It Depends on Your Perspective: Comparing Advanced Manufacturing Employers Expectations to Advanced Manufacturing Curriculum Frameworks

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***Abstract*—To meet the rising skill demands of the dynamic advanced manufacturing (AM) industry, two-year AM programs must produce well trained graduates. This need is especially marked in Florida because the state is an AM leader, producing intermediate and finished products ranging from plastics to tortillas to motor vehicles. In total, Florida is home to over 20,000 AM companies employing over 320,000 workers. Florida is also geographically diverse, being simultaneously one of the most urban and one of the most rural highly populous states in the country. To characterize Florida's AM employment needs, we sought to determine how AM jobs were distributed across the state. We analyzed 108 job postings from Florida employers who were seeking manufacturing and engineering technicians through publicly available job postings. We used text mining to extract the knowledge areas and verbs in the documents that AM employers identified in job postings and desired from their entry-level employees. We compared those topics and verbs to the ones found in the Florida Department of Education's (FLDoE) AM curriculum framework for two-year programs. We found varying levels of alignment, and, in some instances, misalignment, between employers' desired topics and competency levels and those found in FLDoE Frameworks. Our findings not only highlight the importance of industry-education partnerships to tailor preparation to employer needs, but also suggest that a deeper exploration and analysis of AM jobs is needed to further determine alignment to FLDoE frameworks. We conclude that the FLDoE framework may be used as a foundation, but not the sole source, for important AM knowledge areas.**

Keywords—employability, curriculum, advanced manufacturing

I. Introduction

Florida is ranked top 10 among the nation for manufacturing and home to 20,500 manufacturers as of the second quarter of 2018 [3]. Florida produces a wide variety of goods including food and beverage, communications equipment, aerospace products, pharmaceuticals, semiconductors, and more. The state's transportation infrastructure includes over 20 airports, 15 deep water seaports, 3,000 miles of freight rail tracks, and 2 spaceports giving the industry many options for moving and exporting products [4]. Florida ranks 45th among the 50 states in terms of the industry's contribution towards its own GDP. However, Florida's low ranking in contrast to other states' manufacturing output can be misleading, as Florida is also a top world travel destination and engages heavily in international trade. Florida is 27th among the 50 states for its manufacturing "value added" [5], but also first for business creation, 10th for venture capital, and 12th for fastest growing firms; while manufacturing may not be Florida's leading industry, the state is fertile ground for entrepreneurial opportunities [6]. Manufacturing employment in Florida is concentrated in the urban southeast, central, and northeast regions of the state. Seven metropolitan counties attributed for 56% of Florida manufacturing jobs. While the more populated urban areas make the largest contribution to employment to Florida's economy, manufacturing plays a more significant role in the local economies of rural areas [7].

In this study, we explored the alignment between what AM employers seek and what students should learn in AM programs. We focused on the growing AM industry in Florida, where urban areas maintain the highest concentration of manufacturing activities, and also in rural areas where manufacturing represents a more significant portion of the local economy. In this study, we aimed to answer the following research question: To what extent are the knowledge items and competency levels that

Florida AM employers seek aligned with those mandated by the state AM curriculum frameworks?

II. Literature Review

A. Manufacturing Challenges

A top industry challenges is recruiting students into what they perceive as an unattractive field. In a recent interview, one AM program instructor said that "We 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 slots they give us [8]." Similarly, the Manufacturing Leadership Council [9] announced that Americans still believed that manufacturing was vital to the country's economy, but that the vast majority "still 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 (p. 1)." The limited entry of students into the pipeline leads not only to an unmet need for technicians in the AM industry, but also creates a shortage of experienced instructors who have obtained the experience and credentials.

Powers [10] stated that "one of our most significant challenges facing virtually every manufacturer is 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 (p. 24)." CareerSource Florida [11] reported that construction and manufacturing had the highest ratio per vacancy, when comparing technician skills gaps to vacancies. The Florida Chamber Foundation [12] reported that the greatest projected long-term skills gaps in manufacturing were in sales representatives and maintenance and repair workers. Employability skills such as communication, critical thinking, and problem solving were underscored as important, in addition to productivity skills, occupation-specific skills, and advanced digital skills. These skills were specifically mentioned for the manufacturing industry because these skills are a "differentiating factor between entry-level and middle-skill jobs [11, p. 10]."

