Assessing School-to-Career Pathways for Manufacturing in Rural Communities: Further Investigation of Advanced Manufacturing Programs in Northwest Florida

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Abstract

A subset of manufacturing, the advanced manufacturing (AM) sector is defined using two criteria: high levels of spending for research and development (R&D) and a high share of STEM jobs within companies. In northwest Florida, AM employment is concentrated in two sub-sectors (3259-Other Chemicals and 3344-Semiconductor) and in 2015, constituted 24.6% of the region's total employment [1, 2]. Guided by the overarching research question (RQ) "To what extent do curriculum content, employer needs, and student experiences align within an advanced manufacturing educational pathway," this study's goals are to 1) investigate the role AM program pathways have in meeting the needs of employers and new professionals who are employed in the region; 2) expand the research base and curriculum content recommendations for entrepreneur and intrapreneur education; 3) build regional capacity for AM program assessment and improvement by replicating, refining, and disseminating study approaches through further research, annual meetings with the AM employer and education community, and an academy which lead state college and university researchers, in collaboration with educational organization, to empower rural NW Florida colleges.

Motivating Rationale
Having a strong domestic manufacturing base is vital to the U.S. maintaining its world leadership in innovation. Technology-rich advanced manufacturing (AM) provides an important foundation for learning and developing process skills and capabilities that are increasingly intertwined with core R&D in many industries (e.g., specialty materials, biologics, nanotechnology, and precision mechanical devices) most important to the country's economic future [3]. AM is essential to the U.S. economy because it is the main source of innovation and global competitiveness. While the sector makes up just 11% of the economy, advanced manufacturers conduct 68% of the private sector R&D [4].

Although the U.S. Bureau of Labor Statistics forecast manufacturing sector jobs to increase slightly through 2022 [5], a critical aspect of manufacturing positions is the decline of the existing workforce aging out with little backfill of new employees, and the relationship of information technology to all manufacturing jobs [6, 7]. Eighty percent of manufacturing executives reported they are willing to pay more than the market rates in workforce areas suffering a talent crisis, yet six out of 10 positions remain unfilled due to the talent shortage [8].

Manufacturing is portrayed or perceived as a dark and dreary; however, it is diverse in people, technology, and experiences. But many held onto outdated stereotypical images: a 2016 survey revealed that 40% of parents did not see manufacturing as a well-paying employment choice for their children; 50% did not see manufacturing as an exciting, challenging or engaging profession [9]. Even more troubling is the underrepresentation of women and minorities is manufacturing. This underrepresentation is even more dramatic in rural communities where demographics do not explain the disparity [10, 11]. If parents' and counselors' perceptions are flawed about the opportunities in US manufacturing, it is little wonder that students are not exploring the classes needed to excel in industry or the training to do important work as soon as they graduate. Leaders in industry, along with faculty and administrators, need to offer the message often that there are opportunities, wages and benefits, satisfaction and fulfilment in manufacturing careers.

Clearly, the U.S. lacks sufficient numbers of workers in manufacturing to fill these positions. While the number of jobs is important, employment figures miss a significant reason why 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 innovation and entrepreneurship.

Rural communities, in general, are not thought of as major centers of innovation. In fact, the per capita number of patents is much higher in more urbanized cities. Rural communities, however, are much more effective in generating patents associated with incremental innovations, suggesting that rural businesses are effective in adapting existing technologies to more mature business settings. Although rural manufacturers may be less likely to discover breakthrough technologies than their urban counterparts, their ability to adopt and adapt existing technologies appears to be essential to enhancing productivity and the global competitiveness of rural manufacturers [2]. Rural manufacturers' abilities to compete for these emerging global markets will rest on productivity and innovation. Although 73% of the professional and technical

positions in rural manufacturing are filled by workers with at least an Associate's degree or some college training, only roughly half of rural residents have these qualifications [12, 13].

An analysis of rural and rural-adjacent areas within Florida revealed that, while these regions are less densely populated in terms of manufacturing establishments, manufacturing represents a more significant portion of their local economies, as well as higher than state average wage levels 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 [13].

The proportional centrality of rural manufacturing indicates that while these communities present ample opportunities for outside investors 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 [14, 15]. The limited research on intrapreneurship reported that intrapreneurial manufacturing industry firms outperformed firms with lower internal involvement [16, 17]. and that the level of intrapreneurship is observable and measurable [18]. 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.

The growth in advanced manufacturing is highly correlated with levels of educational attainment. Factors such as tax and regulatory climate impact economic growth of advanced manufacturing firms, but the availability of research universities surely matters over the long run. A diverse, well-educated, and ready workforce matters more than any other single factor in the health of advanced manufacturing firms and economic recruitment [19, 20].

Implications for Work

There is need to conduct more research that connects community college students' perceptions of costs and benefits of obtaining their degree with various broader measures of engagement and success as few. Also, there is a great need to enhance a dialogue between community college leaders and employers related to students' career pathways [21]. Employers can help institutions with career pathways to ensure that students are being prepared for 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 [20].

