# Comparing Florida's Advanced Manufacturing Curriculum Framework to the Department of Labor Competency Model

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# Comparing Florida's Advanced Manufacturing Curriculum Framework to the Department of Labor Competency Model

In this research paper, we compare the alignment between advanced manufacturing (AM) competencies in Florida's Career and Technical Education (CTE) AM Curriculum Framework and the U.S. Department of Labor's Advanced Manufacturing Competency Model. AM educators are guided by state department of education documents that specify program content, while employers track the knowledge, skills, and dispositions that AM technicians require to successfully function in the workplace. The Curriculum Framework, created with input from educators and industry, shape AM curricula and course syllabi because they specify the learning outcomes that AM graduates upon completion of two-year AM degree programs. The Department of Labor's Advanced Manufacturing Competency Model, crafted by federal policymakers and industry representatives, includes personal, academic, industry-specific, and managerial competencies needed by successful AM technicians; the Model is intended to influence technicians' hiring, training, and evaluation. Although these documents were created by different sets of stakeholders, they "bookend" AM technicians' school-to-career pathways. To determine the extent to which the 2019-2020 Florida AM Curriculum Framework aligns to the Department of Labor's *Advanced Manufacturing Competency Model,* we used text mining to extract and compare the key competencies found in both documents. Through this approach, we compared these documents and identified: 1) frequently addressed topics; 2) verbs that guided the complexity (i.e., Bloom's *Revised Taxonomy of Learning Objectives* cognitive level) of the course learning task versus workplace competency; and 3) overall match between the documents. Our results suggest that the documents overlap very little, with significant misalignments in higher-level Bloom's verbs. We present implications for educational institutions, AM policy makers, and industry; suggest a revision cycle and process; and propose an ongoing assessment model to improve the congruence between what employers want and what is taught in two-year AM degree programs.

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## 1.0. Background

Florida had over 20,000 manufacturers in 2019, among the nation's highest [1, 2]. Florida manufacturers produce a wide variety of goods including aerospace components, communications equipment, pharmaceuticals, semiconductors, and wood products. Florida's over 20 airports, 15 deep water seaports, 3,000 miles of freight rail tracks, and 2 spaceports gives the industry many options for transporting products [2]. While manufacturing may not be Florida's leading industry, the state ranks 27 among U.S. states for its manufacturing "value added" [3] and is first for business creation, 10th in venture capital, and 12th in fastest growing companies [4]. While the urban areas have made the largest employment contributions to Florida's economy, manufacturing plays a proportionally more significant role in the local economies of rural areas; a critical challenges for rural AM employers is to recruit an adequate supply of skilled AM professionals [5]. Because many students perceive AM as an unattractive field [8], few students enter the pipeline and few professionals transition to instructors with appropriate experience and credentials [6]. As a result, not only are entry-level technicians with industry-specific competencies in short supply, but also employability skills such as communication, critical thinking, advanced digital skills, and problem solving are also contributing to an AM workforce skills gaps [7].

We assessed the alignment between the Florida Department of Education's (FLDOE) Career and Technical Education (CTE) Advanced Manufacturing Curriculum Framework [hereafter AM Framework] and employer needs as expressed in the Department of Labor's (DOL) AM Competency Model [hereafter AM Competency Model]. We used a computational approach to comparative document analysis to gain insight into these research questions:

1) How do the topics in AM Curriculum Framework and the AM Competency Model compare?
2) What are the differences between competencies in FLDOE's AM Curriculum Framework and those desired by employers?
3) To what extent are the DOL's AM Competency Model and the FLDOE's AM Curriculum Framework aligned?

## 2.0. Literature Review

### *2.1. Manufacturing Challenges.*

2.1.1. AM Worker Shortages. Overcoming worker shortages requires increasing student recruitment into manufacturing. Rural areas are challenged to fill open manufacturing positions with skilled workers—even when the training is free. For example, an AM program instructor from a state college in Florida reported that they "have scholarships from the local lumber company for local high school students to take these courses and receive a degree for free, and I can never fill all of the [scholarship] slots they give us" [8]. Americans believe that manufacturing is vital to the country's economy, but the "vast majority wouldn't encourage their children to pursue manufacturing careers, and most don't believe that manufacturing jobs today are interesting, rewarding, clean, safe, stable, and secure" [9]. Marketing manufacturing as an innovative and lucrative occupation is essential because the scarcity of students entering the field has resulted in a shortage of experienced instructors with the proper, current credentials and knowledge to educate the next generation of technicians.

2.1.2. The Skills Gap. In Florida, construction and manufacturing have the highest technician skills gap to vacancy ratio [10]. In *Florida Jobs 2030,* the greatest projected long-term manufacturing skills gaps in sales, maintenance, and repair [10]. Employability skills such as communication, critical thinking, problem solving have been considered essential skills for technicians, along with computer, occupation-specific, and advanced digital skills; these skills have been seen as a "differentiating factor between entry-level and middle-skill jobs" [10]. The lack of skilled labor is "one of [the] most significant challenges facing virtually every manufacturer…trying to find a reliable source of factory-ready workers that can operate sophisticated machine tools and keep automated (and increasingly robotic) factories up and running" [11] (p.24).

