how one acts and thinks in a certain way. To the agent, this is strengthened by positive responses and weakened by failures to have them. To the extent that these dispositions are towards an acknowledged external good, (*e.g.,* generosity or bravery) and become central to the person, these dispositions can be called virtues, but not all dispositions are virtues [16]. To a certain extent, one can think of dispositions as neutral virtues, ways of thinking and acting that can be good, specifically when enacted in the appropriate context. For example, a disposition can be attention to detail. Attention to detail is often a sought-after job skill [17], but it is not always a virtue; its 'goodness' is contextually located. In some settings, too much attention to detail can significantly slow or disrupt a creative process. Similarly, the lack of appropriate attention to detail can be a significant detriment to the product/project quality. While the development of virtue ethics in engineering and computing education has significant merit [18]–[20], this work focuses on understanding and modelling the more fundamental role that disposition plays in the development of engineering and/or computing competency.

C. Using Dispositions in Expressing Competency

Rooted in learning theory, CC2020 strongly advocates the adoption of a competency-based approach to computing curricula. "[Competency Based Education] can be characterized as being an amalgamation of the work of several leading learning theorists: It contains elements of programmed instruction, clearly specified behavioural objectives, hierarchical methods of knowledge acquisition, and social learning techniques." [21] Competency statements aim to describe educational or professional development goals. They are mechanisms for describing intent, and when well formed, provide a mechanism for contrasting that intent with other programs. Following the CoLeaF model developed in 2018 [5], competency statements significantly enable program connections to professional competencies [22] and provide a broader expression of program goals. Meaningful competency statements that are valid from multiple stakeholder perspectives can be difficult to express, particularly in ways that are clear, concise and/or coherent with other educational objectives. Part of the difficulty with expressing competencies is that complete and coherent descriptions are rarely concise or semantically unambiguous.

From a more content-expression perspective developed in the CoLeaF model, complete competency statements include or intuit three educational aspects: knowledge (K), skill (S), and disposition (D); the integration of which can only be demonstrated in relation to a context (C) or task. For a complete competency description, four (K-S-D-C) components should be expressed, and for the description to be well aligned with others, it should leverage consistently understood terminology for expressing the relevant K-S-D-C components [5].

III. Expressing Competency

Competency statements are not a common means for expressing learning goals or outcomes. Properly formulated, they differ from learning outcomes in that they have a structured content that elucidate all four (K-S-D-C) components. The use of all four of these components is often implied within a variety of other educational outcome statements, and in our explorations, the linguistic expression of these concepts, even in well-established domains rarely includes all four aspects, although they often imply them, especially in a rich knowledge domain such as computing. This is described in more detail in the example presented in Figure 2.

There are numerous linguistic issues associated with trying to describe the knowledge and skills (and other personal attributes) associated with demonstrated competence in a highly cognitive area such as computing. In particular, distinguishing knowledge, *e.g.,* what is known vs. how that knowledge is used or applied, can be particularly awkward. An example is the tension between the knowledge of programming vs. the skill needed to program.

A. Knowledge and Skill Components

To address this complexity, this work applies a simplification of the K-S-D-C competency theory. Rather than carefully distinguish conceptual knowledge (know-of/know about) and procedural knowledge (know how), this work proposes modelling knowledge and skill as applied knowledge/skill (KS). This proposal stems from the nature of competency modelling and assessment, in the sense that in developing competencies, all conceptual knowledge (know-of/know about) and procedural knowledge (know how) is observed through the lens of the observation of that knowledge applied in a context. This results in isolating the knowledge vocabulary pre-existing in KA-KU-LO models of curriculum so that may be adopted in CC2020 competency by decoupling skill level from existing K vocabularies (e.g., CS2013).

