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Information Systems Education Journal

eXtensible Computing Curriculum Reporting Language (XCCRL)

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Abstract

Just as the adoption of eXtensible Business Reporting Language has standardized the exchange, transmission, and reporting of accounting and financial data, this paper proposes the eXtensible Computing Curriculum Reporting Language as a standard for the exchange, transmission, and reporting of computing curriculum information in hopes of achieving semantic comparability among the descriptions of the computing disciplines. This specificity in the extension of eXtensible Business Reporting Language to the computing disciplines in the form of eXtensible Computing Curriculum Reporting Language acknowledges the nascent and emergent nature of computing and the need to reconcile, semantically, between uses of computing terminology and concepts to achieve clarity. This paper provides a brief background on eXtensible Business Reporting Language and demonstrates how the same concept may be applied in computing curriculum reporting. This paper is related to efforts to support the Computing Curricula 2020 initiative of the Association for Computing Machinery and the Institute of Electrical and Electronics Engineers and represents the ongoing work of the Education Special Interest Group Standing Committee on Curricular Matters.

Keywords: eXtensible Computing Curriculum Reporting Language, XCCRL, Computing Curriculum, Computing Curriculum Reporting, Computing Curriculum Mapping, Taxonomies

1. INTRODUCTION

Among its many uses, the curricula that are published by computing programs, institutions of higher learning, or by the organizations and agencies that support these institutions, constitute a communication regarding the nature of the knowledge about which the curriculum is focused and the outcomes which the learner will achieve. In effect the curriculum is a communication about the curricular elements within the curriculum such as knowledge areas, learning units centered about skills, and learning outcomes to be assessed and observed. However, the natural language we use to describe these elements is not sufficient to ensure that intended meaning within these descriptions are comprehended as intended. As a simple example lies with the term "database." For the manager, accountant, systems analyst, database administrator, software developer, computer scientist, mathematician, and computer engineer, this term connotes a distinct set of concerns. Thus the knowledge areas, while overlapping, will be dissimilar as each of the roles above assumes a different disciplinary disposition, a unique set of practical concerns, and a history of engagement with the actual computing phenomenon implied in the term "database" that is contextually and historically shaped.

This issue of communicating computing curricula concepts has three principle components: issues related to the complexity of human communication, issues related to overlap in the conceptualization and contextualization of computing phenomenon predicated on required utility, and the need to differentiate these meanings and uses to achieve clarity and understanding for those within and without the computing disciplines. We shall characterize each of these against the assumption that a curriculum is a human communication and is subject to facilities and constraints afforded within human communication.

Responsibility for the reconciliation of meaning could come from a variety of sources. Should there be a need for public or fiduciary accountability, it is possible that such issues would be regulated, and the compulsion of compliance would facilitate a reconciliatory apparatus. There are also informal structures that could reconcile the semantic differences; however, these are ephemeral and subject to distortions and bias that would potentially conflate attempts for reconciliation. A professional and/or disciplinary approach is possible, perhaps assisted by regulatory authorization, such that a professional society, typically charged with performance, ethical, and procedural regulation within a discipline, could provide the leadership necessary.

In the case of computing, this leadership does exists with societies such as the Institute of Electrical and Electronics Engineers (IEEE) and Association for Computing Machinery (ACM), however, computing remains a mostly under-regulated endeavor where the lines between amateur and professional are indistinct and, arguably moot given the inherently emergent nature of the work and the accessibility of many of the tools about which acute skills are necessary. To wit, an "amateur" with a computer, hard work, and ingenuity, may conceive of, craft, deliver, and profit from highly impactful implementations of computing skills and knowledge and remain entirely outside of any professional oversight. As such, the constraints and restraints that are often byproducts of the regulation from the professionalization of a discipline has a difficult time in the case of computing.

The freedom by which many, but not all, of the skills of computing may be acquired and purveyed, suggest not only that the reach of a curriculum will not ensure uniformity in expected professional practice (as would be the case in Law or Medicine outside of the particulars in the localization of licensure), but also that the impact on public perception of computing will be equally non-uniform. Whereas the certification of knowledge matters in so many other impactful areas of human endeavor, in computing, this is less so.

We do not offer the previous derivation to suggest that this issue of semantic clarity in the articulation of computing curricula is intractable, just simply that it is fraught. Nonetheless, an opportunity for leadership lies with the academy such that academics in the computing disciplines may establish maps between concepts such that when a term like "database" is used, there exists a mutual or common understanding. This is undoubtedly a vast ontological, taxonomic and epistemological undertaking and to propose a comprehensive solution within the confines of an academic paper would be ambitious, to put it politely. Rather, the aim of this paper is to reference a solution for semantic reconciliation in the reporting of financial data in the accounting, finance and banking realm to extrapolate lessons from that context onto the computing context.

This paper offers a conceptualization of an eXtensible Computing Curriculum Reporting Language (XCCRL) to support extant efforts of the Computing Curricula 2020 (CC2020) project to produce tooling that offers the visualization, articulation, and exploration of computing curricula to develop a maturing understanding of the interconnectedness between computing disciplines and also into other human endeavors and the disciplines that surround them. We appropriate lessons from the development of the eXtensible Business Reporting Language (XBRL) as a guide and contrast this with the same need to reconcile between semantic meaning embedded in computing terms and phenomena. Our proposed derivation, the XCCRL, is modeled closely on the XBRL and should facilitate interchange between the prototypes and tooling developed by the CC2020 project. Further, it may perhaps serve as an interchange between the computing disciplines and their constituents by way of curricular descriptions for public use. Much as genres serve to signal semantic content in entertainment media such as movies, books, television programs, and video games, it is hoped that the semantic groupings within the terms used to describe computing curricula may also be reconciled through an effort such as XCCRL, in a similar way that XBRL makes use of semantic meaning.