*2.2. Efforts to Solve the Worker Shortage.*

2.2.1. Legislation. The Florida legislature passed Title XIX to create the Rural Economic Development Initiative (REDI), administered by the Florida Department of Economic Opportunity (DEO), to channel resources directly to rural counties. Through this legislation, the DEO established three Rural Areas of Opportunity (RAOs) for rural counties and cities impacted by economic events, distress, natural disasters, or that presented a unique economic development opportunity to the state (e.g., aquaculture). As a result of Title XIX, manufacturers have built capacity and improved economic conditions in RAO counties [5].

2.2.2. Educational Support. Career and Technical Education (CTE) prepares individuals for occupations important to Florida's economic development. The FLDOE has developed secondary and postsecondary education pathways into CTE fields by establishing guidelines for AM courses, industry certifications, and Associate's degrees. Secondary schools offer courses in automation, production, electronic technology, welding, maritime, repair, machining technology, and industrial machinery. Community and state colleges offer two-year degrees in engineering technology with a variety of specializations. AM certifications are also available with a focus on automation, lean manufacturing, mechatronics, and pneumatics, hydraulics, and motors for manufacturing [2, 12].

*2.3. Efforts to Close the Skills Gap*

2.3.1. FLDOE AM Curriculum Framework. The FLDOE generates curriculum Framework to guide classroom instruction and certify two-year programs based on their curriculum's fidelity to framework content. CTE-designated programs use Framework to guide secondary and postsecondary institutions in the development of Florida's economic and workforce needs. The Framework are revised by experts from education, industry, and government. The Engineering Technology Framework, updated in 2018-19 [13], and in 2019-20 [12], include AM and are meant to "prepare students for initial employment with an occupational title as a Manufacturing Engineering Technician or Advanced Manufacturing or Production Technician in various specialized areas, or to provide supplemental training for persons previously or currently employed in these occupations" [12] (p. 8). The six core concepts in the AM specialized track are: pneumatic, hydraulic, and electromechanical components and/or systems; lean and six sigma project management concepts for manufacturing environments; industrial automation systems operations and troubleshooting; principles of robotics and automated systems; human machine interfaces and automated systems; and supply chain and operations management concepts and techniques. These concepts are used to build curricula and measure instructional success in Florida's AM educational programs [12].

2.3.2. DOL's Competency Model. As Figure 1 shows, the U.S. Department of Labor published the AM Competency Model in 2010 [14]. The AM Competency Model was developed through by the Employment and Training Administration and industry organizations. DOL uses the "industry champion" to promote the model and serves as lead in identifying revision dates [14]. The model identified five tiers of competencies: 1) personal effectiveness; 2) academic; 3) workplace' 4) industry-wide; and 5) industry-sector technical.

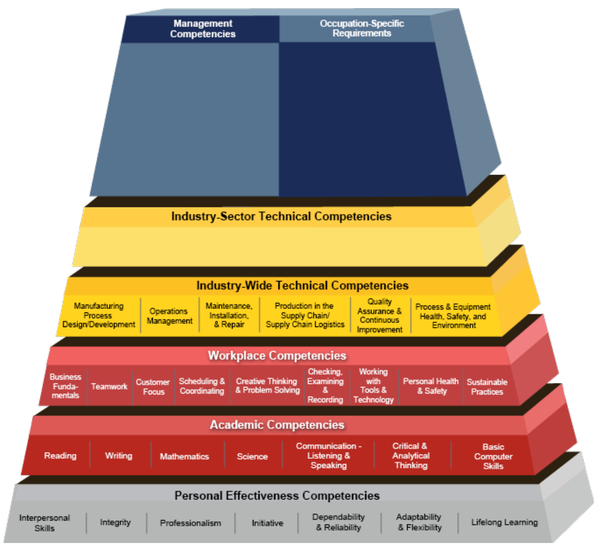

Figure 1. AM Competency Model [14].

Despite what Figure 1 may suggest, the tiers are not intended to suggest that some competencies are of greater value than others; rather, the tiered structure illustrates a progression from industry to occupation-specific competencies. Tiers 1-3 are considered foundational competencies, while Tier 4-5 represent industry competencies. Tiers 6-9, not detailed in Figure 1, represent advanced specializations in specific industry occupations.

## 3.0. Method

### *3.1. Study Design.*

We used computational content analysis to quantify and then analyze text from 2019-2020 AM Curriculum Framework and 2010 DOL's AM Competency Model [14]. We used Natural Language Processing (NLP) to perform document analyses and comparisons. Using SpaCy, an open-source NLP library for the Python programming language that is useful for efficiently analyzing massive volumes of text, we tagged parts of speech (POS) to prepare documents for analysis. We then analyzed the text from the AM Framework and the AM Competency Model using a four-step process (illustrated Figure 1) to transform the text into quantifiable frequencies and comparison percentages. Finally, we categorized verbs according to Bloom's *Revised*

*Taxonomy* [16] to discern the activity complexity (i.e., Bloom's escalating cognitive dimension levels of remember, understand, apply, analyze, evaluate, and create) inherent in documents.