While imperfect psychologically, this modelling of knowledge/skill (KS) as applied knowledge demonstrated with some skill is well suited for competency-based education. It permits connecting identified KS elements to useful observed skill levels (SLs). The revised Bloom's Cognitive domain [23] vocabulary works well for SLs, as it is in common use among computing educators (*e.g*., cognitive skill terms classified as Remembering, Understanding, Applying, Analysing, Evaluating, Creating). This approach has an added benefit in that it reduces the difficulty of distinguishing KS components from each other, enabling a richer vocabulary of knowledge goals to be leveraged and established understandings of cognitive skill levels to be employed in the definition and assessment of competency or competency component.

TABLE II. Sample Computing Knowledge Area Vocabulary [24]

1. Users and Organizations	CK 1.1. Social Issues and Professional Practice
	CK 1.2. Security Policy and Management
	CK 1.3. IS Management and Leadership
	CK 1.4. Enterprise Architecture
	CK 1.5. Project Management
	CK 1.6. User Experience Design
2. Systems Modeling	CK 2.1. Security Issues and Principles
	CK 2.2. Systems Analysis & Design
	CK 2.3. Requirements Analysis and Specification
	CK 2.4. Data and Information Management
3. Systems Architecture and Infrastructure	CK 3.1. Virtual Systems and Services
	CK 3.2. Intelligent Systems (AI)
	CK 3.3. Internet of Things
	CK 3.4. Parallel and Distributed Computing
	CK 3.5. Computer Networks
	CK 3.6. Embedded Systems
	CK 3.7. Integrated Systems Technology
	CK 3.8. Platform Technologies
	CK 3.9. Security Technology and Implementation
4. Software Development	CK 4.1. Software Quality, Verification and Validation
	CK 4.2. Software Process
	CK 4.3. Software Modeling and Analysis
	CK 4.4. Software Design
	CK 4.5. Platform-Based Development
5. Software Fundamentals	CK 5.1. Graphics and Visualization
	CK 5.2. Operating Systems
	CK 5.3. Algorithms and Complexity
	CK 5.4. Programming Languages
	CK 5.5. Computing Systems Fundamentals
6. Hardware	CK 6.1. Architecture and Organization
	CK 6.2. Digital Design
	CK 6.3. Circuits and Electronics
	CK 6.4. Signal Processing

Consequently this work leverages the structure of existing computing curricula observing that when expressing learning goals, knowledge and skill normatively act as paired terms, either explicitly or implicitly, and then rather than work hard to identify skill separately, we propose to identify the intended skill-level in the application of that knowledge.

Table II provides a vocabulary for describing broad computing competencies, drawn from established knowledge-area language from across six computing curricula (e.g., [25]–[27]). This list lacks the inclusion of professional knowledge-skill (PS) categories common to many/all engineering and computing disciplines. A useable list of professional skills for computing has been included in recent computing curricular documents: IT2017 [28] and MSIS2016 [29]. A sample set of distinct professional knowledge-skill categories are presented in Table 3. Other valid formulations are possible, like that developed by Lee et al [30] highlighting: Technical specialties knowledge, Technology Management Knowledge, Business Functional Knowledge, Interpersonal and Management Skills.

TABLE III. PROFESSIONAL KNOWLEDGE AREAS

Professional Knowledge-Skill Categories	
PK 1.	Oral Communication & Presentation
PK 2.	Written Communication
PK 3.	Problem Solving and Trouble Shooting
PK 4.	Project/Task Organization & Planning
PK 5.	Collaboration and Teamwork
PK 6.	Research and Self-Learning
PK 7.	Multi-Task Prioritization & Management
PK 8.	Relationship Management
PK 9.	Analytical and Critical Thinking
PK 10.	Time Management
PK 11.	Quality Assurance / Control
PK 12.	Mathematics and Statistics
PK 13.	Ethical Intercultural Perspectives

These two simplifications of CoLeaF reduce the set of factors to be considered in identifying competency components. First, the K-S pair allows the use of KA models from any of the existing international computing curricula (e.g. IT2017, CS2013, SE2014, etc.), or any synthesis of these models, such as that provided in Table 2. Similarly, the vocabulary of the K-S pair can easily include the integration of 'soft' or professional K-S pairs, such as that provided in Table 3. The SL simplification supports the assessment of the competency (*E.g*., defining the level at which the K-S is expected to be observed). The identification of dispositions remains a missing factor for the consistent modelling of computing competencies.