This paper explores these issues by first reflecting on the fundamental issues of human communication in reconciling meaning among computing terms. Next we explore how XBRL has addressed similar issues in the realm of financial data reporting. We next propose how the features of XBRL could be appropriated into the computing curricula context. This is followed by a brief account of how XCCRL may assist in the under-way efforts of the CC2020 project and the plans to develop prototype information systems and tools use to explore semantic meaning in computing curricula. We conclude with future steps to realize XCCRL, some limitations in extrapolating from XBRL, and conclude with why XCCRL, or a similar solution, will be necessary to assist in the further professionalization of the computing disciplines if those disciplines will make headway in realizing the positive benefits that professionalization may hold for the human activities that are most impacted by computing.

2. A SEMIOTIC TREATISE ON MEANING IN COMPUTING TERMS

For simplicity, it is possible to describe the issue of reconciling semantic meaning for computing terms according to those who use the tools, artifacts and general phenomena of computing and those that conceptualize, design, develop, and articulate these outputs. Between them, these groups articulate a language - replete with terms, concepts, and intensions – that facilitates transactions. What is transacted are needs and fulfillment of needs that shapes the supply and demand exchange in an emergent manner. This is so for other economic systems and is evident in computing. However, there is an expert/non-expert dimension to these exchanges where expert terms fall into common parlance and non-expert approximations, metaphors and allegorical utterances also permeate the lexicon between the suppliers and consumers.

<table>
<tr><td colspan="2" rowspan="2">Computing Producer/Consumer Matrix</td><td colspan="2">Supplier</td></tr>
<tr><td>Expert</td><td>Non-Expert</td></tr>
<tr><td rowspan="2">Consumer</td><td>Expert</td><td>A</td><td>B</td></tr>
<tr><td>Non-Expert</td><td>C</td><td>D</td></tr>
</table>

Table 1. Conceptualizing the Producer/Consumer Relationship in Computing Outputs

The conceptualization in Table 1 illustrates the issue. We propose that the lexicon and language that surround computing is shaped by exchanges in a matrix formed by expert and non-expert language used in the production of computing outputs, artifacts, and phenomena and the expert and non-expert consumption of the same. While other models would be possible, we use this model to propose and illustrate the cases where the language used, and thus the conceptualization begins and shapes the meaning exchanged in the producer/consumer relationship. Table 2 below provides examples and illustrations of each of the interaction cases – A, B, C, and D – described in Table 1.

Interaction Case	Description
Case A	Many business-to-business transactions occur in the context of the specification of computing requirements by trained professionals to be fulfilled in the design and development activities of trained professionals
Case B	Crowdsourcing, customer co-creation, and similar reliance on non-expert input to shape design requirements. In this case, the supply is use behavior.
Case C	Most Commercial-Off-The-Shelf-Software (COTS) and information services operate under this model. Pro-forma, genre-based, and market-targeted software, hardware, and data shape a significant component of the public's experience with computing in their daily lives.
Case D	Online communities, some website and application development. Significant development in the public understanding of computing has emerged in this case as the availability of Information proliferates.

Table 2. Explicating the Expert-Non-Expert Cases in the Producer/Consumer Relationship for Computing

Aggregations of interest and power likely form about these cases and understanding is also shaped by socialization among and within these groups. From these aggregations come terms like "users" and "IT" and other generalizations that characterize patterns of use in the producer and consumer relationship.

Through the communication channels that surround the groups made possible in the cases shown in Table Two, they are amplified by the personal and philosophical perspectives that also bias and shape language between producers and consumers. "Users" for instance, perhaps in itself arguably a pejorative term, runs a gamut of connotations and is metaphorical at its roots whilst also being a pragmatic descriptor. Other terms embed perspectives and worldviews that potentially run the gamut from objectivist/empiricist to subjectivities / interpretivist, to constructivist and beyond (Falkenberg et al., 1998).

In order to better calibrate our own language and approach to reconciling semantic meaning in computing terms, we can appropriate a previous model used to inform the 1998 Framework of Information Systems Concepts (FRISCO) report from the International Federation for Information Processing (IFIP) Working Group 8.1 on the design and evaluation of information systems (Falkenberg et al., 1998). The report provides a framework used to delineate the concepts that describe how individuals and organizations shape information systems. We appropriate this framework to presume the social context that surrounds communication about computing concepts. Further, we adopt their appropriation of semiotics as a means of describing human communication and the conveyance of meaning. We also assume a systems approach to the interaction amongst computing consumers and producers, such that a system of concepts, models, and language surrounds the communication of computing concepts and terms. Lastly, we adopt the perspective that reflections on this issue are ontological and philosophical in nature.

The FRISCO framework will feature more prominently in our explication of XCCRL, but we first delve further into the complexity of communication by reflecting on Stamper's semiotic framework (1973). Stated simply, Stamper's semiotic framework holds that human communication undergoes several mediated transmissions where translation must happen along these mediated phases. Given human sensorimotor design, humans begin by comprehending and sensing at a physical layer of communication. Our voice and ears utilize physical media as do our written communication, as do our signs. This is empirically sensed and categorized such that the syntax for repeatable comprehension is utilized. The translation from syntax to meaning happens at a semantic layer where validity and veracity are assessed. Sensemaking also involves the application of value and discretion such that we then operate at a pragmatic layer to align dispositions. Later, the manifestation of our reactions and actions in light of the communication operate at a social layer.