*3.2. Data Collection and Text Processing.*

Data Collection. Figure 2 depicts the four-step process used in this study: 1) Data Collection and Inventory, 2) Extraction of relevant text (i.e., competencies), 3) Text pre-processing, and 4) topic (noun) and level (verb) extraction.

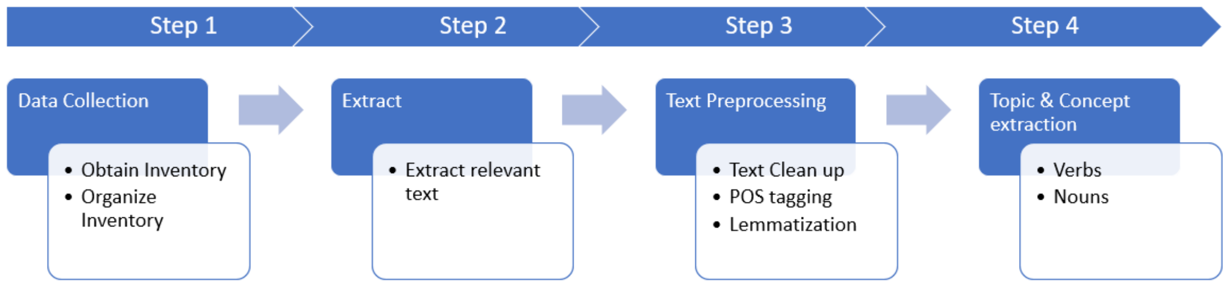


Figure 2. Steps to Processing Documents using NLP

As Figure 2 shows, Step 1 involved the collection and inventory of documents to be used in the analysis (in this case AM Curriculum Framework and AM Competency Model). As a surrogate for employers' valued competencies, we used the 2010 DOL's AM Competency Model [14]. We also used the 2019-20 CTE Curriculum Framework for Engineering Technology AM specialization section [9, 12]. Step 2 involved extracting the competencies from the documents; Step 3 included cleaning the text by removing unnecessary punctuation, numbers, and creating uniform acronyms; lemmatization (i.e., breaking down words into their root form); and tagging parts of POS. Finally, Step 4 involved the extraction of nouns and verbs for the final analysis.

*3.3 Data Analysis*

Data were analyzed to obtain: 1) verb/noun frequencies, 2) unique noun/verb match percentages, and 3) total noun/verb document match scores. Python and SpaCY libraries were used to create descriptive statistics and graphics to illustrate POS and to make document comparisons.

3.3.1. Noun and Verb Frequencies. Once verbs and nouns were extracted using the four-step process illustrated in Figure 2, the Natural Language Toolkit (NLTK, a NLP text processing library) was used to obtain the frequencies and percentages of the nouns and verbs. The data of verbs and nouns, and their frequencies were visualized to aid in the analysis.

3.3.2. Verb Categorization. The verbs were categorized into Bloom's *Revised Taxonomy of Educational Objectives* six cognitive levels [15]. Bloom's six cognitive levels are defined, from low to high, as:

1) Remember – Retrieve relevant knowledge from long-term memory.
2) Understand – Construct meaning from instructional messages, including oral, written and graphic communication.
3) Apply – Carry out or use a procedure through executing or implementing.

4) Analyze – Breaking material or concepts into parts, determining how the parts relate or interrelate to one another or to an overall structure or purpose.
5) Evaluate – Make judgements based on criteria and standards through checking or critiquing.
6) Create – Put elements together to form a coherent whole; reorganize into a new pattern or structure.

Then the percentage of verbs belonging to each level was calculated as:

% of verbs in each of Bloom's Level = $\frac{\boldsymbol{V_i}}{\sum_{\boldsymbol{i=1}}^{\boldsymbol{6}} \boldsymbol{V_i}} * 100$

where $\boldsymbol{i}$ = Bloom's *Revised Taxonomy* level & $\boldsymbol{V_i}$= Total # of verbs in the $i^{th}$ level.

To compare the ranges of categorized verbs within the AM Curriculum Framework and the AM Competency Model, we also visualized the data with pie and radar charts to emphasize aspects of the analysis.

3.3.3. Unique Match (UM) and Total Document Match (TDM).
We calculated two types of match. TDM identified the similarity between two documents using noun and verb occurrence and frequency and results in a Document Match Score (DMS). Unique nouns/verbs were those which are distinct and calculated without considering its frequency and result in a UM. For example, TDM versus UM might look like Match Example 1:

<u>Match Example 1</u>
*Unique_Nouns: (Production, materials, technology, system)*
*Total_Nouns: (Production, Production, materials, technology, technology, system)*
Unique Nouns = 4; Total Nouns = 6

UM between documents was often less than TDM because unique match had a precise matching requirement, as Match Example 2 demonstrates:

<u>Match Example 2</u>
*Document1 Unique Nouns: (<u>Production</u>, <u>materials</u>, technology, system)*
*Document 2 Unique Nouns: (<u>Production</u>, <u>materials</u>, test, drawing)*

In Match Example 2, there were two unique nouns matching. In contrast, total noun match might pick up duplicates, as Match Example 3 shows:

<u>Match Example 3</u>
*Document 1 Total Nouns: (<u>Production</u>, <u>materials</u>, <u>technology</u>, <u>technology</u>, circuit, name, name, system)*
*Document 2 Total Nouns; (<u>Production</u>, <u>materials</u>, <u>technology</u>, <u>technology</u>, test, test, drawings)*

In Match Example 3, there were 4 Total Nouns matching.

