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USING COMPETENCIES FOR SPECIFYING OUTCOME EXPECTATIONS FOR DEGREE PROGRAMS IN COMPUTING: LESSONS LEARNED FROM OTHER DISCIPLINES

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Abstract:

This essay reviews the use of the competency concept in various educational and professional development contexts. Its key purpose is to identify the lessons that computing education and practice can learn from disciplines that have explored and evaluated the use of competency-based approaches much longer than computing. The review reveals a broad variety of definitions and uses of the competency concept in a number of fields but no single unifying success formula emerges. The key recommendations of the essay are as follows: the efforts in computing education that use a competency-based approach should 1) carefully consider ways to specify competencies in an integrated, holistic way instead as a simple combination of components (such as knowledge, skills, and attitude); 2) recognize the purpose and timeframe for which competencies are specified, specifically avoiding a sole focus on short-term professional competencies; and 3) explicitly and transparently communicate whether or not the intent of any effort that uses a competency-based approach is to transform the entire educational model (instead of simply using competencies for specifying outcome expectations).

Keywords: Computing education, competency, competency model, competency-based education

I. INTRODUCTION

Several recent international initiatives in the context of computing have been built around the concept of professional competencies. Some of these initiatives are primarily industry-focused (such as e-CF 3.0 and SFIA; www.ecompetences.edu and www.sfia-online.org/en) and others products of the academic community, such as MSIS2016 [Topi et al., 2017], IT2017 [IT 2017 Joint Task Group], and the Edison project (edison-project.edu). All of them have the same underlying idea: specifications of educational or professional expectations should focus on articulating what knowledge, skills, and attitudes/dispositions a professional (or an aspiring professional) needs to perform well in a computing profession. The alternative approach is to specify learning needs based on knowledge as the core content that needs to delivered by an instructor. The emphasis of the competency-based approach is on needs of the learner instead of the knowledge content that an instructor teaches. The CC2020 (Computing Curricula 2020; see www.cc2020.net) project has also chosen the competency-based approach as its underlying conceptual foundation: its goal of comparing and contrasting computing disciplines will be based on competencies as the common currency.

The purpose of this essay is to explore the foundations of the competency-based approach to education in order to identify its key strengths and weaknesses and recognize better the potential pitfalls that computing education in general and the CC2020 project in specific should avoid. The competency-based approach is in some contexts associated with educational models that traditional universities have been avoiding. This essay will also discuss what this means from the perspective of the choices a project such as CC2020 needs to make.

II. DEFINITIONS OF COMPETENCY

It is essential to recognize that the concepts of competency and competency models have been a target of intensive exploration and discourse in a variety of fields over an extensive period of time. We will discuss these different traditions later in this essay. First we will, however, provide a brief

review of various definitions of competency and related concepts in order to determine whether or not significant differences exist that might make difference for CC2020.

Human resources (HR), a subfield of organizational management, has used the concepts of competency and competency model for an extended period of time. Of the extensive collection of definitions used in HR, we will highlight only a couple. For example, in a major book-form exploration of the topic, Lucia and Lepsinger [1999] define competency as "… a cluster of related knowledge, skills, and attitudes that affects a major part of one's job (a role or responsibility), that correlates with performance on the job, that can be measured against well-accepted standards, and that can be improved via training and development." This definition includes multiple elements that are worth pointing out: 1) A competency has multiple dimensions, two of which are almost invariably called knowledge and skills. The term used for the other elements varies; attitudes used by Lucia and Lepsinger is a common option. 2) To be useful, competencies typically need to be linked to a job role or job responsibility. 3) A competency specification is meaningful only if an individual's level of achievement in relation to a competency can be measured. 4) A competency is meaningless if an individual's achievement level related to it cannot be developed using a systematic approach, particularly if the intent is to use the competency specification as an educational/ developmental target.

In addition to individual competencies, HR literature also discusses competency models. For example, in a comprehensive review of competency models, Campion et al. [2011] refer to competency models as "collections of knowledge, skills, abilities, and other characteristics (KSAOs) that are needed for effective performance in the jobs in question" (p. 226). These authors define competencies simply as "the individual KSAOs or competencies of KSAOs." (p. 226). The competency model concept is used with essentially the same meaning also in MSIS2016.