Stamper's (1973) semiotic framework can be further comprehended, quite usefully, by grouping the layers into technical (physics, empirics, syntactics) and social (semantics, pragmatics, and social). With these layers we can more closely associate a computing curricular term, such as database, which itself is a composite term, with any and all appropriate layers in the work (Liu, 2000; Stamper, 1973; Stamper et al., 2000).

It is important to recognize that these layers in a communication are both coextensive and amalgamated where the discernment of the layers is not a natural step for the sender or recipient in a communication.

3. BACKGROUND ON XBRL

In 2009, the Securities and Exchange Commission (SEC) mandated that all public companies adopt XBRL as a means to standardize the exchange, transmission, and reporting of accounting and financial data (SEC, 2009). XBRL is an extension of eXtensible Markup Language (XML). XML is a text-based, hardware-software independent markup language, like Hyper Text Markup Language (HTML), which unlike HTML, allows for undefined tagging by the author to define the document structure. XML is designed for storing, transporting, and sharing data across multiple platforms, thus avoiding the issue of incompatible formatting across computer systems (W3Schools, n.d.). As noted, XML defines a data structure and allows for a standard format for exchanging data (VanLengen, 2010).

XBRL extends XML by providing a standard for the exchange, transmission, and reporting of accounting and financial data based upon established taxonomies such as those developed by XBRL International and in the United States, the Generally Accepted Accounting Principles (U.S. GAAP) XBRL taxonomy. For example, each aspect of a financial report represents a concept. Each concept is then "tagged" with an XBRL element from the taxonomy. The element must then be precisely defined, and attributes assigned. In addition, relationships between the elements must be defined as a way of defining the scope of the overall taxonomy. The result of this process is the creation of a XBRL instance document (Wenger, Thomas, & Babb, 2013). As noted by Debreceny and Farewell (2010), "the principal idea of XBRL is that if every supplier of information speaks a common language of disclosure, by using the same taxonomy, users will be able to use that information in a productive way" (p. 467). There are numerous resources available in the literature which explain and provide detailed instructions for mapping financial statements using XBRL (e.g., Capozzoli & Farewell, 2010; Debreceny & Farewell, 2010; Elam, Wenger, & Williams, 2012; Pinsker, 2004; Peng & Chang, 2010; White, 2010).

Similar to the adoption of XBRL as a standardized reporting format for accounting and financial data, the authors propose the development XCCRL, as mechanisms for standardizing the exchange, transmission, and reporting of curriculum data and computing curriculum data within higher education. In sum, XBRL utilizes taxonomies (e.g., XBRL 2004-1; XBRL 2004-2) which define accounting and financial concepts by which a financial instance document is created by tagging the document using software developed for this purpose (e.g., DragonTag). The document can then be transmitted electronically as well as be compared to other financial instance documents. XBRL and XCCRL work in similar fashions only instead of tagging an accounting or financial document, a curriculum document (e.g., a course description) is tagged to create a curriculum instance document. The taxonomy used may be from a recognized computing organization such as the Association of Computing Machinery (ACM), Institute of Electrical and Electronics Engineers (IEEE), the or Education Special Interest Group (EDSIG).

The history of computing curricula is well established and the development of model curriculum for the areas of computing is ongoing as demonstrated by the works of computing organizations such as the ACM, Association for Information Systems (AIS), AITP-EDSIG, and IEEE. As such, taxonomies have been published in an effort to classify the areas (concepts, categories, knowledge areas) commonly identified in the computing disciplines (ACM, 2012; IEEE, 2017). In spite of the tremendous time and effort put into the development of computing curricula, higher education suffers from the same fate as that of the accounting and financial sector, which necessitated the development of XBRL, namely the challenge of storing, transferring, and sharing of data due to incompatibilities caused by language, type, culture, and location. Ergo, there is no standard reporting format for the exchange, transmission, and reporting of curriculum data.

4. EXAMPLES FROM BOTH DOMAINS

Perhaps, the best way to demonstrate the extension of XCCRL from XBRL is a simple illustration from both domains. Concepts such as "asset", "liability", "owner's equity", "revenue" and "expenses" are well established in the financial and accounting domain. With XBRL, these concepts have been formalized and are now represented in a taxonomy. As mentioned previously, The U.S. GAAP XBRL Taxonomy, which consists of over 12,000 terms, is a standard among U.S. companies. So, consider that a company needs to map its statement of financial position to the U.S. GAAP XBRL Taxonomy. Debreceny and Farewell (2010) provide a mapping process for this task which includes major steps such as: reviewing the accounting concept and searching the taxonomy for corresponding concept. Smaller steps directly related to the financial and accounting sector occur along the way, but the basic premise is to take the accounting concept contained on the statement of financial position and tagging it with the corresponding concept from the taxonomy. For example, the taxonomy includes a node for Statement of Financial Position, Classified. This node can be expanded to display the Assets node followed by the Assets, Current node, Receivables, Net, Current node and so forth. Using software specifically developed for creating XBRL instance documents, the user can then apply the concept from the taxonomy to the associated concept on the statement of financial position, thus creating an electronic document which can be stored, transmitted, and compared.