IV. IDENTIFYING DISPOSITIONAL COMPONENTS IN COMPETENCIES

In this analysis of the concept of disposition, there appear to be two major categories of dispositions: virtues and value-neutral dispositions [16]. Both are broad individual characteristics that moderate the impact of the application of knowledge and skills to a particular professional task context. The proposed disposition nomenclature assumes that multiple dispositions may be relevant for a particular task context.

Dispositions express themselves in acting, reasoning, and feeling in certain ways. These ways of acting, reasoning and feeling are not items that can be assessed directly; and single action or reflected reasoning or feeling does not make up a disposition; rather the pattern is observable, albeit indirectly. In this sense, disposition can be observed through collections of actions or reflections (what they say or were observed to do), but not assessed directly [7], [31]. This is a helpful observation for distinguishing dispositional elements from cognitive skills.

An essential development in the way the disposition concept has evolved is the separation of foundational professional skills (such as communication clarity, leadership, creative thinking, and time management, which include significant components from the "know-how" category) from dispositions ("know why"). This was accomplished by analysing research on job descriptions [17], [32] and other related sources [19] and then either removing statements identifiable as a KS-SL pair, or appear as a competency combining KS, SL, D, and other components. Hence something as complex as leadership is best modelled as a competency because it has implied KS-SL pairs and one or more dispositions. Other items may well be a collection of KS-SL pairs which then would be constituent parts for a competency. Those concepts that are more complex and hence are competencies themselves (e.g. leadership) were also isolated. The remaining terms are the concepts that moderate knowledge and skill. Table 4 provides a summary of this exploration.

TABLE IV. COMPUTING DISPOSITIONS DERIVED FOR CC2020

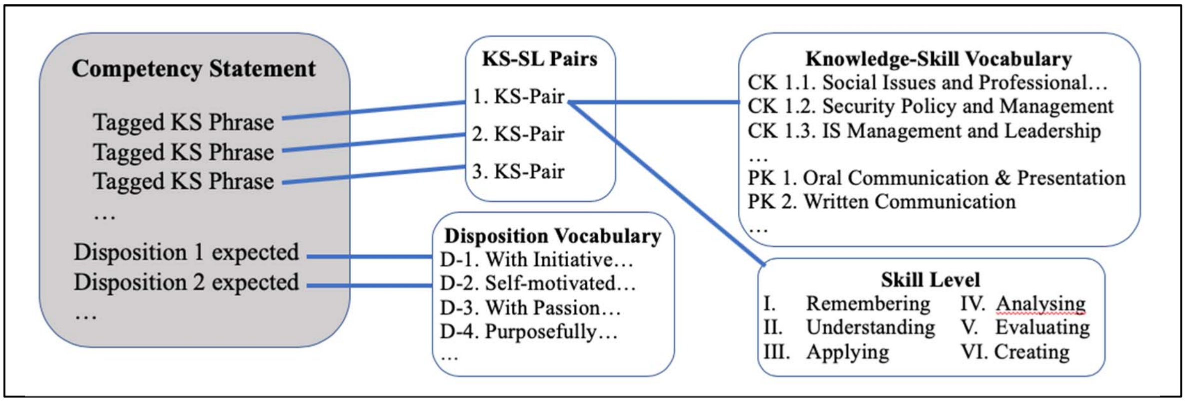
D-1	***With Initiative*** [32] / ***Self-Starter*** [17] Shows independence. Ability to assess and start activities independently without needing to be told what to do. Willing to take the lead, not waiting for others to start activities or wait for instructions.
D-2	***Self-motivated*** [17] / ***Self-Directed*** [32] Demonstrates determination to sustain efforts to continue tasks. Direction from others is not required to continue a task toward its desired ends.
D-3	***With Passion*** [32], [17] / ***Conviction*** [19] Strongly committed to and enthusiastic about the realization of the task or goal. Makes the compelling case for the success and benefits of task, project, team or means of achieving goals.
D-4	***Purposefully engaged / Purposefulness*** Goal-directed, intentionally acting and committed to achieve organizational and project goals. Reflects an attitude towards the organizational goals served by decisions, work or work products. *E.g.,* Business acumen [32], [17].
D-5	***With Professionalism*** / ***Work ethic*** [32] Reflecting qualities connected with trained and skilled people: Acting honestly, with integrity, commitment, determination and dedication to what is required to achieve a task.
D-6	***With Judgement*** / ***Discretion*** [32] / ***Responsible*** [17] / ***Rectitude*** [19] Reflect on conditions and concerns, then acting according to what is appropriate to the situation. Making responsible assessments and taking actions using professional knowledge, experience, understanding and common sense. E.g., Responsibility, Professional astuteness [19].
D-7	***Adaptable*** [32] / ***Flexible*** [17] / ***Agile*** [18] Ability or willingness to adjust approach in response to changing conditions or needs.
D-8	***Collaborative*** [18] / ***Team Player*** [17] / ***Influencing*** [32] Willingness to work with others; engaging appropriate involvement of other persons and organizations helpful to the task. Striving to be respectful and productive in achieving a common goal.
D-9	***Responsive*** [18] / ***Respectful*** [17] Reacting quickly and positively. Respecting the timing needs for communication and actions needed to achieve the goals of the work.
D-10	***Attentive to Detail*** [18], [32] Achieves thoroughness and accuracy when accomplishing a task through concern for relevant details.
D-11	***Curious*** [17] Attentive to what is not known, what needs to be known, what in the problem domain or solution opportunity that does not fit, and how it does not fit.