John Bowden, Professor of education at RMIT in Australia, who served in various university-level functions related to teaching development, published in 1997 an important summary of competency-based education entitled "Competency-Based Education—Neither a Panacea nor a Pariah" [Bowden, 1997]. One important aspect of this paper was a description of multiple types of competency-based approaches, in which he describes the "knowledge, skills, and attitudes" approach discussed above as the generic, Level 0 approach. Based on an analysis of CBE literature, he identifies four additional levels: behaviorist (1), additive (2), integrative (3), and holistic (4). According to Bowden [1997], movement towards Level 4 includes: "1) increasing complexity of outcome; 2) broader curriculum requirements; 3) more complex assessment requirements; 4) increasing ambiguity in the relation between objectives and assessment of outcome, and 5) increasing need for interpretation and professional judgment in assessment." (p. 7).

If the computing education community wants to make a significant move towards competency-based education or even just competency-based specification of outcome expectations, we need to develop an understanding of computing competencies that is systematically and intentionally at the holistic level (Level 4). Bowden describes Level 4 as "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." (p. 7) Clearly, a well-defined specification of a competency is significantly more complex than a listing of knowledge, skills, and abilities or attitudes. The richness and complexity of the outcome needs in organizational contexts is such that advanced competency specifications cannot be expressed only as a combination of component knowledge, skills, and attitudes: the way these components are integrated together matters as much or more than what the components are.

Boritz and Carnaghan [2003], in their comprehensive critical review of the competency-based approach in accounting education, offer a very useful analysis of various perspectives on the competency concept (see p. 10). They identify altogether six dimensions along which competency definitions vary, summarized here very briefly as questions: 1) should competency specifications consider general personal attributes/traits or just skills/abilities associated with a job role?; 2) should competency specifications include (accumulated) knowledge as an element

separate from job outcomes?; 3) should competency specifications focus on the outcomes of skills and activities or an individual's ability to perform the skills and activities correctly?; 4) should the focus be on sufficient, effective, or superior performance?; 5) Is the fundamental nature of competencies atomistic (detailed) or holistic?; 6) How important is observability? Number 3 above is particularly interesting: Hoffman [1999] also makes a difference between competencies seen either as observable performance [in the context of a task] or the underlying attributes of a person [enabling the observable performance].

Medicine is likely to have applied the competency concept more extensively in education than any other academic field, both for physicians and nurses. In the context of medical education, Frank et al. [2010a] (representing International Competency-Based Medical Education (CBME) Collaborators) propose the following definition of competency (p. 641): "An observable ability of a health professional, integrating multiple components such as knowledge, skills, values, and attitudes. Since competencies are observable, they can be measured and assessed to ensure their acquisition. Competencies can be assembled like building blocks to facilitate progressive development." and competence: "The array of abilities across multiple domains or aspects of physician performance in a certain context. Statements about competence require descriptive qualifiers to define the relevant abilities, context, and stage of training. Competence is multi-dimensional and dynamic. It changes with time, experience, and setting." The distinction between competence as a broader context ("array of abilities," "across multiple domains," "multi-dimensional") and competencies as specific, observable, and measurable building blocks is useful also for the conversation in the computing context. The questions we need to answer: is there any reason why we couldn't replace "health professional" and "physician" in the definitions above with "computing professional," and if we do so, are these definitions acceptable and/or helpful? Should computing follow Frank et al. [2010a], who view competency-based education as "a resurgent paradigm in professional education" (p. 638)?

III. LESSONS COMPUTING CAN LEARN FROM OTHER DISCIPLINES

As already initially discussed above, the competency-based approach to education and professional development has been applied to multiple fields and professions, including medicine, chiropractic medicine, social work, education, and pharmacology [Frank, 2010a]. Various medical fields appear to be the most frequent users, but set of perspectives is quite broad. In this section, we will review various disciplines that are most likely to provide useful guidance for computing education.

Management: Organizational Behavior and Human Resources

Organizational Behavior and Human Resources within the business discipline of management have explored the role of competencies within organizations for an extensive period of time. In this context, the key purpose of the analysis has been to determine the specific skills, knowledge, attitudes and other characteristics of the individuals that a company needs to achieve its goals. Schneider and Konz [1989] do not use the term competency, but they are essentially writing about the same concept when they explore the mechanisms to "recruit, select, train, and appraise people" for a specific job (p. 51) in an activity called strategic job analysis. For Schneider and Konz, it is particularly important to recognize that competency analysis focuses on future needs: both recruitment and training will be successful only if the organization recognizes that the goals of competency development within the organization have to be set with future needs in mind. The HR perspective is very interesting for educational programs, also those in computing, because it represents and specifies the needs of employers and should, thus, be particularly useful as guidance for those who are designing educational programs.

