Toward Competent Computer Science Graduates

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Professional Competencies in Computing Education: Pedagogies and Assessment

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Brief Bio

- Middleware expertise
  - ~9 years of software development and management building private cloud infrastructures for near-real-time global financial applications
- Recent research
  - Applying data science and cybersecurity to critical infrastructure protection
- Computing education
  - ABET’s Computing Accreditation Commission (CAC)
    - CAC Criteria Committee Chair 2016-19, CAC Chair-Elect
  - ACM/IEEE-CS/AAAI CS202X Task Force Co-Chair
    - Decennial rewrite of Computer Science curricular guidelines, probably to be released 2024?
Motivators for Ongoing Work

- Societal changes, pre- and post-pandemic
  - Competency-based certificates and education
  - Stackable credentials
- Competence of Computer Science graduates
  - Changes in computing education
  - CS202X Curricular Guidelines Task Force
- Employer needs to drive curricular change
  - NSF IUSE (Institutional & Community Transformation) Grant
    - U Alabama, GWU, Mississippi State U, Purdue, RIT, Tuskegee, UNH, and UIUC, with Shelton State Community College
      - Awards 2111435, 2110771, 2110815, 2110823, 2110788, 2111157, 2111097, 2110850
      - Support a much more diverse student body and workforce
To build sustainable software, you need *competent* programmers!

Underlying Assumption
Competence?

- Dictionary definitions
  - Possession of sufficient knowledge or skill
  - Important skill needed to do a job
  - Quality of being adequately or well qualified physically and intellectually
US Secondary & Post-Secondary Credentials

- US has 967,734 unique credentials
  - Postsecondary institutions
    - 359,713 degrees and certificates
  - MOOC providers
    - 9,390 certificates, micro-credentials, and foreign online degrees
  - Non-academic providers
    - 549,712 badges, certificates, licenses, certifications, and apprenticeships
  - Secondary schools
    - 48,919 diplomas from public and private secondary schools

https://credentialengine.org/counting-credentials-2021/
Stackable Credentials

Competency-Based Education

- Competence, one bite at a time
- Many institutions are developing “pathway” programs
  - BYU-Pathway
  - Colorado State Global
  - Purdue Global
  - Western Governors University
  - Wichita State University
  - And many others
- Students complete several certificates toward a full degree
  - If education is disrupted, the student retains certificates as partial successes
  - Industry engagement can lead to credential acceptance for certain types of employment
- Some employers have also entered this space
BYU Pathways – Example

Bachelor of Science of Applied Technology

Program Requirements

Complete three certificates as described below, plus additional requirements.

**Certificate**
13-15 CREDITS

- **Complete one of the following certificates**
  - Computer Support
  - Web and Computer Programming

**Associate**
60 CREDITS

- **Complete one of the following certificates**
  - Database
  - System Administration
  - Web Development

**Bachelor's**
120 CREDITS

- **Complete one of the following certificates**
  - Database
  - System Administration
  - Web Development

*Note: Web and Computer Programming must be completed before taking Web Development.*

To complete a bachelor's degree, the following courses are required in addition to the certificates stated above:

**Complete the following additional courses:**

- **Senior Project or Internship** (CIT 490 or CIT 498) .................. 3 CREDITS

**Complete the following additional requirements:**

- **General Education Courses** ........................................... 38-39 CREDITS
- **Electives** ................................................................. APPROXIMATELY 30 CREDITS
CSU Global – Example

BACHELOR'S EXAMPLES

Example: Information Technology

- IT Project Management
- IT Security
- IT Healthcare/Data

Bachelor's Degree in IT Core Courses
Bachelor's Degree in IT Gen Ed Courses
Certificate in Cyber Security
Specialization in Criminal Forensics
Specialization in Emergency Management

Credits:
- 41 Credits
- 31 Credits
- 18 Credits
- 15 Credits
- 15 Credits
Competence needs to be a transferable currency

To support flexible pathways
Drilling Down Into Competent Computer Science Graduates