B. Florida's Advanced Manufacturing Competency Efforts

The Florida Department of Education (FLDoE) offers several secondary and postsecondary courses, certifications, and degrees in manufacturing as a part of the Career and Technical Education (CTE) program [13]. The FLDoE reviews and creates curriculum frameworks to guide classroom instruction. As a CTE-designated program, these frameworks are used in secondary and postsecondary institutions to help meet Florida's economic and workforce needs. The standards are revised every 3-5 years on a rotational basis by a diverse group of experts from education, industry, and government. The FLDoE AM Curriculum Frameworks [14] contain seven core topics: pneumatic, hydraulic, and electromechanical components and/or systems; lean and six sigma concepts in manufacturing environments; industrial automation systems; industrial automation systems; principles of robotics and automated systems; human machine interfaces and automated systems; and supply chain and operation management concepts and techniques. These topics reflect the foundational concepts for measuring instructional success in Florida's AM educational programs and for building competency.

C. Assessing Competencies in Two Dimensions: Knowledge and Cognitive Processes

The *Taxonomy of Education Objectives*, developed by Bloom, Engelhart, Furst and Krathwohl (1956), is a scheme for classifyingng educational standards, goals, and objectives. The taxonomy was later revised [15] to a two-dimensional framework of knowledge and cognitive processes. In the first dimension, four types of knowledge are depicted to illustrate how learning objectives (verbs) in combination with disciplinary topics can be structured for competency: Factual, the basic elements a student must know to be acquainted with a discipline or solve problems in it; Conceptual, the interrelationships among the basic elements within a larger structure that enable them to function together; Procedural – How to do something, methods of inquiry, and criteria for using skills, algorithms, techniques, and methods; and Metacognitive – Higher-order thinking that enables understanding, analysis, and control of one's cognitive processes, usually by thinking about one's own thinking.

The second dimension, cognition, refers to the process involved in going from lower order thinking to higher order thinking: Remember, to retrieve relevant knowledge from long-term memory; Understand, to construct meaning from instructional messages, including oral, written and graphic communication; Apply, to carry out or use a procedure through executing or implementing; Analyze, to break material or concepts into parts, determining how the parts relate or interrelate to one another or to an overall structure; Evaluate, to make judgements based on criteria and standards through checking or critiquing; and Create, to put elements together to form a coherent whole or reorganize into a new pattern or structure. [16] Both dimensions used together provide a classification scheme for joining verbs to nouns to describe a process by which thinkers encounter and work with knowledge to become competent in a discipline or acquire a construct [17]. Anderson and Krathwohl [18] also included and a list of action verbs in their revised classification to demonstrate hierarchy.

III. Methods

We gathered job postings on Employ Florida with the criteria: 1) Area – Florida, 2) Job Source – education institution, recruiter, state job board, corporate, government, and private job board, 3) Keyword – manufacturing, 4) Job Occupation Group – architecture and engineering, and 5) Job Education Level – No minimum requirement. The system returned 479 postings from the period of 10/10/17 to 12/28/2018. We reviewed each of the documents for: 1) highest required degree was an Associate's; or 2) that employers who desired an applicant with a Bachelor's degree would also consider a person with a two-year degree with the appropriate experience. This filtering process generated a total number of 108 job postings. We then downloaded RTF files of the 2018–2019 FLDoE Curriculum Frameworks for the Advanced Manufacturing Specialization of Engineering Technology, featured in Appendix A (http://bit.ly/2X8Titv).

We also reviewed text files to remove section markers, correct typos or spelling mistakes, and replace these acronyms with their long form. We also scripted the program to read

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compounded word as one unit, and not two individual words. We then performed text processing which involves several steps using Python language to return the set of nouns from the text and also the number of times that noun was found in the document. A similar, but independent script, was used to extract the verbs. The steps involved in processing the text are: 1) Load data: Load the data into the Python console; 2) Tokenize: Split the strings into tokens (or words) based on white space and punctuation; 3) Filter out punctuation: Review all tokens and keep only those that are all alphabetic; 4) Filter out stop words: Remove words such as "the, "a", and "is" 5) Stemming: Stemming refers to reducing each word to its root or base; 6) Parts of speech tagging: Classify the words into their parts of speech; 7) Restricting: Restrict the output to only words with specific tags (e.g., nouns or verbs); 8) Frequency: To find the occurrence of all the topics in the document, create another type of object to store the frequency of the words, and then coded a function to convert the list of words into a dictionary of word-frequency pairs; 9) Visualization: Create bar charts using the matplotlib function using Python code.

