Identifying Congruence Between Advanced Manufacturing Two Year Curricula and Employer Needs: Findings from 5 Florida State Colleges

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ABSTRACT

In this research paper, we report our assessment of the congruence between two-year advanced manufacturing (AM) program syllabi to employer needs expressed in the Department of Labor's (DOL) AM Competency Model. The dynamic AM industry relies on two-year AM technician program graduates from state and community colleges. These program curricula are mandated to reflect state career and technology education (CTE) curriculum frameworks, but the frameworks are not designed to measure graduates' abilities to meet AM employers' current needs. Because this technology-reliant industry changes so quickly, faculty are challenged to source, develop, and implement responsive educational experiences. Through consultation with industry leaders, the Department of Labor (DOL) developed an AM competency model to illustrate and promote workers' necessary knowledge, skills, and dispositions. To determine whether the AM competency model can function as an exit assessment for AM program graduates, we compared AM program syllabi from five rural Northwest Florida state colleges to the DOL AM Competency Model. We text-mined competencies in both syllabi and the AM Competency Model and compared them to identify: 1) frequently addressed topics; 2) verbs guiding course learning outcomes versus the skill depth desired by employers; and 3) overall match between documents. Our findings indicate that despite being developed to reflect the same curriculum framework, the five AM programs' topical and complexity emphases varied widely. Overall, AM Competency Model content reflected higher levels of the Bloom's *Revised Taxonomy of Educational Objectives*, highlighting industry commitments to fostering analysis, evaluation, and creation. We conclude with implications for educational institutions, AM policymakers, and industry, outline the need for an AM Body of Knowledge, 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

Working in Advanced Manufacturing (AM) requires professionals to understand and apply theoretical concepts. AM program graduates are presumed to have mastered key competencies through their engagement with AM curricula. However, AM program leaders and AM employers rarely work together to ensure tight coupling between classroom content and workplace expectations [1]. Effective AM technical curricula and strong educational policies are keys to increasing the quality and volume of skilled workforce, yet few sound strategies to document the alignment between curricula and policy have been developed.

While AM employers exist throughout the United States, an analysis of rural and rural-adjacent areas within Florida revealed that, while these regions are less densely populated with industry sites, manufacturing represents a more significant portion of local economies, with higher than state average wage levels within represented industries [2]. In rural Northwest Florida, 7% of the region's employment is in manufacturing, producing 4.7% of the gross regional product, with average annual wages higher than in other industries; AM is a driver of economic development and community stability in Northwest Florida. AM employers rely on a steady source of skilled workers to maintain this contribution [3].

In this study, we focus on the alignment between Northwest Florida's two-year AM program curricula [hereafter AM program syllabi] and employer needs as expressed through the Department of Labor's (DOL) AM Competency Model [hereafter AM Competency Model [4]. We use a computational approach to comparative document analysis to investigate three research questions:

RQ1) What are frequently addressed topics in AM program syllabi at five Northwest Florida colleges and the DOL's AM Competency Model?

RQ2) What types of verbs guide course-learning outcomes compared to those desired by employers?

RQ3) What is the overall match between DOL's AM Competency Model and AM program syllabi at five Northwest Florida community colleges?

2.0. Literature Review

2.1. Need for Advanced Manufacturing Technicians.

In 2019, Florida AM jobs increased by 7,700 over the past year alone, evidencing Florida manufacturing jobs plummeted from 520,700 to 308,900 from the period of 1990 to 2010 [5]. Since 2010, Florida manufacturing jobs have begun to rebound, with manufacturing jobs at 381,300 [5]. Manufacturing currently makes up 4.2% of Florida's nonagricultural employment share, and projections indicate that these trends will continue [6].

Because rural communities may not produce as much as other Florida locales, they are more economically affected by fluctuations in the manufacturing industry [5]; for example, in Northwest Florida's rural manufacturing district, one-third of subsectors (e.g., primary metal, machinery, wood products, petroleum, coal) had positive employment and productivity [5]. Northwest Florida's 16-county region outperformed the U.S in employment growth in high-

performing sectors (i.e., aerospace product and parts; ship and boat building; ventilation and air-conditioning equipment; nonmetallic mineral products; sawmills and wood preservation; plywood and veneer wood products; steel products; and tobacco). Although Northwest Florida advanced manufacturing sector represents only 18,000 jobs, or 3.1% of the region's total employment, its productivity represents a higher share of manufacturing employment than the Florida economy, yielding higher wage jobs that contribute to regional and state innovation [5].