For the higher education domain for curriculum data, such concepts as "course prefix", "course number", "course description", "course prerequisites", "credit hours", "knowledge outcomes", and "skill outcomes" are familiar concepts. However, depending upon the type, location, culture, and or category of university, college, or school, there may not be a common "language" or standard for storing, transferring, or comparing these concepts. This is where XCCRL comes into play. By using an established taxonomy such as those developed by ACM (2012) or IEEE (2017), it would be possible to tag the concepts of curriculum data with the appropriate concepts from the taxonomy. For example, the ACM taxonomy contains a categorization for Information Systems. Within this categorization, there are multiple sub-categorizations, such as Data management systems, Information storage systems, Information systems applications, and so forth. For the purposes of illustration, the Data management systems category is utilized, specifically the sub-category entitled, Database design and models. The taxonomical hierarchy is provided below:

Data management systems
- Database design and models
- Relational database model
- Entity relationship models
- Graph-based database models
  - Hierarchical data models
  - Network data models
- Physical data models
- Data model extensions
  - Semi-structured data
  - Data streams
  - Data provenance
  - Incomplete data
  - Temporal data
  - Uncertainty
  - Inconsistent data

To further the illustration, consider a course entitled, Database Theory and Practice and its accompanying course description:

Database concepts and structures. File and data management principles underlying database construction. Fundamental types of database models, with emphasis on relational database as well as on major non-relational forms. Practice in analysis, design, development, and optimization of working database applications on a variety of problems. Small and large system databases will be considered. Prerequiste: BCIS 3332 or BCIS 3333 or approval of department head.

Utilizing the ACM taxonomy categorization Data management systems, the course description can be tagged to create an XCCRL instance document. For instance, 'relational database' from the course description might be tagged with the 'Relational database model' and 'Entity relationship models' concepts from the taxonomy, while 'non-relational forms' might be tagged with 'Graph-based database models' from the taxonomy. This XCCRL instance document could then be exchanged with others and compared against other database courses.

5. A BRIEF ELABORATION ON XBRL

In essence, XBRL predicates on a few simple concepts designed to answer a fundamental question: are these two things comparable? From a metadata and taxonomic standpoint, XBRL is a fairly straight-forward approach and is similar to the keyword tagging that allows to commonly associate concepts and words. Therefore, a given financial concept or phenomena is captured as an XBRL instance such that the associated metadata and taxonomies may convey clear semantic intention. An XBRL instance contains a Discoverable Taxonomy Set which defines the facts of the instance and how these facts should be relatable to other facts. For instance, if an item or tuple used to articulate a business fact should be compared to similar facts, then the context of this fact is stated and the units for relatability are also stated. Figure 1 shows an example XBRL taxonomy:

```
<element
   name="Land"
   type="xbrli:monetaryItemType"
   substitutionGroup="xbrli:item"
   xbrli:periodType="instant"
   />
<element
   name="BuildingsNet"
   type="xbrli:monetaryItemType"
   substitutionGroup="xbrli:item"
   xbrli:periodType="instant"
   />
<element
   name="FurnitureAndFixturesNet"
   type="xbrli:monetaryItemType"
   substitutionGroup="xbrli:item"
   xbrli:periodType="instant"
   />
```

Figure 1. XBRL Taxonomy Snippet

The key to comparability and relatability among XBRL instances is the linked XBLR Taxonomy. The Taxonomy suggests the relationships possible and other identifying attributes that allow one XBML Entity to be relatable to another. The set of additional and related concepts to clarify an XBML instance are established as links of items and tuples that contain substantiating information to serve as the basis of relations. Figure 2 shows associated XBRL Instance entities.

```
  <!--  Units  -->
▼<unit id="U-Monetary">
    <measure>iso4217:USD</measure>
  </unit>
  <!--  Fact values  -->
  <HelloWorld:Land contextRef="I-2007" unitRef="U-Monetary" decimals="
  <HelloWorld:Land contextRef="I-2006" unitRef="U-Monetary" decimals="
  <HelloWorld:BuildingsNet contextRef="I-2007" unitRef="U-Monetary" de
  <HelloWorld:BuildingsNet contextRef="I-2006" unitRef="U-Monetary" de
  <HelloWorld:FurnitureAndFixturesNet contextRef="I-2007" unitRef="U-M
  <HelloWorld:FurnitureAndFixturesNet contextRef="I-2006" unitRef="U-M
  <HelloWorld:ComputerEquipmentNet contextRef="I-2007" unitRef="U-Mone
  <HelloWorld:ComputerEquipmentNet contextRef="I-2006" unitRef="U-Mone
  <HelloWorld:OtherPropertyPlantAndEquipmentNet contextRef="I-2007" un
  <HelloWorld:OtherPropertyPlantAndEquipmentNet contextRef="I-2006" un
  <HelloWorld:PropertyPlantAndEquipmentNet contextRef="I-2007" unitRef
  <HelloWorld:PropertyPlantAndEquipmentNet contextRef="I-2006" unitRef
</xbrl>
```

Figure 2. XBRL Instance Entities

To best extend the XBRL concept, some alignment with the premises of XBRL is necessary. The XBRL Concept is implemented as an XML Schema and these concepts become the basis of the XBRL Taxonomy. The Concept or Concepts contained in an XBRL Taxonomy are extended with one or more Linkbase entities which provide the extended links that make relations possible. Further, the XBRL Instance presents the values particular to fact or facts relevant to a given context. This makes the XBRL Taxonomy and XBRL Instance relate much as a Class and Object relate in Object-Oriented Programming. Figure 3 below illustrates the major elements of XBRL.