It is important to note that the HR community has expended significant resources for understanding and studying issues related to competencies, particularly in the form of job analysis and competency modeling. For example, in 2000 the Job Analysis and Competency Modeling Task Force of the Society for Industrial and Organizational Psychology reported on a comprehensive two-year study on competency modeling [Shippmann & al., 2000]. This study

presents a broad review of various literatures and organizational practices that have contributed to the practice of competency modeling, including individual differences and educational psychology, leadership research and assessment centers, job analysis [see also Schneider and Konz, 1998 above), the concept of multiple intelligences, and Prahalad and Hamel's [1990] work on organizational level core competencies.

As discussed briefly above, Campion et al. [2011] offers another useful summary of HR/management literature on competency modeling. For the purposes of this essay, probably the most important observation made by the authors is that organizations use competency models as the conceptual foundation for "HR systems so that…the organization hires, trains, evaluates, compensates, and promotes employees based on the same attributes" (p. 228). From the perspective of educational programs, this is highly interesting, and particularly so for those programs with a professional focus. Access to a broad range of organizational competency models would give educational programs an excellent way of understanding how to prepare future employees.

Tuxworth [2005], in an early analysis of the history of competence-based education and training (CBET), makes multiple useful observations that are likely to be beneficial for this essay: 1) each professional field needs to develop its own definitions of competencies; 2) competence as a general concept is not value neutral, and neither are individual competencies [Wolfe, 1980]; 3) the processes used to build competency models need to take into account both "analyzed functions of the occupation and characteristics of highly competent role holders" (p. 120)—it is not sufficient to just to analyze the roles but it is essential that specific individual characteristics are analyzed (see also the discussion regarding this above in the context of Boritz and Carnaghan [2003]); and 4) development of guidance for education should "allow for growth and for transfer"; no educational program should only focus on developing competencies for the immediate needs of a specific employee. A competency model underlying educational programs should explicitly incorporate two components: 1) generic competencies for an individual's career as a whole and 2) specific competencies for more narrowly defined organizational roles.

Medical Education

As discussed above, the competency-based education model is probably most widely applied in medical education, both physician and nursing education. It is impossible to briefly summarize the full discourse that has taken place within the medical education community. Some of the outcomes, however, appear to be highly useful now when the computing education community is taking its first steps toward articulating competency-based education in computing. It, indeed, would seem to be a major waste of resources to not learn from a field that is responsible for developing one of the most complex and challenging sets of competencies required in any profession.

Particularly the special issues of *Medical teacher* on competency-based medical education (CBME) in 2010 and 2017 are valuable in understanding the discussions that are taking place within the medical education community related to the ongoing paradigm shift toward a competency-based model. Based on the key articles [such as Frank et al., 2010a; Frank et al., 2010b; Frank et al., 2017; Holmboe et al., 2017], it is clear that the process has been highly thoughtful and one where steps backward have been allowed when they have been necessary.

Frank et al. [2010a] specify four fundamental characteristics of competency-based education in medicine: 1) focus on outcomes (i.e., graduate characteristics), with a specific emphasis on accountability and transparency; 2) focus on abilities ("skills, attitudes, and their synthesis into observable competencies") while reducing the emphasis on knowledge alone; 3) de-emphasizing time as a measure of focus, instead focusing on "developmental progression of abilities and on measures of performance" (p. 640); and 4) stronger focus on learner-centeredness, offering learners a transparent path toward the desired and required outcomes.

Obviously, those of us interested in achieving the best possible outcomes in computing education need to ask whether or not the characteristics specified above have a good fit with the goals we have for computing education. Both MSIS2016 and IT2017 processes independently came to the

conclusion that the competency-based approach would be beneficial in these subdisciplines of computing, and the CC2020 process is now expanding the concept to computing education as a whole. The justifications underlying the use of the competency-based approach in medical education appear to be equally valid in computing. It is, however, important to recognize that simply specifying the competencies and developing a broadly accepted competency model is not sufficient; it will be equally important to provide guidance for educational programs in terms of how to design educational experiences so that students will be able to achieve the outcomes. Furthermore, it is essential for the field as a whole to engage in a similar introspective process that medicine has followed in the context of physician education. Sharing experiences, including those of failure, is critically important. The process of sharing needs to involve the computing education community as a whole and the subcommunities individually, given the significant differences between dominant job roles.

