Assessing Educational Pathways for Manufacturing in Rural Communities: Research Findings and Implications from an Investigation of New and Existing Programs in Northwest Florida

Abstract

In northwest Florida, advanced manufacturing (AM) jobs far outpace the middle-skilled technician workforce, though AM constitutes almost a quarter of the region's total employment. From 2018-2028, of the available 4.6 million manufacturing jobs, less than half are likely to be filled due to talent shortages. This widening "skills gap" is attributed to many factors that range from new technologies in the AM industry (e.g., artificial intelligence, robotics), a need for newer recruiting methods, branding, and incentives in AM educational programs. Some professionals have even indicated that manufacturing industries and AM educational programs should be aligned more to reflect the needs of the industry. Even in the wake of Covid-19, when there have been over 658,000 manufacturing jobs lost due to market conditions, many states still have jobs that go unfilled further suggesting that there are challenges in filling AM technician positions. In a time when technicians in AM are in high demand and the number of graduates are in low supply, it is critical to identify whether AM education is meeting the needs of new professionals in the workforce and what they believe can be improved in these programs. This is especially true in rural locales, where economies with manufacturing industries are much more reliant on them. In the context of a NSF Advanced Technological Education (ATE), through a multi-method approach, we sought to understand: 1) Which AM competencies skills did participants report as benefiting them in gaining employment? 2) Which competencies are needed on the job to be a successful AM technician? 3) What are the ways in which AM preparation can be improved to enhance employment outcomes? This study's results will expand the research base and curriculum content recommendations for regional AM education, as well as build regional capacity for AM program assessment and improvement by replicating, refining, and disseminating study approaches through further research, annual AM employer and educator meetings, and annual research skill-building academies in which stakeholders transfer research findings to practices and policies that empower rural NW Florida colleges. To date, research efforts have demonstrated that competency perceptions of faculty, employers, and new professionals have notable misalignments that have opportunities for AM program curriculum revision and enhancement. This paper summarizes five years of research output, emphasizing the impactful findings and dissemination products for ASEE community members, as well as opportunities for further research.

Motivating Rationale

Manufacturing is often perceived as an unappealing profession; however, it is diverse in people, technology, and experiences. Many critiques are based on outdated stereotypes: a 2016 survey revealed that 40% of parents did not see manufacturing as a good-paying employment choice for their children; 50% did not see manufacturing as an exciting, challenging, or engaging career [1]. Even more troubling is the underrepresentation of women and minorities in manufacturing. This underrepresentation is even more dramatic in rural communities where demographics do not reflect the workforce disparity [2, 3]. If parents' and counselors' perceptions are flawed about the opportunities in US manufacturing, then students will not be encouraged to take the classes or

the training to begin manufacturing work when they graduate. Industry leaders, faculty, and administrators need to offer the message often that there are careers opportunities, financial reward, satisfaction, and fulfillment found in manufacturing careers.

Manufacturing has evolved to predominantly be advanced manufacturing, or the use of innovative technologies to create existing products and the creation of new products through a blend of information, automation, computation, software, sensing, and networking [4].
The U.S. does not have enough advanced manufacturing workers. While the number of jobs is important, employment figures miss a significant reason why advanced manufacturing why is imperative. U.S. quality of life, the ultimate benchmark of the direction of the economy, is contingent upon the competitiveness of the private sector and the speed at which innovative products and processes reach the market. Targeted student recruitment and academic program refinement will ensure that advanced manufacturing remains a linchpin to healthy rural economies, innovation, and entrepreneurship.

Florida manufacturers account for 5.32% of the state's product, employing 4.46% of the workforce. In 2020, there were an average of 384,000 manufacturing employees in Florida, with an average 2019 annual compensation of $73,811.28 [5]. An analysis of rural and rural-adjacent areas within Florida revealed that, while these regions are less densely populated with manufacturers, manufacturing represents a significant portion of local economies and offers higher-than-state-average wages within the industries represented. In rural Northwest Florida (this project's setting), 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 [6]. The vast majority (92%) of the region's manufacturers employ fewer than 50 workers and almost three-quarters are "very small" employers, with fewer than ten employees each. Manufacturing subsectors with large numbers of very small employers include fabricated metal product, petroleum, coal, nonmetallic minerals, furniture, and related products [7].