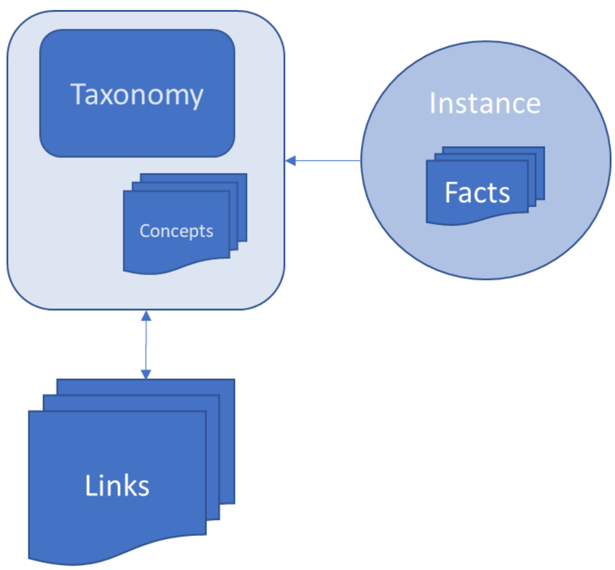

Figure 3. Elements of XBRL

The design of XBRL was to facilitate comparability to standardize meaning in the reporting of financial data, in this regard it holds promise as the basis for a similar approach to reconciling meaning for computing terms as they would inform computing curricula.

6. A SEMIOTIC FRAMEWORK FOR XCCRL

With a high degree of inspiration and direction from the IFIP 8.1 FRISCO report and its semiotic framework to distill and articulate information systems concepts, we extend that work to inform a candidate set of taxonomic structures for XCCRL that may be guided by the assumptions of Stamper's (1973) semiotic framework. Much as the FRISCO report proposed a semiotic-layered accounting for a given information systems term, we extend to account for computing terms in general recognizing that reconciliation at the various semiotic layers holds promise for aligning and mapping terms along and across these boundaries. Recall still that, much as was the case with XBRL, we are looking to align "dialects" across semiotic layers, but, unlike XBRL, we are also attempting to account for commonalities among the layers in a vertical manner.

Semiotic Layer	Question	Answer
Impetus: personal or organizational value	Why do we include database?	Databases track and relate organizational data
Social	What is the context for the concept's use?	Business
Pragmatic	What about this context is important	Transactional data tracking performance
Semantic	What aspects of performance matter?	Sales, Costs, and Profits
Syntactical	How do we represent these?	Models expressed in language that ties back to operations
Empirical	What do we measure?	Identified fields of specific nomenclature
Physical	How do we measure?	Data transmissions from POS systems

Table 3. An Illustration of Semantic Reasoning

Table 3 appropriates the FRISCO report to reason about how a term like "database" has meaning and value in a curricular communication:

From the FRISCO report we realize that a semiotic analysis of any computing curricular concept and term can be derived from the organizational "why" to the technical "how" such that a cogent rationale is maintained. Thus, the following construction is possible (Falkenberg et al., 1998):

organization - which might be regarded as a
system - for which different directions and
  aims are set, as
goals - towards which the organization
  strives in order to create
added value - which normally is
  accomplished by coherent
actions - using certain
resources - meaning that these actions are
  performed by
actors – on
actands - and where these actions are
  aiming at changing the
state - within or external to the organization
  in a desired way

As an analytical technique, the above treatment may not appropriately match all computing curricular concepts, but its structure, informed by semiotics, provides a starting point that is consistent with the XBRL specification.

7. THE IMPETUS FOR XCCRL

The impetus for XCCRL lies with the efforts of the ACM and IEEE inventory and forecast of computing curricula development, Computing Curricula 2020. (See www.cc2020.net.) Directly, the impetus for XCCRL lies within a proposed framework for curriculum description that incorporates and normalizes the structure and intra-connectivity of computing theory and practice (Waguespack and Babb, 2019). The framework underlies a key CC2020 project goal to design a visualization tool capable of both representing and comparing computing guidelines and programs to inform and advance computing education.

The tool specifically focuses on the sub-disciplines of computing at the baccalaureate level and the various prior ACM and IEEE curriculum guidelines: Computer Engineering (2004, 2016), Computer Science (2001, 2008, 2013), Information Systems (1997, 2002, 2006, 2010), Information Technology (2008, 2017), Software Engineering (2004, 2014), and Cybersecurity (2017). (All guidelines are available at www.acm.org/education/curricula-recommendations.).

As the CC2020 effort progresses, the tooling for curriculum visualization has coalesced around the Competency, Disposition, Knowledge, Skill, Task (CDKST) framework that describes the interrelation between these aspects of curricular design, development, and articulation.

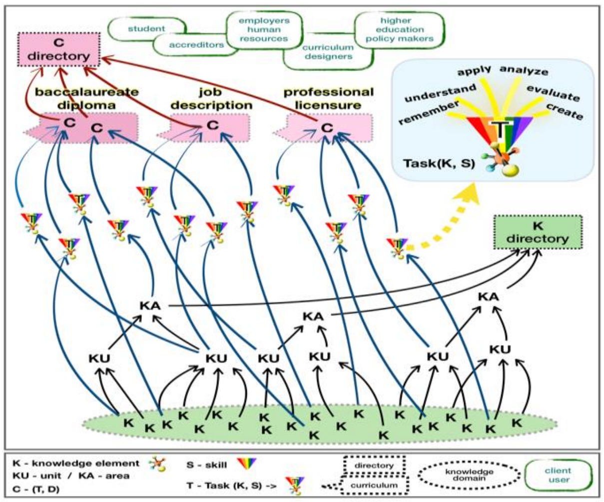

Figure 4. CDKST Curriculum Framework
Appendix B recounts the set-theoretic model devised to support digitization. Figure 4 graphically depicts, and Table 4 summarizes that model, both adapted from (Waguespack & Babb, 2019).