Holmboe et al. [2017] summarize the criticisms targeted toward competency-based medical education, including concerns about reductionism (reducing the work of a physician into a set of narrowly defined competencies without a holistic view of the overall competence), lack of evidence of success of CBME, systemic complexities that require a time-based approach to physician education, difficulties associated with modifying the current educational model, and various philosophical concerns. From the perspective of computing education, the systemic, structural obstacles are unlikely to be as difficult because of the lack of the clinical component. It is, however, important that the computing education community considers the other concerns with the same level of intensity as the medical community appears to have done. In the key papers regarding CBME is particularly impressive their focus on ultimately preparing physicians better so that future patients will receive better care: educational outcomes matter because they will have an impact on the outcomes of the entire profession. Are we able to find the same attitude in computing and have a strong desire to achieve better educational outcomes so that our graduates will contribute more effectively societally?

Business Education

In addition to engineering, business is another professional field of study that is of significant interest for computing education, particularly given the way Information Systems as computing discipline often integrates computing and business as a domain of practice. The literature on competency-based education in business is sparse. One relatively recent example is Dragoo and Barrows [2016], who report on a qualitative comparison between three (non-identified) business programs that follow a competency-based approach. The authors compared the programs from four different perspectives (competencies, alignment, assessment, and variable-paced learning), based on Johnstone & Soares [2014].

Dragoo and Barrows [2016] discovered surprisingly significant differences between the programs in terms how the key competency concepts were defined and student achievement expectations discovered. They specifically call for CBE implementers to “consciously develop a commonly understood set of definitions for use at their institution” (p. 377) even though the interviewees in their study also typically defined competencies as a combination of knowledge, skills, and abilities. The way these three were integrated did, however, vary significantly.

Also in the context of a traditional business discipline, Boritz and Carnaghan [2003] provide a comprehensive review of literature on competency-based approaches in accounting education. This analysis offers a thorough discussion on the variety of options that exist for specifying competencies, one of which was already discussed above in the definitions section of this paper. In addition to material specific to accounting education, Boritz and Carnaghan present an extensive list of research questions regarding the “overall utility of competency-based approaches for professional education” (p. 23). Lack of space prevents a thorough discussion of these questions here, but we will quote the first four of them to demonstrate their importance:

“

1. Will a competency-based approach lead to improved linkages between education and practice?

2. Will a competency-based approach lead to greater student satisfaction?
3. Will a competency-based approach lead to improvements in professional performance?
4. Will a competency-based approach increase access into the [Canadian accounting] profession for those with alternative qualifications?" (pp. 23-25)

Based on the literature review underlying this essay, answers to these questions do not exist either at the general level or in the context of any specific profession (despite the fact that these questions were published about 15 year ago). Physician education in medicine appears to have made the most serious effort to address them, but valid and reliable data is not currently available. When we are taking the first steps towards competency-based models in computing education, it is essential that we ask whether or not we are concerned about the lack of data and what steps, if any, we will take to collect such data based on existing and future efforts in computing.

Education

The final area of study that has extensively covered competency-based education over a long period of time is education, specifically education as a discipline that focuses on pre-university/ pre-vocational education (K-12 in the U.S.). We are using Spady [1977] as a starting point because it provides a concise and relatively widely cited specification of the characteristics of Competency Based Education (CBE) as seen in education. This article specifies six essential characteristics of CBE:

> 1) Focus on outcomes, which can be specified as *competencies* that are "indicators of successful performance in life-role activities (be they producer, consumer, political citizen, driver, family member, intimate friend, recreational participant, or life-long learner)," (p. 23) which are explicitly separate from "discrete cognitive, manual, and social *capacities* (such as reading and computational skills, speaking ability, and motivation) that, when integrated and adopted to particular social contexts, serve as the enablers or building blocks on which competencies ultimately depend" (p. 23). (Again, we are reminded of the difference between two possible competency perspectives: one focused on indicators of performance and the other one emphasizing components of individual's ability to perform, as discussed above in the context of Hoffman [1999], Tuxworth [1985], and Boritz and Carnaghan [2003]. Spady [1997] specifies competency through various life-roles instead of occupational roles; still, also here the whole educational process is specified through outcomes.
>
> 2) Flexible and individualized approach to time. In CBE, as long as the outcome goals are achieved, time required to do so is irrelevant.
>
> 3) Instruction is specifically associated with attainment of the outcomes.
>
> 4) Measurement of attainment of competencies is critically important for the success of the CBE approach.
>
> 5) The only real measure of student success is certified attainment of the pre-specified competencies.
>
> 6) Student performance data is continuously used as a mechanism to diagnose program characteristics and introduce changes as necessary.