This proportional centrality of rural manufacturing indicates that while these communities present ample opportunities for employers to be *entrepreneurial*, just as important is building capacity among local community members to be *intrapreneurial*. Intrapreneurship is a means to identify and leverage the internal resources of an established business or community [8, 9]. The limited research on intrapreneurship reflected that intrapreneurial manufacturing industry firms outperformed firms with lower internal involvement [10, 11]. and that the level of intrapreneurship is observable and measurable [12]. However, the extent to which advanced manufacturing curricula impart competencies that prepare new graduates to not only perform workplace skills but also innovate and create opportunities is undocumented.

Implications for Work

Scant empirical research on students' career pathways informs the dialogue between community college leaders and employers [13]. Employers and educators can work together to define and prepare students for career pathways to economically viable jobs. In addition, employers can advise faculty and program administrators on issues of curriculum and provide students with work-based learning and job-shadowing experiences to enhance their classroom learning [14]. The research presented in this paper is an important complement to investigations that explore

community college students' perceptions of costs and benefits of degree attainment with various broader measures of engagement and success as few.

To ensure that the ET/AM programs, curriculum, training, and potential economic development outcomes can be met, regional stakeholders need to ensure that technician education programs stay in line with industry needs by gathering data and refining the school-to-work pathway. These data also will assist with interpreting the need for additional advanced manufacturing training programs or identifying existing training available at partner college locations.

Research Questions and Design

The overarching goal of this project has been to improve rural manufacturing capacity by better understanding the relationship between NW Florida employers, employees, and curriculum via the following research questions:

RQ1. How do the AM competencies graduates gain through Associate's level AM programs compare to the needs of employers?
RQ2. How do the AM competencies graduates gain through Associate's level AM programs compare to the skill sets new professionals need?
RQ3. What are the differences between the skill sets employers need and the skill sets new professionals report they need?
RQ4. How can AM curricula be modified to best meet the specific needs of AM employers and AM employees?
RQ5. To what extent are AM graduates prepared to engage in entrepreneurial and intrapreneurial activities?

The research team pursued these questions through a multi-method approach, including qualitative and quantitative methods, informed by the lessons learned from the previous *Assessing IT Pathways* project (NSF 1304382). The work met the requirements of Design and Development Research, as specified by the *Common Guidelines for Educational Research* [15]. The study's goal is to identify and scale evidence to inform sound educational practice.

Description of Study Site and Participants

The data presented in this paper were collected from five regional community college partners whose primary emphasis is on two-year degrees and workforce certificates, in addition to limited Bachelor's degrees in nursing, secondary education, and business. The missions of these state colleges are to support the needs of the local community and prepare students for workplace success.

Pre-Research Activities

The research team conducted a comprehensive literature review in the areas of advanced manufacturing education, employment, entrepreneurship, and intrapreneurship. This literature review will be used to refine the research questions and ground the study findings. The research

team has also compiled relevant national, state, and professional AM competency standards as well as prevailing industry certifications.

Data Collection and Analysis Methods

To answer the RQs, the research team completed several data collection and analysis activities including:

1. We used content analysis of AM course syllabi to develop lists of skills gained by students who successfully completed AM coursework. The unit of analysis was a syllabus from an individual course. All occupational completion points, student performance outcomes, or standards and/or certifications covered in the material were be analyzed through an iterative process using a codebook derived from the Department of Labor Advanced Manufacturing Competency Models [16, 17]. Researchers also used established instruments to measure the extent to which the new professionals report entrepreneurial and intrapreneurial intentions [18, 19, 20]. In addition to deriving areas of strong and weak alignment, the researchers calculated the extent of match between the syllabi and the standards. The team employed our tested Python script for text preprocessing and keyword extraction approaches that extract learning outcomes specified in syllabus sections, including course description, course objectives, and course contents. Python is a programming language used in many parts of analysis for automating tedious tasks such as extracting relevant sections from syllabus, tokenizing the text, extracting keywords and identifying these keywords and pattern matches between the standards and certifications in the codebook and syllabi content.