The list in Table 4 defines eleven arbitrarily grouped disposition categories. Like the seven CCTDI terms of Table 1, these eleven are open to the development of assessment instruments and appropriate factoring of those instruments. However, these descriptions each define a concept desired in computing practice for moderating applied conceptual and procedural knowledge, *e.g*., a disposition.

V. Reconsidering Learning Goals

Learning goals, particularly at the program level, are intended to be future-looking and supportive of effective transactional teaching and learning. Well-modelled competencies provide the opportunity for learning goals to support both paradigms, as the modelling task requires uncovering unspoken expectations and documenting them in a way that supports both course delivery and future assessment [5].

Fig. 1. Model for Classifying Competency Statements



Utilizing the disposition vocabulary derived from relevant job descriptions (Table 4), the disposition categories can be used to meta-tag portions of a competency statement using the {KS, SL, D, C} descriptive mechanisms to make more explicit the intended skill-level of the applied knowledge, to identify the contextual/task-related aspects of the statement, and more particularly, to make more explicit the dispositional aspects expected of the learner.

The KS, SL and D vocabularies in Figure 1 and Tables 2-4 provides a structure for analysing competency statements. A particular competency statement can have numbers of KS components and an SL paired with it. Similarly, one or more KS-SL pairs can be moderated by one or more D labels. This conceptualisation extends the CoLeaF model of [5]. This implies a relationship structure for the components (tagged phrases) of a competency statement. Figure 1 depicts a block diagram for this tagged information. The vocabularies and skill levels come from the lists provided in Tables 2-4. In another instantiation, the KS vocabulary of this example could be replaced by any appropriately adjudicated knowledge-area vocabulary (*e.g.,* CS 2013[33], SE 2014 [25], etc.).

A. *Meta-Tagging Process for Analysing Competency Statements for Components*

The task for meta-tagging a competency statement is to take previously drafted competency statement(s) written in natural language, and for each such statement:

1) Identify a candidate phrase in the statement that implies some K-S-D-C components.
2) Utilizing a KS vocabulary (e.g., Tables 2-4), label the phrase for its stated or implied KS competency components, meta-tagging phrases in the statement with stated or implied KS components.
3) For each KS tag, label with the stated or implied skill level (SL) expected for that particular KS-SL pair. Where particular phrases in the statement imply or state this level, these would also be meta-tagged.
4) Tag the phrase of the statement for dispositional elements stated or implied.
5) Repeat steps 1-4 until all taggable phrases have been explored.
6) Tag the statement phrase(s) that communicate the contextual/task information.