To assess the TDM of noun or verb between program curricula and employer needs we uploaded the verb or noun lists of Northwest FL syllabi and AM Competency Model in comma separated values (.csv) format (with frequencies considered) and calculated the cosine and counter cosine similarity. Cosine similarity percentages were then used to compare the similarity between parts of speech in syllabi (nouns or verbs) and the AM Competency Model. The formula for obtaining the cosine similarity is given below, whereas the percent of cosine similarity between AM Curriculum Framework and AM Competency Model is:

$$\cos\theta = \frac{\vec{a}\,.\,\vec{b}}{||\vec{a}||\;||\vec{b}||} = \frac{\sum_{i=1}^{n} a_i\, b_i}{\sqrt{\sum_{i=1}^{n} a_i^2}\sqrt{\sum_{i=1}^{n} b_i^2}} * 100$$

$\vec{a}$ is the vector representation of noun/verb frequency in AM Curriculum Framework document.
$\vec{b}$ is the vector of the representation of noun/verb frequency in DOL's AM Competency Model document.
$a_i$ and $b_i$ are components of $\vec{a}$ and $\vec{b}$.
$i$ represents a row in the corresponding vector or a noun/verb in this case

For example, Figure 2 displays the pseudo code (i.e., an informal high-level example of the code) for calculating the DMS of parts of speech in different documents.

1. **Function: CSV to Dictionary**
2. Input: Path of file
3. Read file content and save
4. Output: File content as dictionary
5. **End Function**
6. **Function: counter_cosine_similarity**
7. Input: Two list of verbs
8. Call function 'Cosine_similarity' from 'sklearn.metrics.pairwise' library to calculate match between documents
9. Output: Value of cosine similarity
10. **End Function**
11. **Function: calculate match**
12. Input: path of both CSV files of target documents
13. Call function: CSV to Dictionary
14. Convert both dictionaries into panda series
15. Convert list to the 'vector'
16. Call Function: counter_cosine_similarity
17. Output: Cosine similarity into a match score
18. **End Function**
19. Call Function: calculate match score

Figure 2. Pseudocode Comparing Parts of Speech Considering Word Frequencies

With knowledge that a DMS below .40 is commonly accepted as a very low match score, we further classified match above .40 in increments of .10, resulting in the following seven levels: <0.40 (Very Low), 0.41-0.50 (Low), 0.51-0.60 (Fair), 0.61-0.70 (Moderate), 0.71-0.80 (Good), 0.81-0.90 (High), 0.91-1.0 (Very High).

UM is based on the pseudocode found in Figure 3.

```
Function: Similar
Input: two array of verbs/nouns called actual array and expected array
Call in-built function intersection and save result
Calculate ratio of (Length or result array/Length of expected array)
End
Call Function: Similar
```

Figure 3. Pseudocode for Comparing Parts of Speech Not Considering Frequencies

UM was based on the following rubric: 0-20% (Very low), 21-40% (Low), 41-60% (Moderate), 61-80% (High), 81-100% (Very high).

### *3.4. Limitations to the Method*

As with any computational content analysis and use of NLP, there are many possible missteps that can lead to inaccurate results. Although NLP is an objective way to code parts of speech, analysts should be able to check and scan data for grammatical errors. There may be a 5% error using NLP, as all words analyzed in documents may not be correctly tagged for processing. This is also true for acronyms, which may also be represented in many ways. Although there are recommendations to improving conceptual analysis, match in this paper is limited to percentage of alignment between nouns and verbs.

The AM Competency Model is also 10 years older than the revised 19-20 Framework, which suggests that the employers needs will have likely changed during this time. Although this gap in time may change some of the results of this study if conducted in the future with the newest 2020 AM Competency Model, the findings highlight a method for measuring alignment of topics and levels and provides evidence for the need to align educational policy with employer needs. It should also be noted that the *Revised AM Competency Model* [14] was published in January 2020 after this paper was submitted.

## 4.0. Results

### *4.1. Topic or Concept Identification and Comparison*

To identify topics that were covered in the Framework versus those expressed by AM professionals, we generated basic frequencies. Figure 5 depicts the top 20 nouns found in the AM Curriculum Framework and AM Competency Model.