2. Interviews with AM educators were conducted at annual meetings with the regional partner colleges (approximately 16 educators from four institutions). The interviews were used to explore factors in curriculum development and delivery and to understand the relationship between faculty and industry stakeholders. Interview questions were derived from our validated interview instruments augmented by project personnel and findings from the literature review. The questions explored issues of AM education broadly as well as of issues pertaining to female and minority student recruitment and retention. The unit of analysis was the transcript of an interview with an individual educator. Transcripts were analyzed for themes relating to match with the AM competency codebook. Researchers will also calculate the extent of match between AM educators' perceptions and AM standards and certifications using a Python process like the ones used in preceding analyses.

3. Interviews and focus groups measured employer needs and were compared to the literature review, senior personnel input, and project objectives. The questions explored issues of AM job candidates and employees broadly as well as of issues pertaining to female and minority hiring and participation.

4. Interviews with NW Florida new professionals (working 3 years or less) were conducted. With the help of lead state college administrators and faculty, 12 recent AM graduates were be recruited to participate. An interview guide was developed from the employer interviews. The questions explored issues of AM job candidates and employees broadly as well as of issues pertaining to female and minority hiring and participation. The unit of analysis was the

transcript of each interview or focus group and the researchers calculated the extent of match between AM educators' perceptions and AM competencies the extent to which the new professionals reported entrepreneurial and intrapreneurial intentions [18, 19, 20].

In the interests of space, we will selectively report these research activities' results, centering on the alignment between curriculum and new professionals' perspectives. This extensive study also includes additional considerations:

Replicability and Generalizability

This project is designed for replication and, in fact, is a replication of a similar project that focused on IT professionals (NSF 1304382). Replication and refinement of study approaches, as well as the creation of freely available modules and a Regional Academy, built capacity among state college participants that the study, can be replicated by other researchers. Findings from an in-depth examination of AM education and employment in NW Florida have profound implications for rural communities throughout the U.S. southeast [21]. At a minimum, study findings are directly applicable to other regional areas of opportunity (RAOs) in Florida because they share economic and demographic profiles [22].

Validity and Reliability

The external evaluator, in collaboration with the research team and educational partners, faculty from four regional AM programs, and a representative from the industry council reviewed and commented on the data collection instruments and reports. This team of experts assessed face and content validity of the instruments. Members included two representatives from each institution and collaborating institutions. Each focus group and interview were summarized and analyzed by research team members so that inter-coder reliability could be assessed for accuracy of transcripts. The interview/focus group questions were developed with input from the panel and field-tested to ensure face validity.

Significance

The research results of this research will help to build a supported community for the personal and professional growth among individual participants as well as the collective group. Such as approach is highly generalizable to other rural communities. A mission of the state/community college system is to support the needs of the local community and prepare students for workplace success and play a role in local economic development. Collaborating with educators and employers offers immediate and accurate information that the state colleges would not have the time or resources to obtain within limited budgets and small staff. Informal relationships provide real-time responses and regional solutions when working closely with employers. Advising and guidance on technical and academic education options for students is supported through this grassroots relationship at the local and regional levels.

Research Dissemination Activities

The team is now in Year 5, its final extension year, and focusing on dissemination and data archiving, but has completed four years of research design, conduct, and reporting. This section will detail research products in addition to traditional papers and poster presentations.