2.2. Importance of College and Career Pathway Alignment.

With Florida manufacturing jobs on an upward trajectory, and Northwest Florida leading several high-performing and emerging sectors, the extent to which advanced manufacturing (AM) programs instill the skills that future graduates need to meet rural employers' needs is unclear. For example, while the number of engineering technicians is expected to increase by 5% from 2018 to 2028 [7], to meet future employment needs, Florida's AM program curricula and courses may not be aligned to national job requirements. Identifying and measuring college-to-work pathway alignment is essential to ensure a workforce ready for dynamic and fast-changing industries situated in economically sensitive rural communities.

3.0. Method

3.1. Study Design.

We used computational content analysis to quantify, and then analyze, text from AM Program syllabi and from the 2020 AM Competency Model shown in Figure 1.

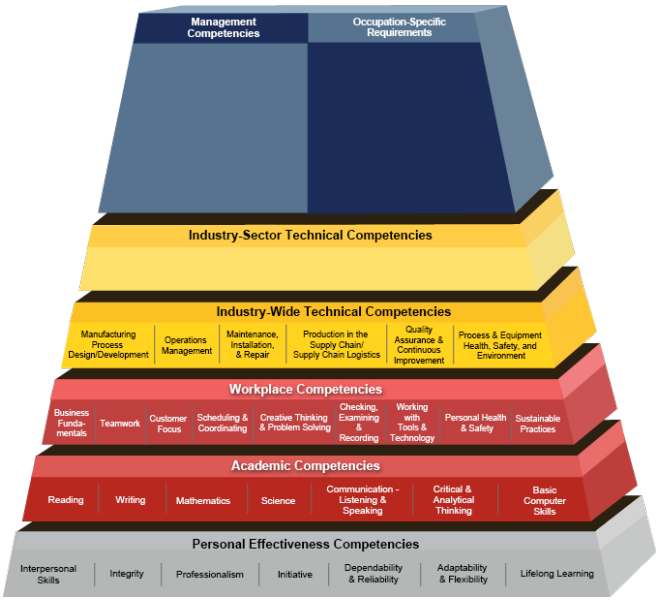

Figure 1. AM Competency Model [4].

As Figure 1 shows, the Advanced Manufacturing Competency Model is a comprehensive industry-wide model that explicates dynamic skill and competency blocks into related skills, knowledge, and abilities essential for successful performance in the industry. The model's conent is available in a machine-readable comma-separated value (.csv) file [4]

Natural Language Processing (NLP), a subfield of computing and technology fields concerned with the interactions between computers and human language, was used to perform document analyses and comparisons. We used SpaCy, an open-source NLP code library for Python useful for efficiently analyzing large amounts of text, to tag parts of speech (POS) to prepare the documents for analysis. We then analyzed the text from AM program syllabi and the AM Competency Model using a four-step process, shown in Figure 2, to transform the text into quantifiable frequencies and comparison percentages.

As Figure 2 shows, the four-step process used in this study included: 1) data collection and inventory, 2) extraction of course descriptions and outcomes (i.e., competencies), 3) text pre-processing, and 4) topic (noun) and level (verb) extraction.

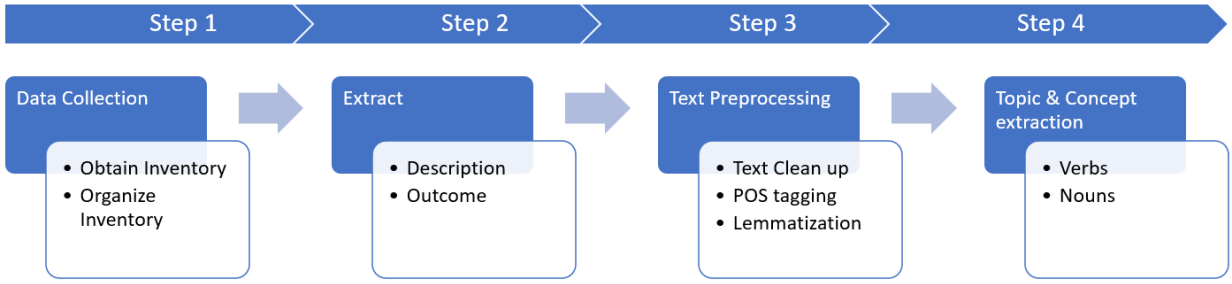

Figure 2. Steps to Processing Syllabi using NLP

3.2. Steps 1 and 2: Data Collection and Text Processing.

In Step 1, we collected and inventoried AM course syllabi and AM Competency Model. We collected 133 of 200 (66.5%) syllabi documents from five Northwest Florida state colleges and separated them into four course categories, based on the AM programs' plans of study: 1) core technical (n=77), 2) core non-technical (n=21), 3) elective technical (n=34), and 4) elective non-technical (n=1). We also used the current AM Competency Model downloaded from the DOL CareerOneStop website [4].