This analysis cycle is designed to identify KS-SL pairs per Figure 2, and routinely ask questions to help uncover and meta-tag implicit KS-SL, dispositional elements (D) or contextual/task information (C).

B. *Finding Dispositions: An Example Competency Analysis*

To illustrate the meta-tagging process used to document and analyse a competency statement, we present an example statement from Software Engineering. The goal is to unpack, in a structured form, phrase decompositions that represent the explicit and implicit K-S-D-C components of the competency. This detailed mapping of a competency statement serves multiple purposes. To begin with, it very much helps one to understand the completeness of the statement, as well as the SL and KS components expressed or implied. The completeness of the statement suggests the nature of a contextually situated example that would have the opportunity of generating multiple different assessment opportunities. It also provides a connection to what is expected to be assessed, e.g., not just what the students did, but how they did it; the quality of both their work and the quality of how that work was accomplished.

The most important aspect of this exercise is the support for the actualization of this competency within this program. It provides a structured way of expressing what needs to be taught, a framework for determining how best to manage the learning activities, and clear discussion points for how best to assess different aspects of this competency within the program. For example, this competency could be inside of a single course, but it could be in multiple courses. It could be a key task within a requirements course, or a project-based course, or even in a learning exercise at an internship or other setting.

Fig. 2. Competency Statement for Software Requirements

Identify and document software requirements by **applying a**
i
known requirements elicitation technique in work sessions with stakeholders, ii
using facilitative skills, as a contributing member of a requirements team.
iii

The natural-language text of Figure 2 can be broken into three constituent phrases for analysis. The list that follows suggests one examination of the explicit and implicit KS-SL pairs, as well as an overall model to capture the implied context of the statement as a whole.

Analysing these three constituent statements results in the following four sets of mappings:

i. "Identify and document software requirements" (somewhat) explicitly expects students to be applying (SL:III) Requirements Analysis and Specification (CK 2.3) knowledge and understanding. It also implies students to demonstrate applying (SL:III) Written Communication (PK 2) knowledge and skills.

ii. "applying a known requirements elicitation technique in work sessions with stakeholders" explicitly expects students to be applying (SL:3) Requirements Analysis and Specification (CK 2.3) knowledge and understanding and implies students to be applying (SL:III) Systems Analysis and Design (CK 2.2) knowledge and understanding.

iii. "using facilitative skills, as a contributing member of a requirements team" explicitly expects students to be applying (SL:III) Requirements Analysis and Specification (CK 2.3) knowledge and understanding and to be applying (SL:III) Collaboration and Teamwork (PK 5) knowledge and skills.

iv. In context, this statement implies that students demonstrate the capability of evaluating (SL:V) Requirements Analysis and Specification (CK 2.3) and Analysing (SL:IV) Collaboration and Teamwork (PK 5). These behaviours are expected to be moderated by students demonstrating that they are purposefully engaged (D4), with judgement (D6) and demonstrating that they are collaborative (D8). The statement is explicit about having a particular (though unspecified) context (C).

This example briefly illustrates a competency-based approach to defining a curricular goal or learning outcome. As such, it sets up the opportunity for (and challenges) the educator to set up a learning situation whereby not only will the students be challenged to engage in the context (work sessions with stakeholders), but also that the instructor can observe student behaviour for assessing to what extent the students demonstrate the K-S-D components.

VI. Broadening Curricular Goals

One advantage of this formulation is the pair-wise expansion: On one side, a concise, free-form stakeholder-friendly competency statement is available for descriptive purposes. On the other, a detailed expansion with assessable KS statements rooted in an underlying professionally understood vocabulary paired with pedagogically useful skill-levels. To this extent, the enhanced CoLeaF structure of CC2020 significantly extends more traditional curricular goal / program outcomes descriptions.