To ensure that the ET/AM programs, curriculum, training and potential economic development outcomes can be met, regional stakeholders want to ensure that 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.

In our research, we are examining faculty, student, and employer perceptions of intrapreneurship, which will provide the data to determine if a need exists to strengthen the entrepreneurial component in the AM curriculum, and include greater emphasis on "intrapreneurial" skills and

team building. Because most recent graduates will not enter the workforce as entrepreneurs, the researchers will explore how individual students learn and become self-employed, or learn to use their local knowledge assets on behalf of their employers; that is, do students see themselves as a contributor to a company and enjoying a career dedicated to helping a firm remain competitive in a global market.

Research Questions and Design

The overarching goal of this project is 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 will pursue these questions through a multi-method approach will be taken for the project, including qualitative and quantitative methods, informed by the lessons learned from the existing *Assessing IT Pathways* project. The work meets the requirements of Design and Development Research, as specified by the *Common Guidelines for Educational Research* in that it contains: 1) Development of a solution based on a well-specified theory of action appropriate to a well-defined end user; 2) Creation of measures to assess the implementation of the solution(s); 3) Collection of data on the feasibility of implementing the solution(s) in typical delivery settings by intended users; and 4) Conducting a pilot study to examine the promise of generating the intended outcomes [22].

Theory of Action

Human capital theory is a theory of investment in human capital, or the abilities and skills, acquired through investment in education and training, of any individual, that enhance potential income earning [23]. Human capital models examine how students make cost–benefit analyses and subsequent decisions on whether to attend and persist in college based on their perceptions of payoff (e.g., salary, preferred location). There is robust evidence that Associate's degrees and vocational certificates yield extra earnings compared with high school graduation [24]. Still, there is need to study how students form perceptions of the less tangible benefits and costs of higher education, like ability to become an active member of the community, or establish a lifelong career pathway. Though Human capital theory is this study's core theory of action, the researchers recognize that students' interest in entrepreneurship and intrapreneurship in their rural communities leads us to consider the intertwining of human and social capital, as in

Bourdieu's concept of habitus. According to Bourdieu, the amount of social capital held by an individual depends on the extent he or she is able to mobilize a social network from the capital (including the economic, cultural or symbolic capital) held by the network, such as a rural community. For graduates who stay in their communities, using an AM degree to invest their education in the local economy as an engaged employee or business owner is a means to build social capital through human capital [25, 26].

Description of Study Site and Participants

The lead state college's primary emphasis is on 2-year degrees and workforce certificates in addition to limited Bachelor's degrees in nursing, secondary education, and business. One of the missions of lead state college is 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. These documents were the basis for an initial Body of Knowledge (BOK) to be used in content and transcript analyses. The BOK is being refined during analyses in Y2 and Y3.

Data Collection and Analysis Methods

To answer the RQs, the research team has undertaken and will complete several data collection and analysis activities including:

1. Content analysis of AM course syllabi will be used to develop lists of skills gained by students who successfully complete AM coursework. The unit of analysis is a syllabus from an individual course. All occupational completion points, student performance outcomes, or standards and/or certifications covered in the material will be analyzed through an iterative process using the codebook derived from relevant national, state, and professional standards and industry certifications. Researchers will also use established instruments to measure the extent to which the new professionals report entrepreneurial and intrapreneurial intentions [27-29]. In addition to qualitatively deriving areas of strong and weak alignment, the researchers will calculate the extent of match between the syllabi and the standards. The team will employ 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.

The team is in the process of performing a content analysis of NW Florida AM job and internship postings gathered from available sources will be used to develop a list of job requirements for AM positions in the region. The team will analyze the postings through an iterative process using open and axial coding to develop a list of job requirements with the unit of analysis each job posting. Again, the team will calculate the extent of match between the postings and the syllabi using a Python process similar to the one used with syllabi. This analysis will be completed twice (Y2 and Y3) with the first version informing refinement of research processes and the second version allow the research team to examine any curriculum changes

2. Interviews with AM educators will be conducted at Annual Summits with the Panhandle partner colleges (approximately 16 educators from four institutions). The interviews will be used to explore factors in curriculum development and delivery and to understand the relationship between faculty and industry stakeholders. Draft interview questions will be developed from prior interview instruments augmented by project personnel and findings from the literature review. The questions will explore issues of AM education broadly as well as of issues pertaining to female and minority student recruitment and retention. The unit of analysis is the transcript of an interview with an individual educator. Transcripts will be analyzed for themes relating to human capital theory and habitus as well as match to the AM standards/certifications codebook. Researchers will also calculate the extent of match between AM educators' perceptions and AM standards and certifications using a Python process similar to the ones used in preceding analyses.