Step 2 involved extraction of competencies within the documents (e.g., from syllabi course descriptions and outcomes and from competencies listed in the model). Cleaning the text (e.g., removing unnecessary punctuation, numbers, and creating uniform acronyms), tagging parts of speech (i.e., POS tagging), and lemmatization (i.e., breaking down words into their root form), are part of the Step 3. Finally, Step 4 involved the extraction of nouns and verbs for the final analysis.

3.3 Data Analysis

Python and NLP libraries were used to create descriptive statistics and graphics that can aid in the categorization of certain parts of speech, and to make document comparisons. Data were analyzed to obtain: 1) verb/noun frequencies, 2) unique noun/verb match percentage, and 3) total noun/verb Document Match Scores.

3.3.1. Noun and Verb Frequencies. Once the list of verbs and nouns were extracted using the four-step process, we used the Natural Language Toolkit (NLTK, another NLP text processing library) to obtain the frequencies and percentages of the nouns and verbs. The verbs and nouns, and their frequencies were then visualized to aid analysis and illustrate.

3.3.2. Verb Categorization. We categorized verbs according to Bloom's *Revised Taxonomy* [6] to discern verb complexity levels (i.e., Bloom's escalating cognitive dimension levels of remember, understand, apply, analyze, evaluate, and create) inherent in documents. Cognition, which refers to the process involved in going from lower order thinking to higher or critical thinking, was used to classify and rank verbs. The six cognitive levels are listed below (from lowest to highest):

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. [8]

The percentage of verbs belonging to each level was calculated as:

$$\frac{\boldsymbol{V_i}}{\sum_{\boldsymbol{i=1}}^{\boldsymbol{6}} \boldsymbol{V_i}} * 100$$

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

To compare the ranges of categorized verbs within the AM program syllabi and the AM Competency Model, we also visualized the data with pie and radar charts.

3.3.3. Unique Match (UM) and Total Document Match (TDM). 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 Match Percentage (MP). For example, TDM versus UM might look like Match Example 1 shows:

Match Example 1
Unique_Nouns: (Knowledge, course, circuit, system)
Total_Nouns: (Knowledge, Knowledge, course, circuit, circuit, 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:

Match Example 2
Document1 Unique Nouns: (Knowledge, circuit, name, system)
Document 2 Unique Nouns: (Knowledge, circuit, 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:

Match Example 3
Document 1 Total Nouns: (Knowledge, knowledge, circuit, circuit, circuit, name, name, system)
Document 2 Total Nouns; (Knowledge, knowledge, circuit, circuit, test, test, drawings)

In Match Example 3, there were four total nouns matching.

To assess the TDM of nouns or verbs between program curricula and employer needs, we uploaded the verb or noun lists of Northwest FL syllabi and AM Competency Model in .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 between AM program syllabi and AM Competency Model is:

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

In which:

$\vec{a}$ - vector representation of noun/verb frequency in Northwest FL Syllabi document.
$\vec{b}$ - vector representation of noun/verb frequency in DOL's AM Competency Model document.
a_i and b_i - components of $\vec{a}$ and $\vec{b}$.
i - represents a row in the corresponding vector or a noun/verb.
n - total rows or total nouns/verbs.

For example, we operationalized this formula within the code as Figure 3 shows. Figure 3 displays the pseudocode (i.e., an informal high-level example of the code) for calculating the DMS of different 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_simiarity
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 3. 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 4.

1. Function: Similar
2. Input: two array of verbs/nouns called actual array and expected array
3. Call in-built function intersection and save result
4. Calculate ratio of (Length or result array/Length of expected array)
5. End
6. Call Function: Similar

Figure 4. Pseudocode for Comparing Parts of Speech between Two Documents Not Considering Word 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 may not be correctly tagged for processing. This is also true for acronyms, which may be represented in many ways and thus incorrectly tagged during processing. Although there are recommendations to improving conceptual analysis, match in this paper is limited to percentage of alignment between nouns and verbs.

4.0. Results

4.1. Topic or Concept Identification and Comparison.

To identify the topics that were covered in syllabi versus those expressed in the Competency Model, we generated basic frequencies. Figure 4 depicts the top 20 nouns found in Northwest Florida AM program syllabi and the AM Competency Model. From this list of frequencies, we were able to determine whether there is congruence between the most mentioned nouns in corresponding documents.