We used the text mining process to extract words from both the FLDoE frameworks and job postings to make comparisons between the topics (i.e., nouns) and competency levels (or verbs) as written in each of the compiled documents. Note that the data presented in this study are limited and reflect only employers who use Employ Florida and who posted their advertisements during the timeframe in which the data was extracted from the website. Additionally, to comply with the page and space limitations, only the most frequently mentioned topics were shared, whereas action verbs were able to be shared in totality.

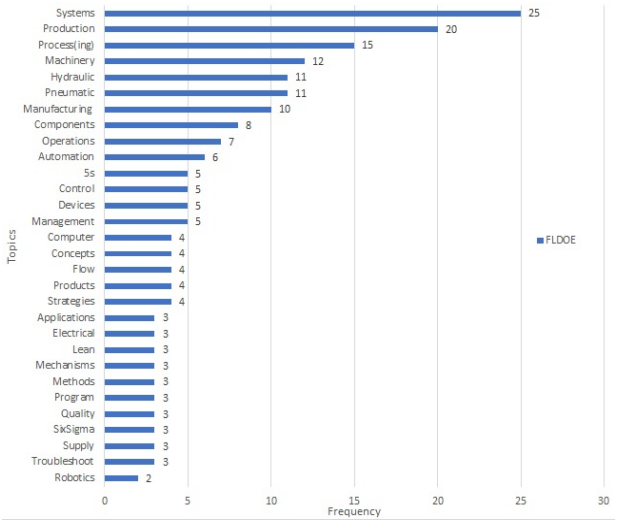

Fig.1. FLDoE Framework Topic Frequencies

IV. Results

A. FLDoE Frameworks

In a review of over 228 nouns, nouns listed more than twice were identified, resulting in the top 30 nouns shown in Figure 1. The top three topics that occurred the most in the FLDoE frameworks were systems (n=25), production (n=20), and process and processing (n=15).

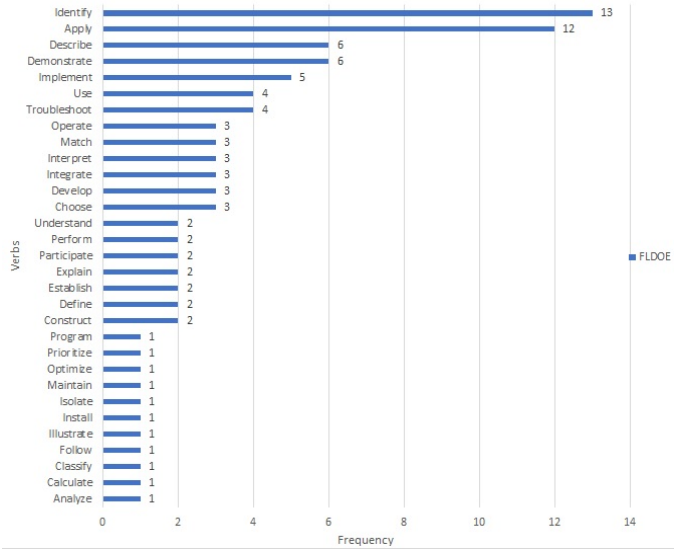

Fig. 2. FLDoE Verb Frequencies

We also identified the verbs with the highest frequencies in the AM curriculum frameworks. The verbs in Figure 2 depict the verbs that are associated the FLDoE AM curriculum frameworks, or those that are used to develop two-year degree-seeking students in AM. Thirty one verbs were found in the FLDoE AM Curriculum Frameworks' objectives for AM technicians.

The top five verbs from the frameworks were identify, apply, describe, demonstrate, and implement. The FLDoE frameworks' most frequent verbs in the "apply" and "analyze" categories of the cognitive dimension, with 11 (35.5%) and 8 (25.8%) verbs in those categories, respectively. Procedural verbs were most used in the knowledge dimension with nearly half (n=15, 48.3%) of the action words belonging to this category. Metacognitive verbs were the next highest mentioned category in the knowledge dimension, with 7 (22.6%) verbs belonging to this category. The least mentioned cognitive dimensions were in the categories of remembering (n=1, 3.2%), evaluating (n=3, 9.6%), and creating (n=3, 9.6%). Factual (n=5, 16%) and conceptual (n=4, 12.9%) verbs were the least mentioned in the knowledge dimension.