3. Interviews and focus Groups with NW Florida AM employers will be developed from all available resources with major support from the industry council (at least 47 businesses) and the educational partners. Interviews / focus groups will continue until saturation is reached. Interviews / focus groups will measure employer needs and can be identified from the literature review, senior personnel input, and project objectives. The questions will explore issues of AM job candidates and employees broadly as well as of issues pertaining to female and minority hiring and participation. A skills card sort can be employed with skills sets from the course syllabi and course frameworks and job postings analyses informing the instrument.

4. Interviews with NW Florida new professionals (working 3 years or less) will be conducted. With the help of Lead state college administrators and faculty, 12 recent AM graduates will be recruited to participate. AM managers will also be asked to identify potential participants from their organizations. An interview guide will be developed from the employer interviews. The questions will explore 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 is the transcript of each interview or focus group. Researchers will also calculate the extent of match between AM educators' perceptions and AM standards/certifications as well as use established instruments to measure the extent to which the new professionals report entrepreneurial and intrapreneurial intentions [27-29].

Sampling Note

Rural NW Florida is highly diverse, with over 30% of residents reporting that they are black, Hispanic, or of multiple races; the enrollments of the participating state colleges reflect their communities. Because an intent of this project is to increase participation in AM education and careers, the research team will reach out to minority graduates and business owners for interviews and focus groups.

Replicability and Generalizability

This project is attuned for replication. Replication and refinement of study approaches as well as the creation of freely available modules and a regional Academy ensure 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 [30]. At minimum, study findings are directly applicable to other regional areas of opportunity (RAOs) in Florida because they share economic and demographic profiles [31].

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 will review and comment on the data collection instruments and reports. This team of experts will assess face and content validity of the instruments. Members will include at least two from representatives from each institution and collaborating institutions. Each focus group and interview will be summarized and analyzed by research team members so that inter-coder reliability can be assessed for accuracy of transcription. The interview / focus group questions will be developed with input from the panel and field tested to ensure face validity.

Significance

The result of this research will be to build a supported community for the personal and professional growth of 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.

Timeline

Table. Project Timeline

Major Activity	Y1				Y2				Y3			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4

	Y1 Q1	Y1 Q2	Y1 Q3	Y1 Q4	Y2 Q1	Y2 Q2	Y2 Q3	Y2 Q4	Y3 Q1	Y3 Q2	Y3 Q3	Y3 Q4
Y1, Phase 1. Pre-research (G1)												
All Project Meeting	▓											
Literature Review	░	░										
BOK create/refine	░	░							░			
BOK module/refine			░							░		
Y1 & Y2, Phase II. Content analysis (G1; RQ1, RQ5)												
Course syllabi analysis		░	░	░					░	░		
Job posting analysis		░	░						░	░		
Match calculation			░	░					░	░		
Analysis module/refine				░					░	░		
Annual Meeting/Academy				▓								
Y2 & Y3, Phase III. Interviews and focus groups (G2; RQ2, RQ3)												
AM educator interviews						░	░	░				
AM employer focus groups					░	░	░	░				
AM employee interviews					░	░	░					
Interview module/refine								░	░			
Annual Meeting/Academy								▓				
Y2 & Y3 Data Integration and Dissemination (G3; RQ4)												
Data Integration									░			
Recommendations									░			
Integration module										░		
Academy curriculum											░	
Annual Meeting/Academy												▓

Research Dissemination Activities

Research Technique Modules

At the conclusion of each set of research activities, the research team will develop a module that explains why the research technique was used, how data were gathered, and how data are best analyzed. These modules will be web-based, linked to the project website, and also linked through FLATE. The modules will be:

1. Body of Knowledge Creation (Y1)
2. Assessing Alignment: Qualitative Analysis and Text Mining (Y1, Y2)
3. Interviews and Focus Groups (Y2, Y3)
4. Data Integration (Y3)

These modules will be reviewed by the research team, the project staff, and the Advisory Board. The modules will also function as the curriculum for the Academies.

Annual Meeting

At the conclusion of each project year, the project team will convene 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.

Regional College Academies

The research team will devise and deliver Academies to selected faculty participants from the regional colleges represented on the Advisory Board. The purposes of this Academies are 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 dissemination of project products. Regional colleges will receive mini-grants from Lead state college to defray the costs of their participants' attendance. The Academies will meet each year, at the Annual Project Meeting, during which the project team will work 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.

Activities to Date

As the team embarks on Y3 of the project, they are able to report a successful Y1 and Y2. The team has held four All Project Meetings, two during Y1, one to kick off Y2, and one to kick off Y3. All syllabi and job posting data have been collected and analysis is nearly complete. The literature review and initial BOK creation are complete. The team has also held two very successful Regional Academies in which partner colleges engaged in a syllabi analysis simulation using the initial BOK and provided valuable feedback for its continued refinement. This feedback not only improved the BOK, but also has provided a roadmap for the module we will be creating 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.

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