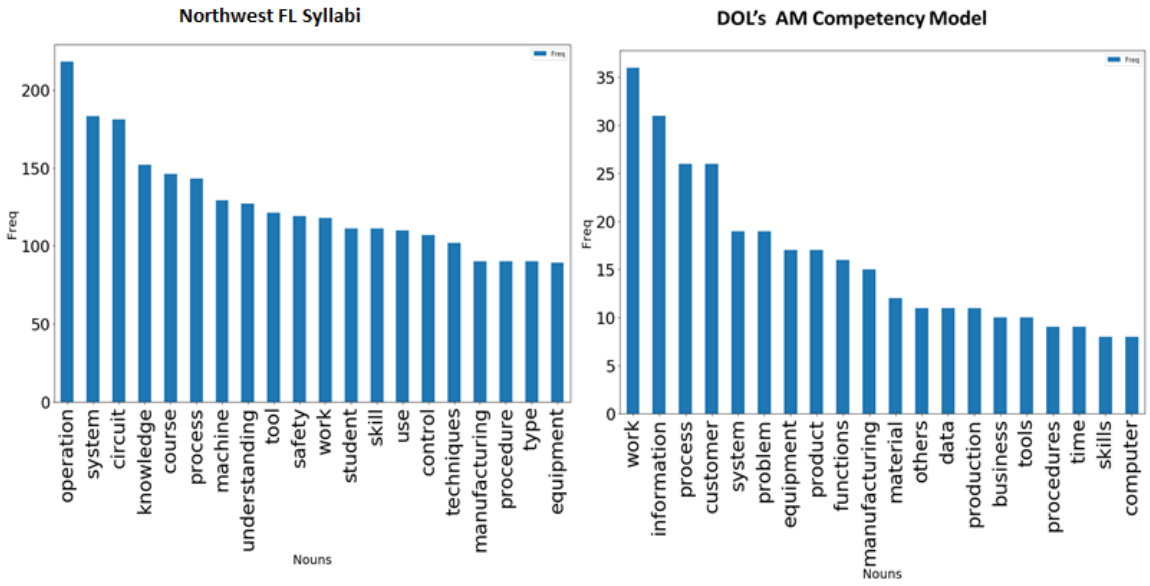

Figure 4. Most Frequent Topics (Nouns)in All Syllabi Compared to AM Competency Model

Figure 4 illustrates the 20 most frequently occurring nouns in both syllabi and the AM Competency Model. Table 1 compares the 20 most frequently occurring nouns in the AM Competency Model and syllabi. The seven underlined nouns (e.g., equipment, manufacturing, procedures, processes, systems, tools and work) are top 20 nouns common to both the AM Competency Model and college syllabi.

Table 1. Top 20 Nouns

Syllabi	Circuit, control, course, equipment, knowledge, machine, manufacturing, operation, procedure, process, safety, skill, student, system, techniques, tool, type, understanding, use, work (20)
AM Competency Model	Business, computer, customer, data, equipment, functions, information, manufacturing, materials, others, problem, procedures, process, product, production, skills, system, time, tools, work (20)

As Table 1 suggests, it was possible to get a sense of nouns that are more prevalent (or occur more frequently) in the AM Competency Model (e.g., business, customer, data, equipment,

functions, information, materials, problems, product, production, tools, and work) than in syllabi (e.g., circuits, control, course, circuits, knowledge, machine, operation, safety, and techniques).

Total and Unique Noun Match. There were 10,784 total nouns in syllabi, compared to 1291 in the AM Competency Model, and of those 14.83% (n=1600) and 44.30% (n=572) were unique nouns, respectively. The percent match of total and unique nouns between the corpus of course syllabi and DOL competencies is 18.5% (Very Low) and the TDM was 0.48 (Low).

4.2. Verb and Level Identification and Comparisons.

We analyzed verb frequency in both the syllabi and the AM Competency Model.