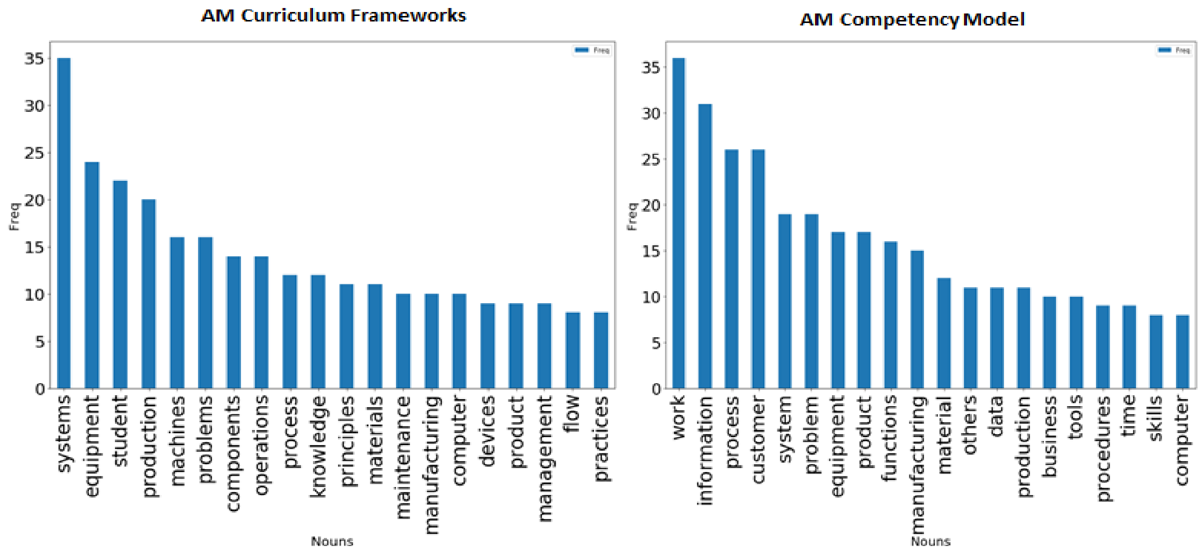


Figure 5. Most Frequent Nouns in AM Curriculum Framework and AM Competency Model

As Figure 5 suggests, systems, equipment, student, production, machines, and problems occurred 13 or more times in the AM Curriculum Framework while work, information, process, customer, system, and problem occurred 18 or more times in the AM Competency Model. Table 1 further summarizes these results alphabetically.

Table 1. Top 20 Nouns in AM Curriculum Framework and AM Competency Model

| | |
|---|---|
| AM Curriculum Framework | components, computers, devices, equipment, flow, knowledge, machines, operations, maintenance, management, manufacturing, materials, practices, principles, problems, process, product, production, students, systems |
| AM Competency Model | business, computer, customer, data, equipment, functions, information, manufacturing, materials, others, problems, procedures, process, product, production, skills, systems, time, tools, work |

As Table 1 suggests, the seven nouns (e.g., computers, equipment, manufacturing, materials, problems, process, products, production, systems) were common to the AM Curriculum Framework and the AM Competency Model.

Total and Unique Noun Match. There were 881 total nouns in AM Curriculum Framework compared to 1291 in the AM Competency Model, and of those 247 and 571, respectively, were unique. The UM and TM between the AM Curriculum Framework and AM Competency Model is 20.49% (Very low), with a DMS of .45 (Low).

*4.2. Verb and Level Identification and Comparisons.*

We analyzed verbs for occurrence frequency in both the AM Curriculum Framework and the AM Competency Model.