For the purposes of this essay, it is important to note, again, these authors' emphasis on the system as a whole, in which the competency specifications are only one dimension of it. The other characteristics of the system are close to those specified in the other contexts discussed above. Furthermore, it is also useful to point out that even based on a layperson's understanding of K-12 education in the U.S., it is clear that CBE has not become a dominant paradigm in U.S. schools. This is confirmed by reports such as Brodersen et al. [2017]. Many histories of competency-based education [such as Bowden (1997]) claim that competency-based model was

first introduced in a U.S. teacher education in late 1960s. Despite this early start, progress has not been particularly fast.

The Bowden [1997] paper is, in general, a useful summary, discussing many of the debates that have taken place in the education community regarding CBE. In addition, Bowden summarizes the "principles and intentions of competency-based education" as follows:

1) Focus on outcomes;

2) Attempt to achieve greater workplace relevance;

3) Specification of outcomes as observable and measurable competencies;

4) Improved skills recognition as part of the educational system; and

5) Improved articulation and credit transfer.

Together with Spady's articulation of the key characteristics discussed above, these two education researches provide a good summary of the general characteristics of the CBE systems.

IV DISCUSSION

As discussed above, the purpose of this essay was to review key elements of important streams of literature on competencies and competency-based education in a way that will be helpful in future efforts in computing education (with a specific focus on Information Systems education). Given recent academic (MSIS2016, IT2017, ongoing CC2020) and professional (e-CF 3.0 and SFIA) initiatives that use competencies as a foundational concept, there is clearly significant interest in competency-based approaches in computing education and the computing industry. It is not, however, clear how well prepared we as computing education or information systems education communities are to follow the principles of competency-based education. This final major section of this paper will summarize the benefits, disadvantages, and open questions as discovered during the preparation and writing process.

Proposed Benefits

Since the emergence of the CBE model in 1960s in teacher education [Bowden, 1997], the advocates of CBE have proposed the following benefits, which all would appear to apply also to computing education (they have been summarized from the material discussed earlier in this paper):

- Focus on student learning instead of faculty teaching
    - Curricula built based on student needs instead of, for example, faculty preferences or availability of faculty resources
- Development of educational programs that focus on outcomes instead of the time that is spent on a specific subject
- Recognition of individual differences in learning
- Particularly in professional and vocational education, a common language for effective conversations with employers, who are increasingly interested in the professional preparation that graduates of degree programs have
- Focus not only on knowledge or knowledge and skills; in addition, competencies integrate also other elements of professional behavior, the label for which varies (the most commonly used are attitude, disposition, and abilities)
- Increased transparency and accountability through integrated competency (outcome) specifications, educational processes, and assessment.

- Improved foundation for life-long learning that integrates formal educational components and learning on the job.

All of these benefits would seem to apply also to computing education. As the literature discussed above shows, achieving these benefits is not, however, simple and will require significant structural changes in educational models and systems.

Disadvantages and Challenges

Again, summarizing key elements from the material presented earlier in this paper [such as Boritz and Carnaghan, 2003; Talbot, 2004; Frank et al., 2010; and Holmboe et al., 2017], the competency-based approaches to education have both real disadvantages and cultural and political challenges. They can be avoided but only if they are recognized and openly discussed in the contexts in which competency-based education is implemented.

- Particularly in vocational and professional education, it is easy to fall into the trap of focusing only on current and near term competencies, instead of providing students with a strong life-long foundational preparation. Particularly in pre-university and undergraduate education, it is essential that long-term foundational competencies (those not associated with a single occupational role) are not ignored.
- There is a risk that competency-based approach can lead to a largely utilitarian view of education. Part of university education has always involved exploration of topics and discovery of findings that are not immediately necessary.
- Competency-based education involves a risk of a narrow focus on the needs of a particular organizational role instead of the development of general capabilities needed over one's career
- Potential for promoting mediocrity (lowest common denominator) instead of setting aspirational competencies as goals.

In addition to these real difficulties, competency-based education suffers from reputational challenges, such as a perceived close association with non-university vocational education and, in the university context, connection with large-scale online universities (as exemplified by Rasmussen et al. [2016], which is almost entirely based on work by authors working for large online programs).