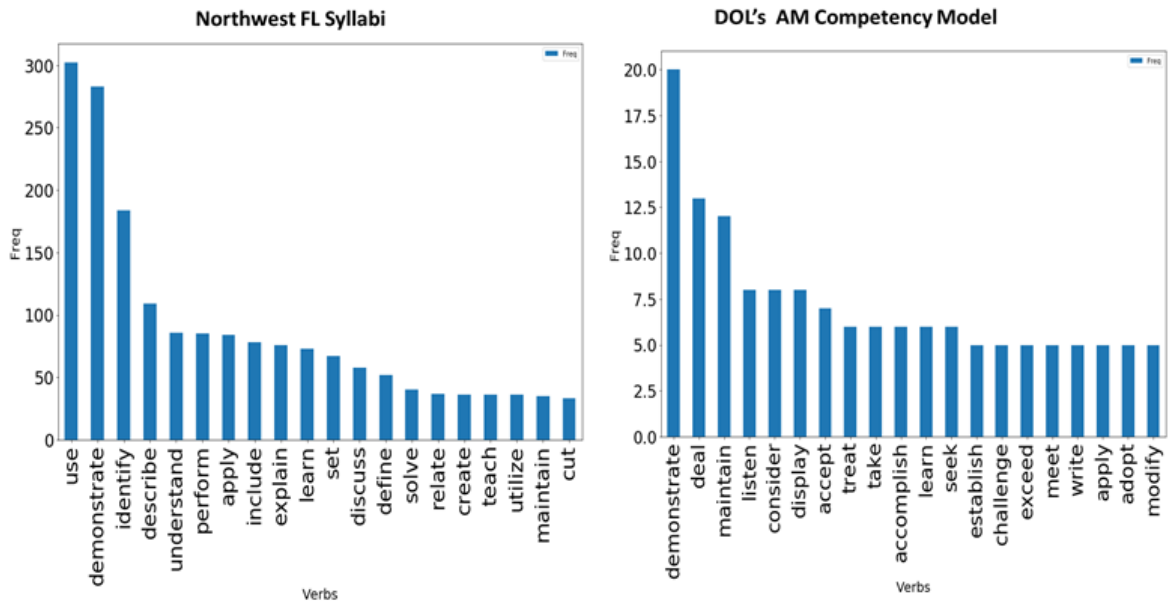

Figure 5. Verbs Frequencies in All Syllabi Compared to AM Competency Model

The top 20 verbs from Figure 5 are shown alphabetized in Table 2; the most similar verbs are underlined.

Table 2. Most Frequently Mentioned Verbs

Top 20 Verbs in Northwest FL syllabi	<u>apply</u>, create, cut, define, <u>demonstrate,</u> describe, discuss, explain, identify, include, <u>learn</u>, <u>maintain</u>, perform, relate, set, solve, teach, understand, utilize, use
Top 20 Verbs in DOL's AM Competency Model	Accept, accomplish, <u>apply</u>, adopt, challenge, consider, deal, <u>demonstrate</u>, display, establish, exceed, <u>learn</u>, listen, meet, <u>maintain</u>, modify, seek, take, treat, write

As Table 2 shows, we determined commonalities between the most frequently mentioned verbs in syllabi and the AM Competency Model. Four verbs (apply, demonstrate, learn, work), reflected a 20% similarity among the top 20 most frequently mentioned verbs

Total and Unique Verb Match. There were 3587 total verbs in syllabi compared to 415 in the AM Competency Model, and of those 11.43% (n=410) and 43.13% (n=179) were unique verbs, respectively. The percentage match of unique verbs between the corpus of course syllabi and DOL competencies is 28.85% (Low), while overall Document Match Score is 0.47 (Low).

Categorized Verbs. To identify similarities and differences between AM Syllabi and the DOL AM Competency Model, we categorized verbs according to Bloom's Revised Taxonomy cognitive dimension [6]. Table 3 indicates verb frequency and percentage, along with differences in percentages between the DOL AM Competency Model verbs and those found in syllabi, by Bloom's level.

Table 3. Verb Category Distribution by Bloom's Cognitive Levels

Bloom's Cognitive Level	Syllabi Verbs (%)	Syllabi Rank	DOL Verbs (%)	DOL Rank	Difference (%)
1. Remembering	530 (17.38)	3	75 (14.31)	3	-3.07
2. Understanding	683 (22.39)	2	100 (19.1)	2	-3.31
3. Applying	1352 (44.33)	1	208 (39.69)	1	-4.64
4. Analyzing	142 (4.65)	5	44 (8.4)	5	3.75
5. Evaluating	113 (3.70)	6	41 (7.82)	6	4.12
6. Creating	230 (7.54)	4	56 (10.69)	4	3.15

Frequency and percentage distributions revealed that "applying" (level 3) verbs were most mentioned, with 1352 (44.33%) of Northwest FL AM program syllabi and 208 (39.69%) the DOL AM Competency Model including verbs in this category. The remaining verb levels in both the AM Competency Model and syllabi were, in descending order, understanding (level 2), remembering (level 1), creating (level 6), analyzing (level 4), and evaluating (level 5). The AM Competency Model, however, gave more emphasis or weight to level 6 (creating), level 4 (analyzing), and level 5 (evaluating) verbs than the same verbs in the syllabi, by a difference of 3.15%, 3.75%, and 4.12%, respectively. Negative percentage differences reflect instances when more verbs of a particular level were found in the syllabi than in the DOL AM Competency Model; positive percentage differences are instances in which the DOL AM Competency Model had more verbs of a particular level than the syllabi.