B. Advanced Manufacturing Job Postings

Our 108 job postings represented 71 employers, mainly from urban areas (n=100, 92.6%), with a few rural employers (n=5, 4.6%); the remaining postings lacked job location details (n=3, 2.8%). Per Appendix B (http://bit.ly/2X8Titv), many job postings lacked details such as salary and hourly rate information. Postings were for full-time positions with benefits (n=65, 60.2%), followed by part-time positions (n=14, 13%), full-time positions without benefits (n=5, 4.6%), and the remaining postings (n=24, 22.2%) had full- or part-time details. We identified 341 nouns used in the job postings and narrowed

that list to topics with more than 90 mentions to identify the 25 of the highest demand knowledge areas in Figure 3.

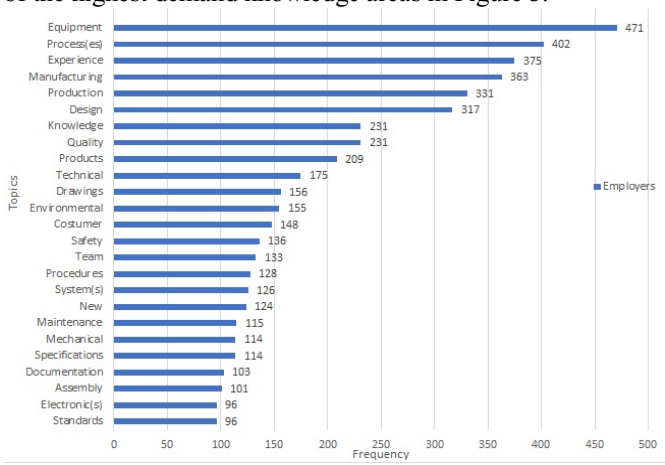

Fig. 3. Job Posting Topic Frequencies

Of the 25 nouns, 22 were topical and 3 were non-topical; nouns such as "experience," and "knowledge," were generated in the text mining output. Without modifiers, words such as "experience" and "knowledge" were considered meaningless in the context of this study, and were considered out of the scope. Employers mentioned 683 verbs in the 108 job postings analyzed. Of these, we extracted 28 verbs, as shown in Figure 4 that were mentioned more than 10 times.

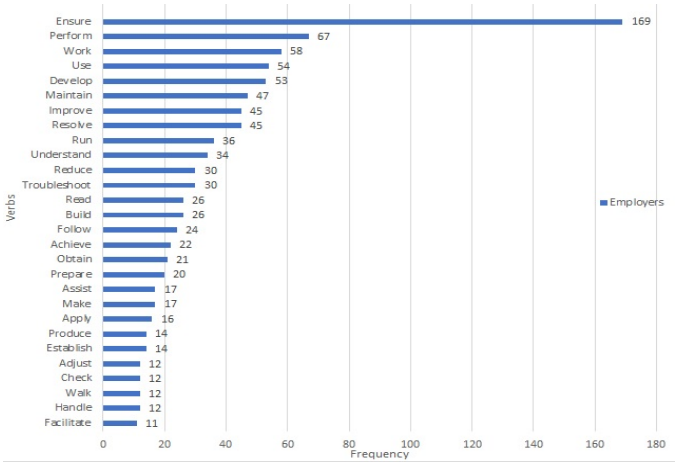

Fig. 4. Job Posting Verb Frequencies

As Figure 4 shows, the top five mentioned verbs were ensure, perform, work, use, and develop. Of the 28 verbs, we only classified 26, as two of them were related to physical requirements (e.g., walk), while others referred to abilities, such as ability to "work with" other people or "work during" certain hours or on specific shifts. The verbs found in the job postings were highest in the "apply" (n=8) and "create" (n=6) categories of the cognitive dimension, and in the procedural (n=17) and "metacognitive" (n=5) knowledge dimensions.

C. *Comparing the FLDoE and Employer Topics and Competencies*

To explore the extent to which FLDoE frameworks matched the competencies that employers expressed as desirable in job postings, we extracted 25 most frequently mentioned topics by employers and then extracted the number of times that each of those nouns were mentioned in the FLDoE Frameworks. We then converted frequencies to percentages for each of the groups to make comparisons shown in Figure 5.