C {competency, demonstrable capability}
D {desired value result, disposition "why"}
K {knowledge, "what"}
S {skilled application of knowledge "how"}
T {task, as situated context of is a situated

T = task
T --> {(Ki,Sj)} knowledge used at a level of skill
[A task is skillfully applied knowledge engaged in a purposeful act.]

C = competency
C --> {(Σ(Ki,Sj) | (Ki,Sj) ∊ T), Dk}
[Competency demonstrates task(s) in accord / compliant with disposition(s).]

E = educational program
E --> {Ci}
[An educational program is the cumulation of competencies that comprise it.]

B = baccalaureate degree
Be --> {Σ(Ci) | Ci ∊ E}
[A baccalaureate is the cumulation of the assessments of constituting education program.]

J = job description
J --> {Ci}
[A job description is the cumulation of competencies defining that job's responsibilities.]

JP = job permit
JPj --> {Σ(Ci) | Ci ∊ J}
[A job permit is the cumulation of competencies assessed that certify job competency.]

P = profession
P --> {Ji}
[A profession is the cumulation of job competencies that define it.]

L = professional license
Lp --> {Σ(Ji) | Ji ∊ P}
[A professional license is the cumulation of assessed job competency that certifies professional status.]

Table 4. CDKST Curriculum Framework

8. MOVING FORWARD WITH CC2020 AND XCCRL

A key to appropriating the design and intent of XBRL for XCCRL would be to understand its object-oriented design as the basis for relations. The basis for the visualization project in CC2020 for computing curricula are competencies, dispositions, knowledge, skills, and tasks. These almost align with the semiotic "ladder" that runs from the physical to the social realm as shown in Figure 5 (Falkenberg et al., 1998):

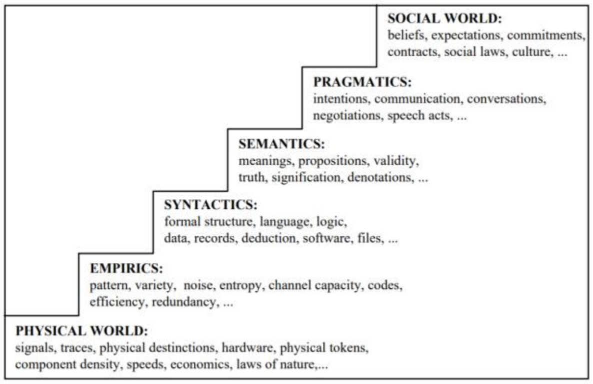

Figure 5. From the physical to the social realm on the semiotic "ladder"

Attempting to relate these, we can align the basic components with XBRL with the elements of the CDKST model to delineate a possible direction for the appropriation of XBRL's design.

XBRL Concept	CDKST Concept	Semiotic Level
Taxonomy	Competency	Social World
	Disposition	Pragmatics
Concept	Knowledge	Semantics
Instance	Skill	Syntactics and Empirics
Units	Task	Empirics and Physical Realm

Table 5. Comparing XBRL Concepts to CDKST Concepts and Semiotic

As we can see, the concepts do not cleanly map and we address this as a shortcoming in the following section. However, the mapping to the semiotic levels is plausible and the XBRL has proven to be successful in reaching its design aims such that it does facilitate successful financial reporting across problem domains, business sectors, and regulatory boundaries.

However, a deeper point of comparison would be to compare the elements of the FRISCO framework with XBRL's key concepts as they relate to the Semiotic levels. Table 6 shows select elements of the key terms that define XBRL along with those of the FRISCO framework to determine whether the FRISCO framework, as a tool designed to reconcile key information systems terms, holds promise for the design of XCCRL (see Table 6).

XBRL	FRISCO	Semiotic Level
Context	Organization Social System System Goal	Organization
Taxonomy Concept	Conception Intention Rule	Social World
Entity	Actor Decision	Pragmatics
Resource	Action Resource Effect Model	Semantics
Instance	Protocol	Syntactics
Fact	Observation State	Empirics
Item	Pattern	Physical World

Table 6. Comparing XBRL Concepts to FRISCO Framework Concepts and Semiotic Level

The FRISCO elements would likely serve at multiple levels but also suggest some consistency with the XBRL organization.

It is likely that the FRISCO framework's language could serve as the descriptors necessary to further elaborate the Taxonomy that would clarify, through linked resources and metadata, the Competency, Disposition and Knowledge that constitute the social dimension of the CDKST model. Further, the CDKST framework is a broad-level means of articulating the wider structure for data collection. We find that XBRL design approach is promising as a design referent for XCCRL. The ontological, philosophical, and epistemological grounding of the FRISCO report is equally informative to serve as the basis for our design.