The pie charts in Figure 6 provides a more visual depiction of the percentage of verbs, categorized by Bloom's *Revised Taxonomy* [6] that are not as apparent in Table 3, between the AM syllabi and AM Competency Model.

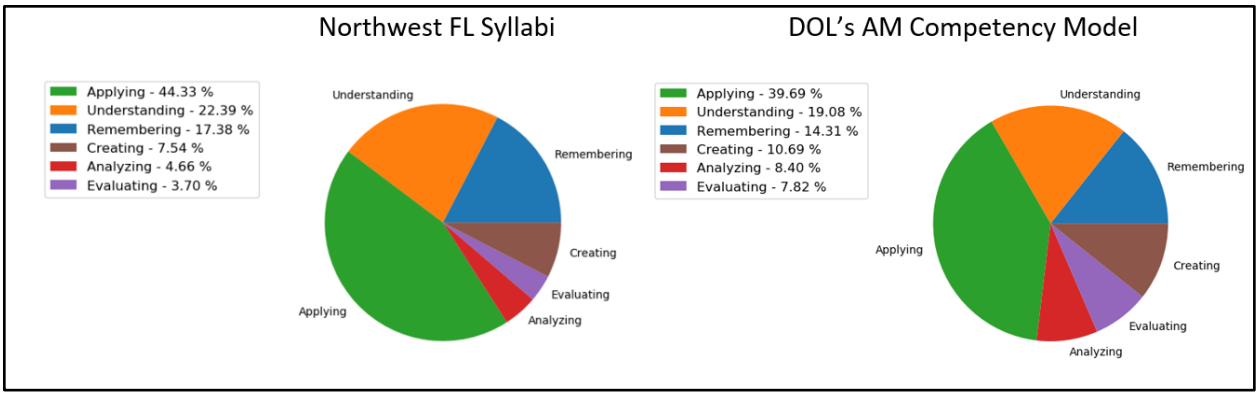

Figure 6. Program Syllabi Compared to Competency Model by Bloom's Classification

Figure 6 draws attention to where the majority of verbs are concentrated in AM program syllabi and the AM competency Model: mid- to low cognitive level verbs (i.e., applying, understanding, and remembering). The higher-level verbs (creating, analyzing, and evaluating), although similarly ranked between documents, are more pronounced in the AM Competency Model, with percentages almost doubled.

The radar chart in Figure 7 depicts Bloom's cognitive levels by overlaying AM program syllabi verbs (blue) and AM Competency Model verbs (orange). This representation highlights the similarity in shape, confirming that the ranking of the levels is similar between the AM syllabi and AM Competency model, with applying-level verbs with the highest percentage. The overlay also shows areas of misalignment, whereas the syllabi (blue) shift more to lower-level verbs (remembering, understanding, and applying) and the AM Competency Model (orange) shifts more towards higher level verbs (analyzing, evaluating, and creating).

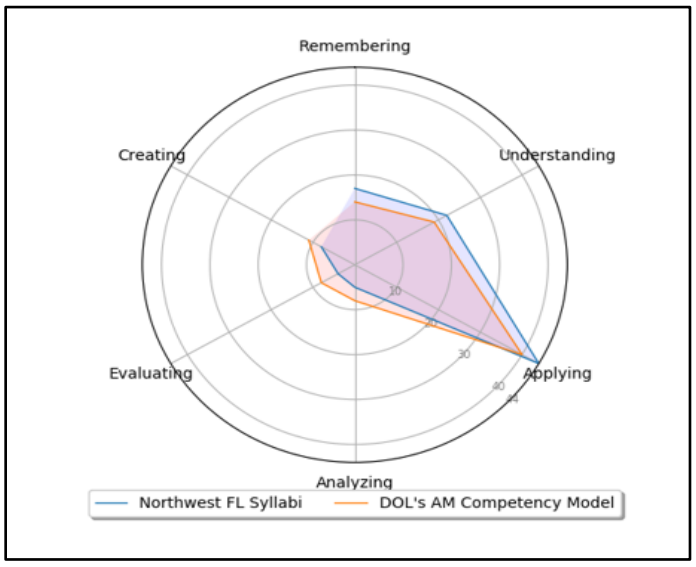

Figure 7. Combined Syllabi and the Competency Model Match by Bloom's Cognitive Level Verb Classification

The analysis revealed that verbs in both syllabi and the DOL model were similarly aligned at the applying level, while syllabi then shifted more toward the lower level verbs (understanding and

remembering) in Northwest Florida AM program syllabi. The verbs in the DOL AM Competency model slightly emphasized higher-level verbs (analyzing, evaluating and creating).