Research Technique Modules

At the conclusion of each set of research activities, the research team has developed a module that explains why the research technique was used, how data were gathered, and how data are best analyzed. These modules are:

1. Using Body of Knowledge to Map the Field (Y1)
2. Assessing Alignment: Qualitative Analysis and Text Mining (Y1, Y2)
3. Consistent Engagement through Regular Interviews and Focus Groups (Y2, Y3)
4. Integrating Heterogeneous Data for Program Assessment (Y3)

These modules will be reviewed by the research team, the project staff, and the Advisory Board. The modules also functioned as the curriculum for the Regional Academies. Video excerpts of module content are available at https://bit.ly/AMPathwaysVideos

Annual Meeting

At the conclusion of each project year, the project team has convened an Annual Meeting in conjunction with the industry council annual meeting. The meeting will allow AM students, prospective students, faculty, and employers to network and discuss project findings to date and provide input. Due to Covid-19 restrictions, the Y3 Meeting was held virtually and had excellent attendance. FLATE's Marilyn Barger has provided keynote addresses each year.

Regional College Academies

The research team devised and delivered Academies to selected faculty participants from the regional colleges. The purposes of these Academies were to: 1) gain formative and summative feedback and validation of research approaches and findings; 2) build capacity among regional colleges to use the research approaches to assess their own programs; and 3) enhance the dissemination of project products. Regional colleges received mini-grants to defray the costs of their participants' attendance. The Academies met each year, at the Annual Project Meeting, during which the project team worked with the participants to review project findings relating to each module and help participants apply the module content to their own college programs. The Academy is the result of the researchers' desire to assist fellow institutions with a means to survey and evaluate program outcomes from the student and employer perspectives because the data can provide clear gaps for effective strategies as a measure of continuous improvement.

High-Level Findings

In the interests of paper length, in this section, we recall findings from two of the research activities described previously in this paper: curriculum analysis and new professional interviews.

Curriculum Analysis. This section includes select high-level findings from the syllabus analysis (N=145) portion of the study. Figure 1 illustrates the comparison between the top 20 actual verbs in all the 2010 and 2020 Department of Labor (DOL) Advanced Manufacturing Competency Models. We compared these models not only because the DOL updated the competencies right when we were analyzing the syllabi with the 2010 model, but also because our partner colleges' syllabi were written when the 2010 competency model was in effect.

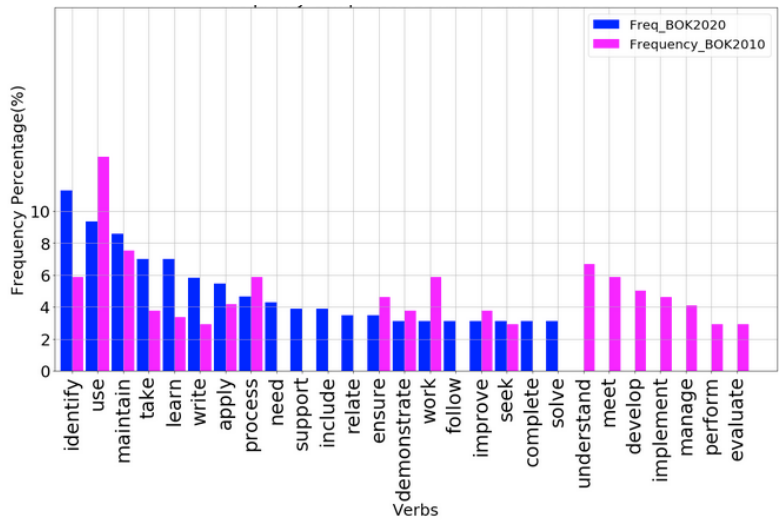

Figure 1. Verb frequencies between 2010 and 2020 DOL Competency Model documents

The blue indicates top 20 verbs in the 2020 Model and the pink are verbs found in the 2010 Competency Model. The verbs identify/use (in blue) are the top two verbs in the 2020 AM DOL Competency Model while use/maintain (in pink) are the top verbs in the AM Competency Model. Note the pink bars to the right. The 2020 competency model does not include those verbs. Likewise, the blue bars with no pink indicate verbs missing from the 2010 model.