The nascent architecture for our work is shown in Appendix A. The curriculum object store would likely contain a structure that is similar to and derivative of the XBRL Instance. Further, the computer terms taxonomy would be developed in a manner like XBRL taxonomies. Other aspect of our design includes the collection of curricular texts to assimilate in an overarching taxonomic store. The categorization of concepts (as the serve as the basis of competencies and dispositions) would constitute relations between computing concepts and concepts from related domains. The translation of these curricular inputs will be obtained from text processing using the natural language toolkit for Python (or a similar toolset). The categorization will be accomplished via both an expert system as well as a machine learning component using TensorFlow and/or SciKit-learn. The piece of our architectural puzzle that XBRL addresses is the need for a standards-based (in this case XML) storage and interchange format such that any curriculum object is relatable, mutable, and transferrable. Further, other XML-related technologies increase the likelihood that the visualization engine may directly use items from the curriculum object store without further translation.

9. LIMITATIONS, DISCUSSION, AND CONCLUSION

Among the limitations of the XCCRL concept is the different contexts of curriculum versus XBRL's financial data orientation. Further, the use of FRISCO as the basis of organizing Computing Concepts is the skewness in its business and organizational orientation.

Further, none of the prototypes developed thus far demonstrate sufficient maturity to ensure that the proposed architecture is viable. XBRL has many proven use cases and instantiations suggesting that starting from a reference implementation would be ideal. Rather, our design did not start with XBRL as a referent and may contain assumptions that are incompatible with XBRL.

These limitations aside, XCCRL shares overall design goals with XBRL. Also, the FRISCO report should support a prototype to articulate the additional metadata and fields required to elaborate the elements of the CDKST framework into the tool described in Appendix A and B.

The CC2020 project has among its aims the development of a tool to assist the designers, developers, administrators, and stakeholders of computing curricula to interact with visualized descriptions of curricula. An XBRL and FRISCO combined approach accelerates the prototyping process and assists in the realization of the CC2020 project's aims and objectives.

10. ACKNOWLEDGMENTS

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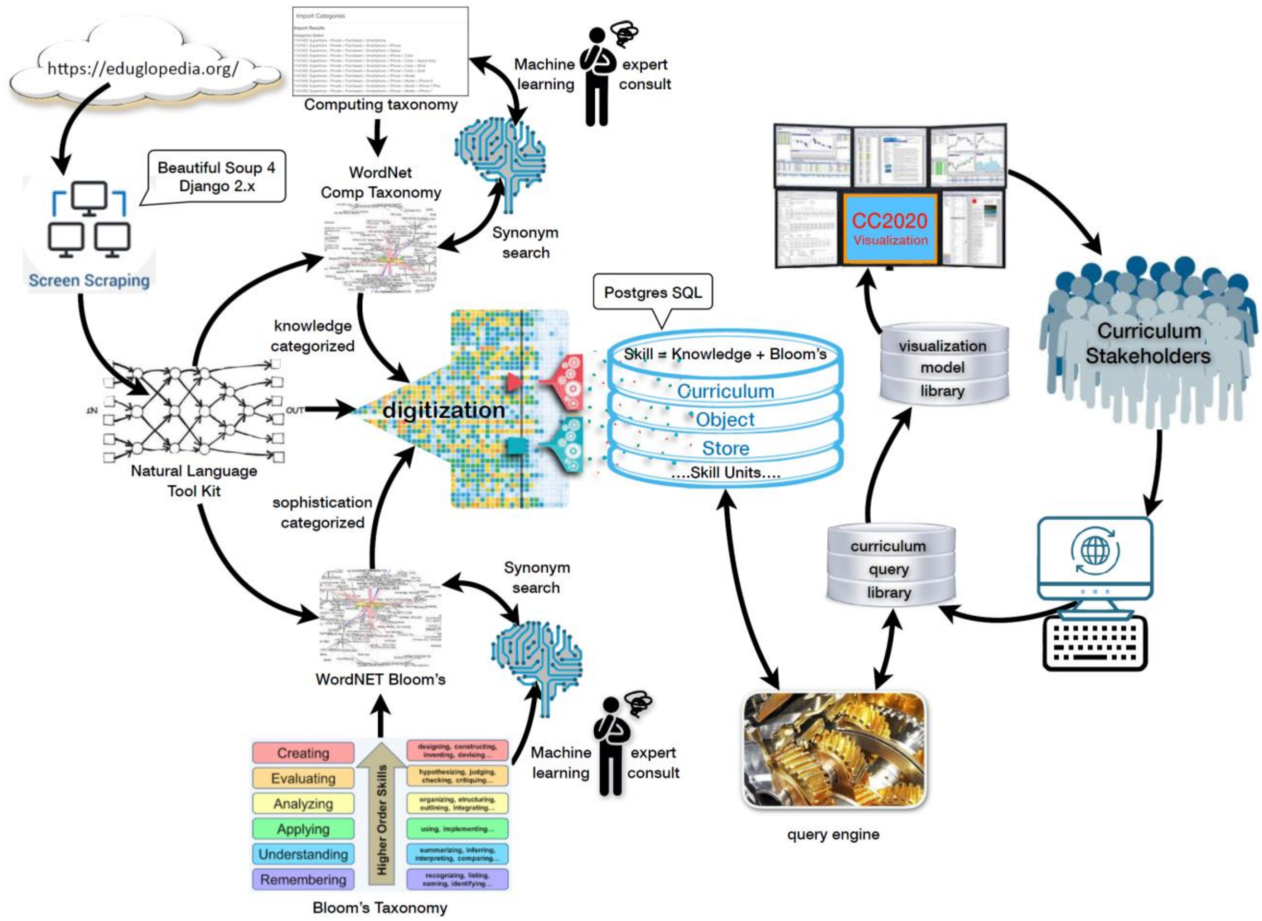
Appendix A – The CC2020 Computing Curriculum Project Tools Architecture and Concept



Appendix B - CDKST Curriculum Framework

Competency-Disposition-Knowledge-Skills-Task

In the following set theoretic representation, *Competency-Disposition-Knowledge-Skills-Task* (CDKST), we adopt three grounding propositions to conceptualize curriculum: 1) learning is acquiring knowledge elements arranged taxonomically that enable satisfactorily performing relevant tasks; 2) the concept of "skill" is a degree of mastery of a knowledge element modulated by disposition to achieve a valued outcome, and 3) disposition denotes the values and motivation that guide applying knowledge while designating the quality of knowing commensurate with a standard of desired performance.