5.0. Discussion

5.1. RQ1: What are frequently addressed topics in AM program syllabi at 5 Northwest Florida Colleges and the DOL's AM Advanced Competency Model?

With Northwest Florida's positive employment and productivity in AM [9], and especially in high-performing sectors (i.e., aerospace product and parts; ship and boat building; sawmills and wood preservation; plywood and veneer products; steel products; and tobacco) [5], the local AM industry must employ skilled graduates that can advance regional and state innovation. In order to do this, it is essential that local state and community colleges that offer AM programs focus on the topics that will help the AM industry and the local, state, and national economy thrive.

Findings from the study reveal commonalities between the most highly mentioned topics in AM syllabi and the AM Competency Model. Both sets of documents highlighted the importance of training students in various equipment, procedures, processes, systems, and tools with the manufacturing industry. Also of interest were frequent topics addressed in syllabi that were not as prevalent in the AM Competency Model and vice-versa. Of those, some were more general topics (e.g., machines, operations, and techniques) in syllabi, whereas the AM Competency Model also included general references to materials, products, and production. Of particular interest were differences in references to specific conceptual concepts. For example, among the most frequent nouns in AM syllabi that were not expressed as often in the AM Competency Model were circuits, controls, and safety; and vice-a-versa the AM Competency Model mentioned specific topics in business, computers, customers, others, data, functions, information, problems, and time more often. The AM Competency Model focused more on customer skills, working with others, and use the use of data, information, and computers to solve problems.

A comparison of most frequent nouns provides a starting point from which to modify or update curricula. In the AM industry, and especially in Northwest Florida where high-performing sectors are thriving, it is important that curricula are saturated with competencies that can improve students' skills with information technologies to improve AM inputs, processes, and outputs, while serving customers.

5.2. RQ2: What types of verbs guide course learning outcomes compared to those desired by employers?

AM employers in rural communities rely on a stable, and ever-growing, competent workforce [9]. The AM Competency Model reflects the knowledge, skills, and abilities (i.e., cognitive dimensions or noun/verb combinations) that translate into appropriate AM professional competencies. Because applying knowledge is essential for workplace performance, comparisons of verbs found in AM program syllabi versus verbs found in the AM Competency Model lend insight into the extent to which AM programs are preparing new AM professionals.

Our findings showed areas of alignment and misalignment between course learning outcomes and those desired by employers. For example, examination of the top 20 verbs found in Northwest FL syllabi and professional documents show that specific verbs (e.g., apply, demonstrate, learn, maintain) occurred often within both sets of documents. These verbs (all at levels 1-3 in Bloom's Knowledge Dimension) are often read by instructors and professionals to understand the level of competency needed in a certain topic area. Misalignment, or differences in the most frequently mentioned verbs, may be perceived if judging only by how often these verbs occur. For example, the verb "write" is one of the most commonly occurring in the AM Competency Model, but not in the top 20 of Northwest FL syllabi. Perception of importance due to frequency of occurrence or mention should be considered, especially if these verbs are not at the core of the competency levels desired.

Percentage distributions also revealed that "applying" verbs are most mentioned in course documents and professional AM documents, with 1352 (44.33%) verbs from Northwest FL syllabi and 208 (39.69%) in the AM Competency Model in this category. Although findings revealed alignment in the ranking of verb levels, the AM Competency Model had a higher percentage of level 4, level 5, and level 6 verbs. Thus, to be more aligned across the level of verbs with the AM competencies in the cognitive dimension, AM program syllabi would need to reduce the concentration of verbs in the applying, understanding, and remembering levels, and place more emphasis in analyzing, evaluating and creating levels (i.e., the higher-level verbs).

5.3. RQ 3: What is the overall match between DOL's AM Competency Model and the corpus of AM program syllabi at 5 Northwest Florida Colleges?

The AM industry has reestablished momentum and Florida is regaining manufacturing jobs once lost [2, 5]. In many rural counties, the AM industry has become critical to local economic success, and, in the case, of Northwest FL has become a national leader in many ways [5]. To continue this momentum, pathway alignment is integral for students to be properly trained for the workforce.

We analyzed 133 out of 200 (66.5%) AM course syllabi in five AM programs in Northwest FL and compared the total and unique match of nouns and verbs between Northwest FL course outcomes and DOL employer-based competencies. The congruence between nouns in the documents showed a match of .48 (Low), with a unique match of 18.5% (Very Low). For verbs, the total match was .47 (Low), with a unique match of 28.85% (Low). Total match considered word frequency, as opposed to unique match, which compared only exact or precise match. The large percentage differences between total and unique match meant that the documents were somewhat similar; specifically, there was a lightly more unique or precise match in verbs than there were in the nouns, although both were very low.