We analyzed verb frequency and percentage of occurrence in all 145 syllabi and in the competency models, as Figure 2 shows. Concentrate on the percentages in Figure 2.

No	Verb	All Syllabi	Competency Model 2020	Competency Model 2010
1	Identify	195(5.22%)	29(3.92%)	14(2.10%)
2	Use	275(7.35%)	24(3.25%)	32(4.79%)
3	Maintain	30(0.80%)	22(2.98%)	18(2.69%)
4	Take	19(0.50%)	18(2.43%)	9(1.34%)
5	Learn	83(2.21%)	18(2.43%)	8(1.19%)
6	Write	14(0.37%)	15(2.03%)	7(1.05%)
7	Apply	88(2.35%)	14(1.89%)	10(1.50%)
8	Process	6(0.16%)	12(1.62%)	14(2.09%)
9	Need	12(0.32%)	11(1.49%)	5(0.75%)
10	Support	3(0.08%)	10(1.35%)	6(0.90%)
11	Include	94(2.51%)	10(1.35%)	3(0.45%)
12	Relate	5(0.80%)	9(1.21%)	3(0.45%)
13	Ensure	3(0.08%)	9(1.21%)	11(1.65%)
14	Demonstrate	350(9.36%)	8(1.08%)	9(1.35%)
15	Work	44(1.17%)	8(1.08%)	14(2.10%)
16	Follow	1(0.66%)	8(1.08%)	5(0.75%)
17	Improve	2(0.05%)	8(1.08%)	9(1.35%)
18	Seek	0(0%)	8(1.08%)	7(1.05%)
19	Complete	12(0.32%)	8(1.08%)	3(0.45%)
20	Solve	40(1.07%)	8(1.08%)	6(0.90%)

Figure 2. Very frequencies in syllabi and DOL competency models

As the highlighted area in Figure 2 indicates, in syllabi and the two DOL competency models, "identify" and "use" were the frequently used verbs, though the most frequently used verb in syllabi is "demonstrate." We concluded that these verbs were places to begin taking a closer look at the competency overlap, as Figure 3 suggests.

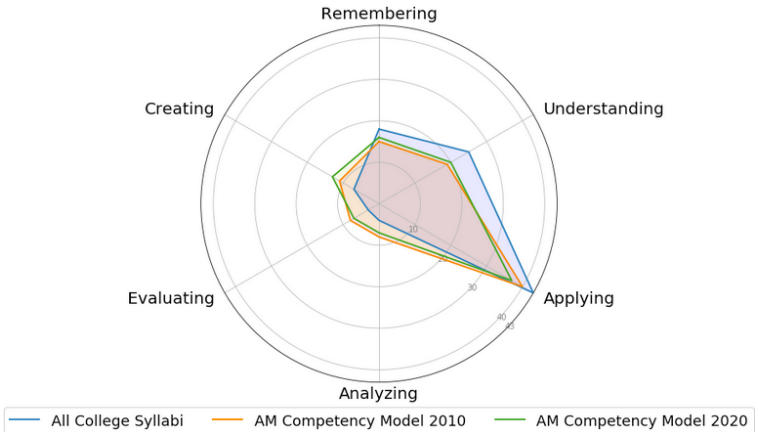

Figure 3. Comparison between syllabi and DOL competency models

In the three-layer radar chart shown in Figure 3, we compared verbs in the syllabi (N=145) to the DOL 2010 and 2020 AM Competency Models according to Bloom's Revised Taxonomy level. The blue layer denotes all combined syllabi, the orange layer the 2010 AM Competency Model and the green layer represents the 2020 AM Model. The syllabi were focused on lower-level verbs ("remembering," "understanding," and "applying"), while the 2010 and 2020 DOL Competency Model shifted toward the higher-level verbs (analyzing, evaluating, creating). This weight makes sense for a learning environment but begs the question of where students get the experience to close the gap between "understanding" and "creating."

Then, we visualized the differences between all college syllabi, the type of syllabi (i.e., core technical content, elective technical content), and the 2020 DOL Competency Model, as Figure 4 shows.