Knowledge elements, **K**, are factual concepts supported by science and/or professional practice that underpin a vocabulary of objects, behaviors, and relationships as the domain of interest in a discourse (be it curriculum, task, job, or profession). **S**, the skill attribute, denotes the *quality of knowing* (e.g. mastery, expertise, adeptness, or proficiency) that an accomplished learner must possess to satisfactorily apply a knowledge element in a circumstance of performance. In this sense it is the capacity to demonstrate a degree of *cognitive command* over that knowledge. In this conceptualization cognitive command is represented by Bloom's (revised) taxonomy of learning objectives: remember, understand, apply, analyze, evaluate, and create (See Appendix A, Anderson, 2001). Disposition, **D**, represents a commitment, motivation, toward an aspect of desired practice that reflects the attitude deemed critical to satisfaction in a circumstance or context. Task, **T**, is a situated instance of engaging knowledge with a degree of mastery. **C**, competency is a demonstrated sufficiency in a task with an appropriate disposition. **C** effective defines both the nature of the competency and the assessment that certifies in a specific task instance.

T = task
T --> $\{(K_i,S_j)\}$ knowledge used at a level of skill

[A task is skillfully applied knowledge engaged in a purposeful act.]

Task, **T**, is *knowledge applied* in a "live" context to accomplish a designated purpose. **T** represents a *specification* of capability that curriculum is obligated to inculcate in the accomplished learner.

A task is the application of specific knowledge to a situation at hand. Note that tasks may be of varying complexity in terms of the range of knowledge elements engaged. Individual knowledge elements may participate in a variety of tasks. A task may be a collection of constituent tasks within which each knowledge element is applied with a distinct skill. As a collective, the task's satisfactory accomplishment demonstrates a sufficiency of knowing and doing.

C = competency
C --> $\{(\Sigma(K_i,S_j) \mid (K_i,S_j) \in T), \{D_k\}\}$

[Competency demonstrates task(s) in accord / compliant with disposition(s).]

Competency, **C**, is the capacity to accomplish a task by applying knowledge and skills framed by one or more dispositions. This is the goal sought by a competency-based perspective on curricular design. This forms a focus for assessment as each competency represents both a requirement and the instrument of certification to assure the learner's successful performance – success denoted by the satisfactory outcome of applying the knowledge in accord or compliant with one or more disposition(s). It is reasonable to expect that a system of competency specifications would form a telescopic or hierarchical arrangement of modularized task complexity and thus, would lead to an incremental or progressive process of learning and experience accumulation that would subsequently justify advancement to more elaborate, intricate, or difficult tasks or higher degrees of desired performance.

E = educational program
$\mathbf{E} \dashrightarrow \{C_i\}$

[An educational program is the cumulation of competencies that comprise it.]

B = baccalaureate degree
$\mathbf{B}_e \dashrightarrow \{\sum(C_i) \mid C_i \in E\}$

[A baccalaureate is the cumulation of the assessments of constituting education program.]

E, is a composition of competencies relevant to (or defining) a professional or academic course of study, a curriculum. A baccalaureate degree, **B**, is granted by an authorized institution. In fact, the list of competencies may be the vary testimony to the focus of an intended career direction shaping an academic program's intension. This would be the construct for comparing educational programs, assessing guideline or accreditation compliance, or prototyping distinct perspectives on the larger domain of knowledge such as across subdomains of *computing*!

J = job description
$\mathbf{J} \dashrightarrow \{C_i\}$

[A job description is the cumulation of competencies defining that job's responsibilities.]

JP = job permit
$\mathbf{JP}_j \dashrightarrow \{\sum(C_i) \mid C_i \in J\}$

[A job permit is the cumulation of competencies assessed that certify job competency.]

In its own fashion, a particular job description is in effect a "mini-curriculum" as it prescribes performance requirements that usually distinguish the desired applicant or employee attributes. The particulars of the organization, the industry, or the marketplace would shape both the collection of knowledge elements, skills, and the disposition of their application, thus, aligning with a particular vocation.

P = profession
$\mathbf{P} \dashrightarrow \{J_i\}$

[A profession is the cumulation of job competencies that define it.]

L = professional license
$\mathbf{L}_p \dashrightarrow \{\sum(J_i) \mid J_i \in P\}$

[A professional license is the cumulation of assessed job competency that certifies professional status.]

In this last aggregation, professional societies and governmental agencies specify collections of competencies that qualify a legal standing as a licensed professional (e.g. professional engineer, medical doctor, physician's assistant, nurse, a member of the bar, barber, cosmetologist, etc.).

The CDKST model does not attempt to shape or bound the dimensions of pedagogy as that requires integration with the cultural context within which it must be applied. However, pedagogy must align with the designated disposition modulating the *quality of performance* the student must demonstrate as competency in context.