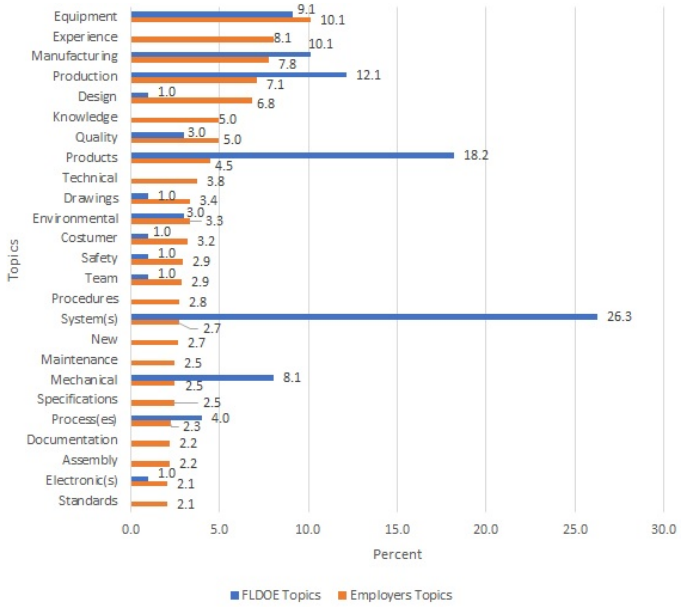

Fig. 5. Comparison of Employer and FLDoE Framework Topics

In Figure 5, FLDoE frameworks met or surpassed the desires of employers when the blue bars (FLDoE) where equal to or surpassed the orange (employer) bars in areas such as production, products, systems, mechanical operations, and processes. There were also topics with adequate coverage, defined when the bars were within one percentage points from one another, such as equipment, environmental and electronics-related topics. Finally, gaps in coverage between employer job postings and FLDoE frameworks were identified by areas in which there was more than one percentage point of separation between mentions. These gaps were seen in topics such as design, quality, technical topics, drawings, costumer services, safety, team concepts, procedures, concepts related to maintenance, specifications, documentation, assembly, and standards.

To discern differences between desired competency levels in FLDoE frameworks and job postings, we compared verbs using Bloom's Two-Dimensional Taxonomy. Table 1 illustrates the results.

TABLE I. COMPARISON OF MOST FREQUENT VERBS

Knowledge Classification	Knowledge Dimension	
	Mention by Employer (%)	*Mention by FLDoE (%)*
Factual	7.7	16.1
Conceptual	7.7	13.0
Procedural	65.4	48.4
Meta-Cognitive	19.2	22.5
Total	100	100
Cognitive Classification	**Cognitive Dimension**	
	Mention by Employer (%)	*Mention by FLDoE (%)*
Remember	3.8	3.2
Understand	15.4	16.1
Apply	30.8	35.5
Analyze	11.5	25.8
Evaluate	15.4	9.7
Create	23.1	9.7
Total	100	100

As Table 1 shows, in the knowledge dimension, the largest differences between FLDoE Frameworks and job postings were found in the area of procedural knowledge, whereas employers mentioned procedural verbs (65.4%) more than FLDoE frameworks covered them (48.4%), although FLDoE Frameworks (22.5%) covered slightly more meta-cognitive verbs than employers required (19.2%) for entry level positions. Additionally, FLDoE covered factual (16.1%) and conceptual knowledge (13%) dimensions more than desired by employers, with employers mentioning factual and conceptual knowledge dimensions in job postings 7.7% of the time. The cognitive dimensions of both sets of documents aligned in remembering, understanding, and applying. Differences were in the cognitive classification of analyzing, evaluating, and creating. Specifically, the AM frameworks mentioned verbs associated with analyzing (25.8%) more than double than employer job postings (11.5%) indicated that they desired them. Employers were more likely to desire employees with cognitive abilities in evaluating (15.4%) and creating (23.1%), compared to the AM Frameworks (each 9.7%).