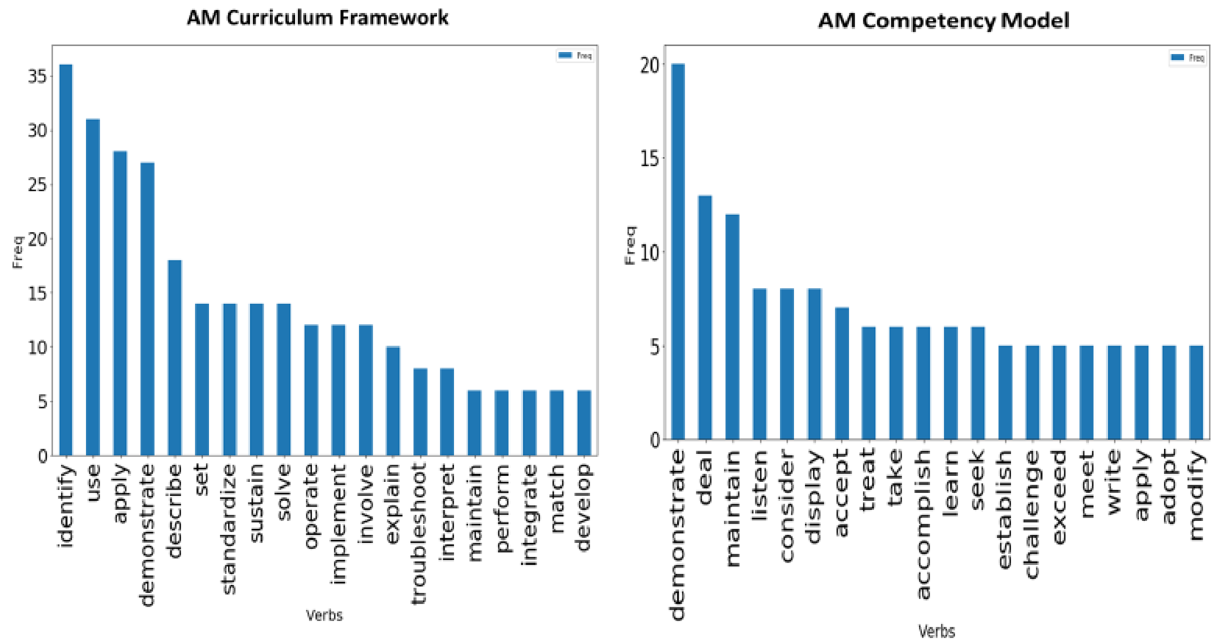


Figure 6. Verbs Frequencies in AM Framework Compared to AM Competency Model

As Figure 6 shows, identify, use, apply, demonstrate, and describe appeared 18 or more times in the AM Framework while demonstrate, deal, maintain, listen, consider, and display (the latter three tied) all appeared 8 or more times in the AM Competency Model. The top 20 verbs from Figure 6 are alphabetized in Table 2.

Table 2. Top 20 Verbs in AM Curriculum Framework and AM Competency Model

| | |
|---|---|
| AM Curriculum Framework | apply, demonstrate, describe, develop, explain, identify, implement, integrate, interpret, involve, maintain, match, operate, perform, use, set, solve, standardize, sustain, troubleshoot (20) |
| AM Competency Model | accept, accomplish, apply, adopt, challenge, consider, deal, demonstrate, display, establish, exceed, learn, listen, meet, maintain, modify, seek, take, treat, write (20) |

As Table 2 shows, three verbs (i.e., apply, demonstrate, and maintain), reflected a 15% similarity among the top 20 most frequently mentioned verbs found in the compared documents.

Total and Unique Verb Match. There were 438 total verbs in the AM Curriculum Framework to 415 in the AM Competency Model, and of those 16.21% (n=71) and 43.13% (n=179) were unique verbs, respectively. The UM between the AM Framework and AM Competency Model is 23.03% (Low), while TM has a DMS of 0.34 (Very low).

Categorized Verbs. Verbs were categorized according to the Cognitive Dimension of *Bloom's Revised Taxonomy* to identify similarities and differences between AM Framework and the AM Competency Model. In Table 3, we see the frequency verbs in each of the categories and the corresponding percentage of verbs in each of those levels.

Table 3. Verb Distribution by Bloom's Cognitive Level

| Bloom's Cognitive Level | Framework Verbs (%) | Framework Rank | Model Verbs (%) | Model Rank | Model to Framework Difference Percent |
|---|---|---|---|---|---|
| 1. Remembering | 66 (18.18) | 2 | 75 (14.31) | 3 | -3.87 |
| 2. Understanding | 63 (17.36) | 3 | 100 (19.1) | 2 | 1.74 |
| 3. Applying | 186 (51.25) | 1 | 208 (39.69) | 1 | -11.56 |
| 4. Analyzing | 6 (1.65) | 6 | 44 (8.4) | 5 | 6.75 |
| 5. Evaluating | 20 (5.51) | 5 | 41 (7.82) | 6 | 2.31 |
| 6. Creating | 22 (6.06) | 4 | 56 (10.69) | 4 | 4.63 |

As Table 3 suggests, frequency and percentage distributions revealed that level 3, i.e., applying, verbs were most often mentioned in the AM Framework and the AM Competency Model, with 51.25% of AM Framework and 39.69% AM Competency Model including verbs in this category. Verb level rankings, categorized by Bloom's cognitive dimension, also indicated that in the AM Framework, in rank order of most to least frequent, applying (level 3), remembering (level 1), understanding (level 2), creating (level 6), evaluating (level 5) and analyzing (level 4). This ranking is slightly different from the AM Competency model with the verbs most frequently occurring in applying (level 3), understanding (level 2), remembering (level 1), creating (level 6), analyzing (4), and evaluating (level 5).

In Table 3, the negative differences reflect instances when more verbs of a particular level were found in the AM Framework than in the AM Competency Model, while positive differences are instances in which the AM Competency Model had more verbs of a particular level than the AM Framework. For instance, the AM Competency Model contained a higher percentage of level 4, level 5, and level 6 verbs. However, as Table 3 showed, the AM Competency Model had more emphasis on level 4 (analyzing), level 5 (evaluating), and level 6 (creating) verbs the AM Curriculum Framework, by a difference of 6.75%, 2.31%, and 4.63%, respectively.

Figure 7 provides a visual representation of the percentage of verbs, categorized by Bloom's *Revised Taxonomy* [16], that are not as apparent in Table 3, between the AM Framework and AM Competency Model.