Misalignment between AM courses and employer documents should be further explored to identify possible content additions or verb level adjustments that should be made to increase students' success. Assessments can serve multiple purposes by identifying essential topics and competency levels. For instance, alignment studies can serve in a formative capacity, to improve or strengthen curricula as often as needed.

5.4. Implications.

5.4.1. Implications for Educators. With unique or precise match important achieving competency alignment, considering more employer perspectives in the development of curricula might improve match. This enhancement would be especially achievable if the AM Competency Model became more commonly used to assess competency alignment and treated as the foundation for a comprehensive AM Body of Knowledge to be vetted by experts in education, government, and industry to integrate perspectives. Curriculum planning committees could also benefit from knowing the extent to which there is topical and rigor alignment in order to develop future AM students for entry level or other positions.

5.4.2. Implications for Policymakers. Assumptions should not be made that educational policies reflect the exact specifications of written documents. Syllabi, for example, are often reflective of state frameworks, which may not align with employer needs. Additionally, an assessment component should be included in program reviews every 5 years, or as often as needed, to ensure that program curricula are progressing in breadth and depth, as required by policy.

5.4.3. Implications for Industry. Industry must be very specific about the types of competencies needed to be successful in AM positions. These competencies are often expressed in job descriptions and job advertisements and should express the true qualifications needed for AM positions. A better understanding of how employers assess employee's preparation and fit for positions (e.g., tests, work scenarios, training, observations) is needed.

5.5. Directions for Further Research.

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

5.5.1. Core versus Elective Course Analysis. An analysis of topics (nouns) and levels (verbs) by course type to determine the extent to which there is an appropriate match in core versus elective courses would improve our understanding of where the competencies are most prevalent in curricula. This is important to ensure that core courses are carrying the greatest weight in terms of the competencies that students should master.

5.5.2. Conceptual Analysis. Another extension of this work is to use Graph Theory to identify and then compare the first, second, and third order concepts found between documents (e.g., program curricula, curriculum standards, and other desired policy documents). Using Graph Theory, a comparison of program curricula and the AM Competency Model would be achieved by analyzing the main concepts to determine whether these concepts are equally prioritized. Graph theory allows for connections between elements and concepts to be systematically documented and visualized [10]. Using this approach means that findings would generate the degree to which there is conceptual alignment between syllabi and professional competencies. The joining of parts of speech, such as bi-grams (e.g., verb-noun combinations) could also enhance analysis of sentence structure to include both topical and level analysis simultaneously.

5.5.3. Creation of a Body of Knowledge. The methods described in this study can be used to compare alignment among and between different stakeholders and accrediting bodies [11]; however a unifying document which incorporates the views of all stakeholders (i.e., academic, professional, government, industry) is preferred to aligning multiple documents. Similar to the field of Information Technology, it is advisable that AM develop a Body of Knowledge (BOK)

that unites all competencies among the major players in the field. A central document, such as a BOK, would aid in school-to-career pathway alignment studies.

5.5.4. Improve Pathway Alignment Assessment. AM needs a model to assess pathway alignment, especially from college-to-career, and likely extending back to secondary school. We propose that the AM industry would benefit from a comprehensive model to assess pathway alignment in program curricula, employer needs, professional organizations, and students' perceptions of the competencies needed for entry into AM professions. The study findings also underscore the need for an entry-level AM competency assessment. Although the DOL Competency model was used to understand employer competency needs for entry-level positions, there is little knowledge about how employers assess or determine whether perspective employees or recent graduates possess these desired competencies. How are employers measuring the extent to which prospective employees are prepared for entry positions (i.e., are they looking at syllabi or course outcomes, employment interviews, or pre-employment tests)? A future study to identify preparation of entry-level AM employees would be useful to both postsecondary AM instructors and employers.

6.0 Conclusion

In this study, we explored the alignment between course outcomes found in five Northwest Florida AM programs' syllabi and employer needs based on the AM Competency Model. We use syllabi to represent curriculum content and the AM Competency Model to reflect employers' views of valuable competencies. Although program syllabi reflected high-level learning objectives, they varied in the extent to which the topic-enactment (i.e., noun-verb or verb-noun) pairs matched the DOL competency model. There was evidence of both alignment and misalignment in topics, competency levels, and the types of verbs used in curricula. Overall, there were higher levels of the Bloom's *Revised Taxonomy of Educational Objectives* in the AM Competency Model, reflecting industry values for analysis, evaluation, and creation.

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