Figure 4. Comparison between verb levels in syllabi and 2020 DOL Competency Model

Higher-level verbs appeared more frequently in the technical elective syllabi than in the technical core syllabi. The balance between introductory material and coverage must be tracked very carefully because if employers are expecting higher-level competencies than programs can deliver in core curriculum courses, then adjustments may need to be made. Figure 4 highlights employers' need for higher-level competencies than what is expressed in syllabi, but also shows that elective technical curricula have a slightly higher percentage of verbs belonging to the creating category than core technical syllabi.

New Professional Interviews. This section will report the new professionals' interviews. We interviewed six AM graduates working in-field to identify the extent to which their AM program prepared them for employment as AM technicians. The six study participants graduated from an AM program in Northwest Florida. We open coded transcripts to identify competencies and AM program elements that new professionals felt prepared them for employment attainment and retention, as well as for preparation improvement. Themes were identified and described using participant quotes.

One new professional said, *"What* [the instructor] *taught us is self-learning. You compensate for a continually changing environment in this industry by continually learning... you have to be self-disciplined and self-driven to learn continuously."* Concepts of critical thinking and problem solving were also necessary to job retention. Another new professional stated that *"you have to be able to be a problem-solver and come up with creative ways to work around problems"* and how *"sometimes you have to make the equipment do what you need it to do."*

In addition to the technical and employability skills reflected in the participants' responses, experiential learning was also significant to their educational experiences because these experiences contextualized their classroom learning and provided them with opportunities to network with others in the industry, which could potentially yield future employment. Overall, new professionals thought these skills were needed as part of their profession and not based on rural or urban requirements, although they suggested that the types of products in different locales could vary and that the role of the technician was to be prepared to perform tasks at their location.

Note that this portion of the study represents a small number of graduates from regional AM programs. These volunteer participants' experiences may not represent all rural AM graduates' experiences and may not translate to AM preparation and employment needs in other regions, industry sub-sectors, or locales.

We selected just two of our research activities to share in this paper. These two research activities suggest that while curricula are at a relatively low level of complexity when compared to national employer perspectives reflected in the Department of Labor's Advanced Manufacturing Competency Models [13,14], new professionals are addressing skill gaps through experiential learning and professional networking. Rural manufacturers depend on workers' training specifically to work in the local subfield; formal education imparts foundational knowledge and a sense of professional identity.

Conclusion

As the team makes its way through Y5 of the project, the researchers can report successful Y1, Y2, Y3, and Y4. The team has held four annual meetings, two during Y1, one to kick off Y2, one to kick off Y3, and one to wrap up Y4. All syllabi and job posting data have been collected and the analysis is complete. All interviews are complete and analyzed. The literature review and initial body of knowledge (BOK) creation are complete. The team has also held three very successful Regional Academies in which partner colleges engaged in a syllabi analysis and provided valuable feedback for its continued refinement. This feedback provided a roadmap for the modules we have created for community use. The second Regional Academy focused on sharing the results of syllabi analysis and initial employer interviews; participants provided feedback on analysis results and learned strategies to engage employers in systematic, meaningful interviews, and the third guided participants through data integration for program assessments. Though this paper featured only two completed research activities, this wide-ranging study has demonstrated that employers and new professionals appreciate a foundation of advanced manufacturing knowledge, but most often value and make use of critical thinking, communication, and creative problem-solving skills. To date, the project has emphasized the need for ongoing triangulation between curriculum content, program completer experiences, and employer expectations. Due to the nature of their co-location and many routes to interconnection, rural community colleges and rural employers have a particular advantage in being responsive to national trends; consistent, in-depth communication between all aspects of the education-to-workplace relationship will ensure that rural communities remain agile economic drivers.

Acknowledgments: This material is supported, in part, by National Science Foundation grant 1700581. Portions of this paper have previously appeared in 2019, 2020, and 2021 NSF Grantee Poster Session presentations by the authors.

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