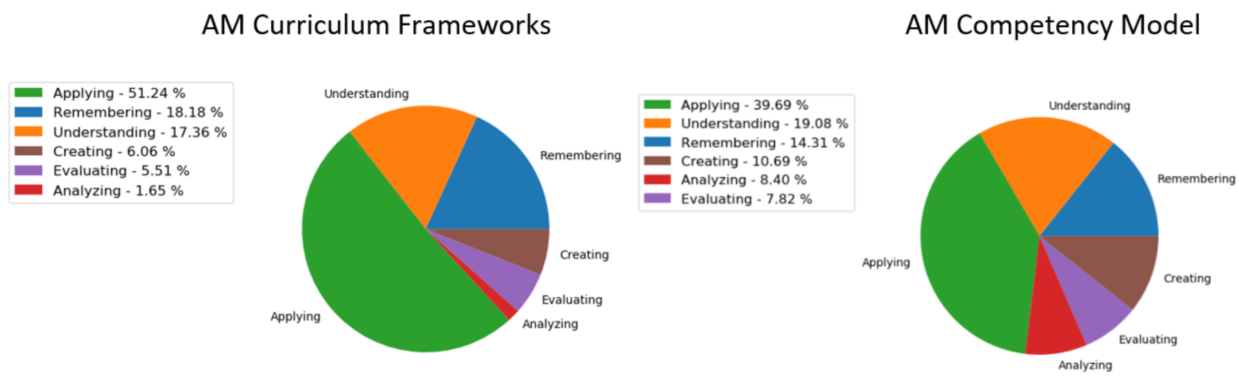


Figure 7. Bloom's Classification of AM Curriculum Framework and AM Competency Model Verbs

Figure 7 emphasizes the concentration of verbs in AM Curriculum Framework and AM Competency Model are mid- to low cognitive level verbs (applying, understanding, and remembering), although the percentage of higher-level verbs (creating, analyzing, and evaluating) are much greater in the AM Competency Model than the AM Framework.

The radar chart in Figure 8 depicts Bloom's cognitive dimension by overlaying AM Curriculum Framework (blue) and AM Competency Model verbs (orange). The graphic highlights the areas of similarity, with both documents peaking the highest towards the applying level. The overlay also shows areas of misalignment, whereas the AM Competency Model (orange) shifts more to higher level verb categories (i.e., analyzing, evaluating, and creating).

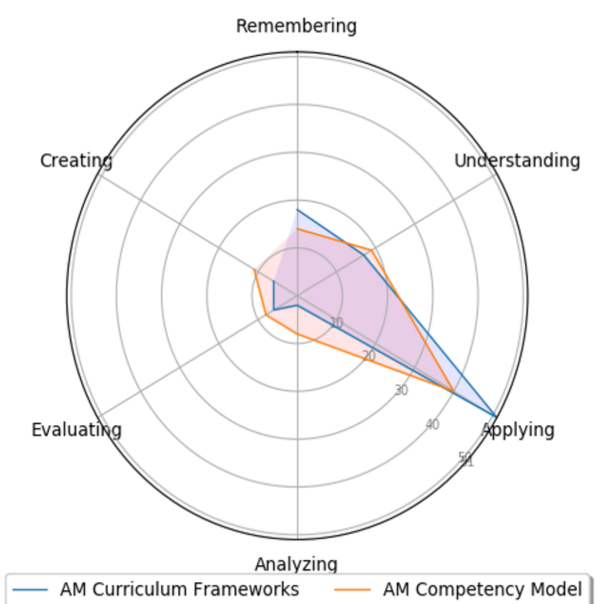


Figure 8. AM Curriculum Framework and AM Competency Model Match by Bloom's Cognitive Level

## 5.0. Discussion

*5.1. How do the topics in AM Curriculum Framework and the AM Competency Model compare?*

The AM Curriculum Framework is the conceptual foundation for two-year AM programs in Florida. The Framework must reflect content that will prepare students for the dynamic field of AM. To meet production demands, AM employers need a ready pool of workers prepared to meet their needs immediately. Because manufacturing is a key part of Florida, especially rural, employment, the Florida Department of Education's requirements must reflect what employers expect.

The AM Curriculum Framework and  AM Competency Model highlighted the importance of training students in computers, equipment, manufacturing, materials, problems, process, products, production, and systems. Many frequently addressed topics in the AM Curriculum Framework that were not as prevalent in the AM Competency Model, and vice-versa. Of these topics, some were general (e.g., components, devices, flow, knowledge, machines, operations, maintenance, practices, and principles) in AM Curriculum Framework; the AM Competency Model also included general references to procedures, skills, time, tools, and work. The documents differed in reference to specific topics. For example, management was frequent topic in the AM Framework, but not in the AM Competency model, and the AM Competency Model mentioned specific topics in business, customers, data, functions, and information more often than the AM Framework did. The AM Competency Model was more focused on customer skills, working with others, and using data, information, and computers to solve problems. A comparison of most frequent topics provides a starting point from which to modify or update AM Curriculum Framework to be more inclusive of employer needs. For AM industry, curricula must include competencies that ensure students' skill with information, technologies, business, and data to improve AM inputs, processes, and outputs, while serving customers.

*5.2. RQ2. What are the differences between competencies in FLDOE's AM Curriculum Framework and those desired by employers?*

The CTE Curriculum Frameworks guide program curricula, so must offer the rigor needed to prepare students for the workforce. The AM Framework should include current competencies appropriate for the task level that students will face as new professionals; the findings of this study are important for understanding the ways in which school and work competencies align.