V. DISCUSSION

In this study, we used text mining of topics (i.e., nouns) and verbs to compare competencies as expressed by educators and employers to answer the question: To what extent are the knowledge items and competency levels that Florida AM employers seek aligned with those mandated by the state AM curriculum frameworks? A comparison of employer job postings and FLDoE frameworks indicated that there are areas of alignment and misalignment in both the knowledge areas and levels of competency attainment. Our findings also included topics that FLDoE frameworks did not emphasize to that employers expressed in job postings:

- Design and drawings: Strong mechanical design ability in new hires, and their ability to design for excellence, which included both design for manufacturing and assembly.
- Quality: Quality and accuracy in building customer products as essential. The importance of quality was evident with high impact to management, assurance, controls, products, and standards.
- Technical. Ability to provide technical support to streamline manufacturing processes and minimize product build-time was conveyed as valuable to employers.
- Customer. Employers described the importance of appropriating the time delivery of products to meet customer demands, including the ability to service and test customer returns and production systems.
- Safety. Employees should be knowledgeable about safety components in industrial and manufacturing environments and specifically have knowledge of component safety products and the relevant machine safety standards.
- Team. Employers expressed that team collaboration is essential, and that employees must be able to function effectively in a team environment. Employees that can both work in teams and direct teams are highly valued.
- Maintenance. Employees should have knowledge of preventative, corrective, and predictive maintenance, as well as be able to maintain and troubleshoot equipment (e.g., such as printed circuit boards, assembly machines, equipment, and tooling).
- Procedures. Employers desire employees with policy and procedures experience in development, production, and testing.
- Specifications. Employees should be able to read and follow established procedures and guidelines to manufacture the organization's products according to production specifications.
- Standards. Employees should be able to ensure quality work that meets or exceeds workmanship standards and improves efficiency.
- Documentation. Entry-level employees should know the documentation related to manufacturing activities, such as standard work instructions.
- Assembly. Employees should be able to conduct and support critical assembly tasks to ensure activities meet required specifications.

Employers have stated desires that employees possess competencies at different levels, consistent with Bloom's taxonomy [15], [16]. An analysis and comparison of verbs retrieved from FLDoE frameworks and employer job postings showed gaps in both knowledge and cognitive dimensions. In the knowledge dimension, the greatest gap between employer (65.4%) and FLDoE framework (48.4%), mentions were in the classification of procedural knowledge (a difference of 17%). Procedural knowledge involves the use of verbs that measure how something is done, methods of inquiry, criteria for using skills, algorithms, techniques, and methods. It should also be noted that the word "procedures" was among the most frequently mentioned knowledge areas by employers, in which a gap was also found between employers and the AM frameworks, which serves as a confirmation for this finding. As a result, the inclusion of procedural verbs that span across the

cognitive dimensions (e.g., tabulate, predict, calculate, differentiate, conclude, compose) are recommended for inclusion in the AM frameworks.

Both knowledge and cognitive dimensions are hierarchical for each competency being learned and are considered as levels in competency development, meaning that attaining procedural knowledge of a specific competency means that student also understands the associated conceptual and factual categories, one and two levels of the procedural category. As a result, the FLDoE frameworks (22.5%) covered more meta-cognitive verbs than employers required (19.2%); however, FLDoE covered factual (16.1%) and conceptual knowledge (13%) dimensions more than desired by employers, which suggests that choosing more procedural verbs when developing competencies would better meet employer needs. In the cognitive dimension, there was evidence that employers sought employees with cognitive abilities in "evaluating" (15.4%) and "creating" (23.1%), compared to 9.7% mention of verbs related to these categories in the AM frameworks. This suggests that incorporating verbs that focus on the higher cognitive processes (i.e., create and evaluate) in order to meet job posting requirements is advisable. Additionally, FLDoE frameworks mentioned "analyzing" (25.8%) slightly more than double the percentage points than job postings (11.5%) revealed that employers they desired them. This suggests that focusing on higher cognitive processes are both achievable and warranted. Specifically, to increase competency levels at the cognitive levels recommended, the AM frameworks would need to include measurable competencies that use verbs like evaluate and to create.

VI. Conclusion

In this study we explored whether educators are teaching what employers desire. We found that there are areas of both alignment and incongruity in both knowledge areas and competency levels. Areas that can be addressed immediately as a result of this study include the review of the frameworks to incorporate the appropriate knowledge and cognitive levels for instruction and the workforce. Furthermore, the development of a Body of Knowledge that integrates knowledge areas and competency levels is recommended, in order to align the needs of AM stakeholders and facilitate the evaluation of AM programs, curricula, syllabi, and pathways to employment.

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