Open Questions

The first major open question revealed by this review is the fundamental nature of the competency concept. As discussed, for example, by Tuxworth [1985], Spady [1987], Hoffman [1999], and Boritz and Carnaghan [2003], there are two significantly different ways to define and understand competencies: one that focuses one observable performance in relevant job roles and another one that emphasizes the individual capabilities that enable individual performance. As seen above also in this essay, many definitions of competency focus on knowledge, skills, and attitudes/dispositions/etc. as components or dimensions of competency. In computing education, we have to carefully evaluate whether or not that should be our first focus. Emphasizing the fundamental importance of the components will easily lead us to lose the higher-level, integrated and holistic—Bowden's [1997] Level 4—perspective on competencies. Maybe we should recognize that even if we are able to define and specify the measurement for a job-role based competency, we are often not able to articulate its full component structure. Trying to express the competencies in natural language with the intent of fully capturing this component structure might lead to written expressions of competencies that lose their integrated, holistic identity and fail to capture the component structure sufficiently. Instead, we might be better off by specifying the job-role based competencies based on job performance expectations and then, separately, specify the component capabilities (knowledge, skills, dispositions, etc.) with the acknowledgement that the structural specifications will not be complete and that they do not capture the integrated, holistic nature of a competency. In brief, we may have to transparently recognize that job

performance requires more than its knowledge, skills, and attitudes/dispositions components individually; at least equally important is the way in which they are integrated.

The second open question related to the development of the competency models in computing (including the completed MSIS2016 and IT2017 initiatives and ongoing CC2020 project) involves the ways in which we encourage degree programs to use the competencies developed in the initiatives. In all future competency-based community efforts in computing, we have to be very clear about whether our intent is to simply specify competencies as outcomes or to encourage degree programs to move toward a broader implementation of competency-based education. Both approaches have their challenges: to be useful in the context of a traditional time- and course-content based educational model, competencies require a relatively elaborate model with which they are converted into a curriculum (such as the one proposed in MSIS 2016; Topi et al., 2017, pp. 28-42), and it is not clear if this will allow us to gain the full benefits. If, however, our intent is to encourage movement fully toward CBE, the required change is likely to be more substantial than is realistically possible in most university contexts. It is essential that we will be open and transparent about the intent.

The third major open question is the extent to which we see our educational contexts of interest as professional education. Based on this review, the field of study that is using the CBE model most extensively and successfully is medical education (both physician and nursing education, although in this paper the focus was on physician education; see, for example, Frank et al., 2010a, Frank et al., 2010b, and Frank et al., 2017). In the context of CBME, it is clear that the use of CBE is justified by the nature of medical education as preparation for a profession. In all contexts, CBE is designed to prepare an individual for specific roles: in pre-university education, the preparation is for life-roles [Spady, 1977]; in vocational training, for occupational roles requiring specific technical competencies; and in areas such as medicine for advanced professional roles. To what extent do we see computing education as a whole to be preparation for a profession? This is likely to vary depending on the degree type: for example, MSIS2016 chose a competency-based approach specifically because of the need to strengthen the identity and visibility of the information systems profession at the graduate level, but would the same to rationale apply to all degree programs in computing? In CC2020 and other future computing education initiatives that utilize competency concepts as central elements, it is essential to recognize that different degree program types have different goals in terms of roles for which they prepare the students.

V CONCLUSION

The purpose of this essay was to review literature on use of the competency concept in several academic and professional fields in order to discover and summarize guidance for related efforts in computing education. The review demonstrates that fields such as organizational human resources, medicine, and education are clearly significantly further in their use and understanding of the competency-based approaches than computing is. Still, it is clear that few of the models used in other fields are directly applicable to computing; the differences between the specific application contexts are sufficiently large to require a careful analysis of the ways in which the competency-based approach should be applied to computing. This essay identified three major areas requiring further exploration and careful consideration: 1) Should competencies within computing be viewed as integrated, holistic, and measurable specifications of individual performance in a specific context instead of combinations of components consisting of knowledge, skills, and attitudes/dispositions?; 2) Should computing disciplines explore moving towards a full competency-based education model or view competencies simply as an alternative way to specify outcome expectations?; and 3) To what extent is the use of a competency-based approach in computing an indication that we view computing degrees as professional degrees? Are there significant differences between computing disciplines in this respect? The competency-based approach is likely to provide significant benefits for computing but it is not yet clear what the best ways to apply it are.

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