The most important advantage is the inclusion of dispositional elements associated with the context. While dispositions are difficult to assess directly, they can be observed and like other affective-domain assessments, assessed indirectly [7], [34]. In particular, defining the dispositions expected for a particular set of learning activities encourages faculty to include learning modules related to disposition-helping students understand what is expected of not just the products of their work, but the human, interactive aspects of their work. These expectations help significantly motivate the need for, institutionalization of, and assessment of authentic project-based learning [35]–[37], explicitly embracing the 'transactional' teaching paradigm identified by Clear and Young [2].

The impact of this clarity in educational goals has the potential to be transformational. Disposition as a required component of program learning goals adds another dimension: It extends learning goals to specify the enacted values, the directions in which students are expected to develop as learners and enlarge their minds. This embraces the third, 'critical' teaching paradigm as well as the broader goals of education. By specifying context and disposition, this style of learning goal represents "an innovative means of transmitting knowledge" [21].

This broadening of curricular goals has the potential for expanding student learning beyond a learning outcomes approach common to many engineering and computing syllabi and curricula. For example, consider the differences between items i-iii in Figure 2, which are easily translated into learning outcomes. However, the inclusion of expected dispositional elements in item iv (*Purposefully Engaged, With Judgement*, and *Collaborative*) transforms both the expectations and the expected assessment of the teaching and learning activities. These additional documented expectations (see item iv) provide the instructor with the opportunity to discuss what these values mean in practice, and particularly in the context of how students might demonstrate these enacted values in their project. When communicated to students, dispositional expectations emerge from the 'hidden curriculum' of professional expectations into concepts that students can observe in themselves, observe in others, and most importantly, make intentional efforts to do and reflect on the attempt.

For the instructor as well, this broadening of curricular goals similarly sets a different expectation for teaching and learning. Taking on a competency statement like that in Figure 2 sets a higher requirement; such a course or program could not rely on learning about requirements elicitation, but rather an active pedagogy that engages students (items i-iii). More importantly expectations around disposition (item iv) sets the expectation for the instructor to encourage and observe not just collaboration, but purposeful collaboration; about students practicing good judgement of the requirements they elicit, the processes they use, and their interactions with their stakeholder(s).

Dispositions concern not what abilities people have, but how people are disposed to use those abilities [14]; It a sense, they name something within the learner. Consequently it challenges both student and teacher to develop their awareness, inclination, and reflective abilities; For faculty to develop explicit cues for when to call upon specific theories or when to use specific skills, and the expectation for students to try them [12]. Hence, the addition of disposition as an aspect of documented learning goals inevitably sets up ethical questions: about what the 'correct' disposition(s) are, the valid observations of students' dispositions, and how these observations translate back to the adjudication of the students' performance vs. a judgement of the students' themselves. The implication is that the highly moral nature of teaching and learning becomes more obvious. These considerations require further exploration. Similarly, the connection to learner agency provides a different exploration into the connection to engineering and computing ethics.

VII. CONCLUSION

Recognising dispositions and context in the competency statements of computing curricula is now becoming well-established as the key to advancing the use of competency for describing the goals of professional education. Dispositions serve as a filter through which knowledge and skills are framed, and from which student behaviour emanates. In a professional setting they are observed in relation to conceptual and procedural knowledge. This paper has described the structure of competency statements with particular emphasis on the development and inclusion of dispositions. It has also described the disposition statements. The meta tagging of skill level using the disposition categories makes it clear for educators what is required in the curriculum, the *know what*, the *know-how*, and the *know why*, enabling better learning environments for the students.

Areas of future work will be the expansion of models like CoLeaF for describing whole curricula, as well as the expanding work into connecting competency to developing graduate attributes and program assessment as this paper suggests. This work only suggests a potential set of disposition categories (Table 4). These may not be the definitive statements, or may evolve like the development of a semiotic ladder [24] of terms for cognitive skills as in [23]. Further development on dispositional language and the presence of these in competency-specified computing curriculum statements is ongoing.

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IX. REFERENCES

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