Our findings showed alignment and misalignment between the AM Curriculum Framework and AM Competency Model. For example, the verbs apply, demonstrate, and maintain, at Bloom's cognitive levels 1-3, occurred often, and reflected agreement between the AM Curriculum Framework and the AM Competency Model. However, the verb "write" was common in the AM Competency Model, but was not in the AM Curriculum Framework's top 20 verb. While it is possible that frequency is not linked to importance, if few competencies in one document center on a particular action and many competencies in another document center on that same action, it is safe to assume that the documents reflect different importance perceptions.

Percentage distributions also revealed that applying verbs were most mentioned, with 51% of verbs from AM Curriculum Framework and 40% in the AM Competency Model belonging to this category. Although the Framework emphasized applying verbs 12% more than in the AM Competency Model, the AM Competency Model had a higher percentage of level 4, level 5, and level 6 verbs mentioned in the AM Curriculum Framework. Thus, to be more aligned in the cognitive dimension, AM Curriculum Framework would need to place more emphasis in analyzing, evaluating and creating levels (i.e., the higher-level verbs). Verbs in the analyzing category were particularly underemphasized in the AM Curriculum Framework, when compared to the AM Competency Model.

*5.3. RQ 3. To what extent are the DOL's AM Competency Model and the FLDOE's AM Curriculum Framework aligned?*

School-to-career competency alignment is essential for the AM industry to address worker shortages and skills gaps. In this study, we compared AM Curriculum Framework and AM Competency Model to assess the match between the nouns (or topics) and verbs (levels) of competencies in these documents. To explore this alignment, we compared the competencies in the 2019-20 AM Curriculum Framework and the 2010 AM Competency Model. We also calculated the total and unique match of nouns and verbs between these documents. The congruence between nouns in the documents was low, with very few unique nouns. Similarly, the match between verbs in the documents was very low, with less than 25% of the unique verbs found between the documents.

Precise match between topics (nouns) and rigor (verbs) is important for competency alignment; employers' perspectives on skills needed by future technicians should be considered more in AM Curriculum Framework development of ensure a higher match. This consideration is especially true since the AM Competency Model is the source for employer-desired competencies.

*5.4. Implications.*

5.4.1. Implications for educational institutions. Two- and four-year AM degree programs are deeply connected to their local communities and economy. These programs, such as those at state and community colleges in Florida, should strongly align with the needs of local employers, and incorporate state and national workforce needs. Curriculum planning committees may benefit from knowing the extent to which there is topical alignment and rigor in curricula to develop future AM students. Including employers in curriculum development be another way to gather about essential topics and needed competency levels. Employers can also be critical friends in formative and summative AM program evaluation.

5.4.2. Implications for AM policymakers. Because of the industry's dynamic nature, the FLDOE revises the AM Curriculum Framework often. Assessing alignment between framework content and employer needs is important to assess prior to Framework revision. With the AM Competency Model revised every decade (i.e., the newest Model released in January 2020), AM industry leaders may also benefit from understanding curriculum content. The approach used in this study is an example of a measurable way for employers and educators to stay aware of AM entry-level technicians' competencies.

5.4.3. Implications for industry. Industry must be very specific about the types of competencies needed to be successful in AM positions. Competencies, often expressed in job descriptions and job advertisements, should delineate the most accurate qualifications needed for AM positions. Industry leaders must document the types of needs they have of entry and managerial AM technicians in order for educational policymakers to incorporate those needs. Formalizing the needs of local, state, and national AM employers may be one of the ways in which evaluators and academic specialists can work together.

*5.5. Next steps.*

The findings of this study can be extended and improved in several ways:

DOL, Framework, and Syllabi Alignment. In related work [16], we compared AM program syllabi to the AM Competency Model to assess the alignment between course learning outcomes and employer needs. In our next step, we will triangulate the competencies from syllabi, the AM Competency Model, and the AM Curriculum Framework to chart competency alignment among stakeholders.

Conceptual Analysis. Another extension of this work is to use Graph Theory to identify the first, second, and third order concepts in the documents for comparison[17]. This process generate the degree to which there is conceptual alignment between compared documents. The joining of parts of speech, such as bi-grams (e.g., verb-noun combinations) can also be analyzed to better understand sentence structure and include both topical and level analysis simultaneously.

Creation of a Body of Knowledge. While the methods described in this study can be used to compare alignment among and between different stakeholders, a unifying document that incorporates all stakeholders (i.e., academic, professional, government, industry) views is the most comprehensive view of competency needs. An AM Body of Knowledge (BOK) would be an inclusive and vetted document to aid comparisons and alignment studies, as well as enlighten new professionals to their possible roles and specializations. A Body of Knowledge, which can identify which competencies are not being covered through instruction or training, would ultimately assist decision-makers in determining whether academia or industry should be responsible address identified skills gaps.

**Conclusion**

In this study, we explored the alignment between competencies found in the AM Curriculum Framework and employer needs based on the DOL's AM Competency Model. There is evidence of both alignment and misalignment in topics, competency levels, and the rigor used in the documents analyzed. An important finding is the high prevalence of mid-level activities, but lack of higher-level activities, such as analyzing, evaluating, and creating. The results of this study provide a strong imperative for ongoing, systematic investigation and monitoring of the extent to which curriculum guides reflect industry needs.

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