Where We Are and Where We Need To Go
ACM/IEEE-CS CS2013 Curricular Guidelines

<table>
<thead>
<tr>
<th>Knowledge Area</th>
<th>CS2013 Tier1</th>
<th>CS2013 Tier2</th>
<th>CS2008 Core</th>
<th>CC2001 Core</th>
</tr>
</thead>
<tbody>
<tr>
<td>AL- Algorithms and Complexity</td>
<td>19</td>
<td>9</td>
<td>31</td>
<td>31</td>
</tr>
<tr>
<td>AR- Architecture and Organization</td>
<td>0</td>
<td>16</td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>CN- Computational Science</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>DS- Discrete Structures</td>
<td>37</td>
<td>4</td>
<td>43</td>
<td>43</td>
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<tr>
<td>GV- Graphics and Visualization</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>HCI- Human-Computer Interaction</td>
<td>4</td>
<td>4</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>IAS- Information Assurance and Security</td>
<td>3</td>
<td>6</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>IM- Information Management</td>
<td>1</td>
<td>9</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>IS- Intelligent Systems</td>
<td>0</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>NC- Networking and Communication</td>
<td>3</td>
<td>7</td>
<td>15</td>
<td>15</td>
</tr>
<tr>
<td>OS- Operating Systems</td>
<td>4</td>
<td>11</td>
<td>18</td>
<td>18</td>
</tr>
<tr>
<td>PBD- Platform-based Development</td>
<td>0</td>
<td>0</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>PD- Parallel and Distributed Computing</td>
<td>5</td>
<td>10</td>
<td>--</td>
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</tr>
<tr>
<td>PL- Programming Languages</td>
<td>8</td>
<td>20</td>
<td>21</td>
<td>21</td>
</tr>
<tr>
<td>SDF- Software Development Fundamentals</td>
<td>43</td>
<td>0</td>
<td>47</td>
<td>38</td>
</tr>
<tr>
<td>SE- Software Engineering</td>
<td>6</td>
<td>22</td>
<td>31</td>
<td>31</td>
</tr>
<tr>
<td>SF- Systems Fundamentals</td>
<td>18</td>
<td>9</td>
<td>--</td>
<td>--</td>
</tr>
<tr>
<td>SP- Social Issues and Professional Practice</td>
<td>11</td>
<td>5</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td><strong>Total Core Hours</strong></td>
<td><strong>165</strong></td>
<td><strong>143</strong></td>
<td><strong>290</strong></td>
<td><strong>280</strong></td>
</tr>
</tbody>
</table>

- All Tier1 + All Tier2 Total: 308
- All Tier1 + 90% of Tier2 Total: 293.7
- All Tier1 + 80% of Tier2 Total: 279.4
Toward Competence

- Knowledge
  - "know-what"
- Skills
  - "know-how"
- [Professional] Dispositions
  - "know-why"

Competency = [Knowledge + Skills + Dispositions] in Task
Healthcare Professional Competence: Captured by [Amended] Miller’s Pyramid

- Upper levels, reflect behaviors, describing repeated practice to consolidate and attain professional competence
- Lower levels reflect Bloom competencies, describing acquisition and application of knowledge (knowledge and skill)

Signature Pedagogies and Competence

- Capture how to prepare future practitioners in professional programs
  - Meet academic standards of the program
  - Shape character of future practice
  - Convey its values and expectations
- Three dimensions of student competencies
  - Think like a professional
  - Perform like a professional
  - Act responsibly and with integrity
Assessing Computing Competencies

- Assessment of knowledge
  - Been done forever
- Assessment of computing skills
  - Sparingly done in isolation
- Assessment of professional dispositions
  - Most challenging still
  - Formative versus summative
- Assessment of workplace competencies
  - Ultimate context for skills + dispositions
  - Internships/placements/co-op programs
  - Employer-led competency frameworks
Current Status of This Vision

- Background preparation
  - Employer-Academia Workshop, October 2020
  - Kicked off NSF IUSE ICT Grant, June 2021
  - Launched CS202X Task Force, May 2021
- Challenges and opportunities
  - Inertia to change
  - Employer-academia relationships
  - Barriers to real-world experiences
  - Teaching and assessing competencies
  - Needs of a diverse workforce
  - Rapid developments in the credential space
"Any opinions, findings, conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the Networking and Information Technology Research and Development Program."

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