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

Dr. Marcia A. Mardis, Florida State University

Marcia A. Mardis is a Professor and Associate Dean at Florida State University's College of Communication and Information and Associate Director of the Information Institute. Author of numerous publication and recipient of over two decades of federally funded research grants, Dr. Mardis' work focuses on professional identity development, educational text and data mining, and technician education improvement.

Dr. Faye R. Jones, Florida State University

Faye R. Jones is a Senior Research Associate at Florida State University's College of Communication & Information. Her research interests include STEM student outcomes and the exploration of student pathways through institutional research.

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) job outstrip the number of middle-skilled technicians, though AM constitutes almost a quarter of the region's total employment. 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 NSF-funded study's goals have been 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 regional AM education; 3) 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 four 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 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 [1]. 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 [2, 3]. 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 healthy rural economies, innovation, and entrepreneurship.

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 [4].

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 [5, 6]. The limited research on intrapreneurship reported that intrapreneurial manufacturing industry firms outperformed firms with lower internal involvement [7, 8]. and that the level of intrapreneurship is observable and measurable [9]. 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

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 [10]. 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 [11].

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.

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 existing *Assessing IT Pathways* project. The work met 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 [12].

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 2-year degrees and workforce certificates, in addition to limited Bachelor's degrees in nursing, secondary education, and business. The missions of these state colleges 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 as a result of the analyses performed in Y2 and Y3.

Data Collection and Analysis Methods

To answer the RQs, the research team has 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 [13, 14]. Researchers also used established instruments to measure the extent to which the new professionals report entrepreneurial and intrapreneurial intentions [15, 16, 17]. 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 similar to 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 [15, 16, 17].

Replicability and Generalizability

This project is attuned 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 [18]. At minimum, study findings are directly applicable to other regional areas of opportunity (RAOs) in Florida because they share economic and demographic profiles [19].

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 from representatives from each institution and collaborating institutions. Each focus group and interview was summarized and analyzed by research team members so that inter-coder reliability could be assessed for accuracy of transcription. 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.

Timeline

Table. Project Timeline

Major Activity	Y1				Y2				Y3 (Y4)			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	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 (Y4) Data Integration and Dissemination (G3; RQ4)												
Data Integration										▒		
Recommendations										▒		
Integration module											▒	
Academy curriculum												▒
Annual Meeting/Academy												█

The team is now in Year 4, an extension year, in which they are completing in-progress dissemination products and will hold another virtual annual meeting in August 2021.

Research Dissemination Activities

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. 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, Y4)

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 Annual Meeting was held virtually and had excellent attendance. FLATE's Marilyn Barger has provided keynote addresses each year. The team plans a final Annual Meeting in summer 2021.

Regional College Academies

The research team devised and delivered Academies to selected faculty participants from the regional colleges. The purposes of this 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 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

This section includes select high-level findings from the syllabus analysis (N=145). Findings from other research activities are still in preparation. 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.
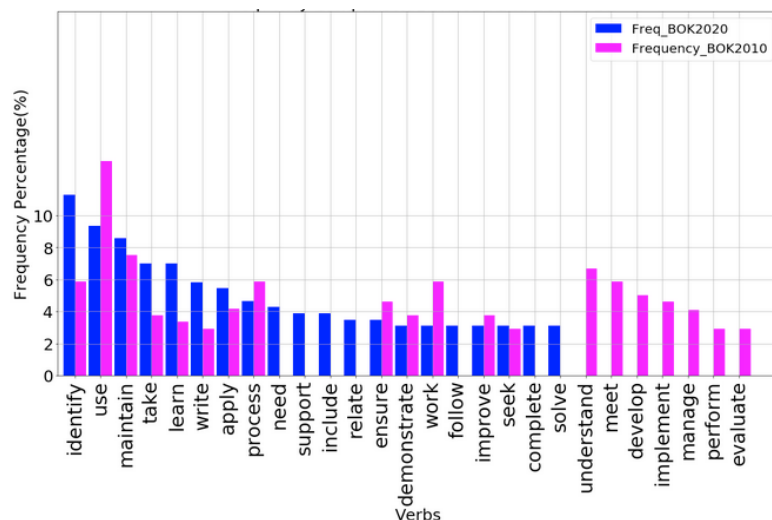
Figure 1. Verb frequencies between 2010 and 2020 DOL Competency Model documents

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.

For the verbs in all of the syllabi, the frequency and percentage of occurrence in all of the 145 syllabi we analyzed and the verb occurrence in the competency models. 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

In syllabi and the two DOL competency models, "identify" and "use" were the frequently used verbs, though the 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.
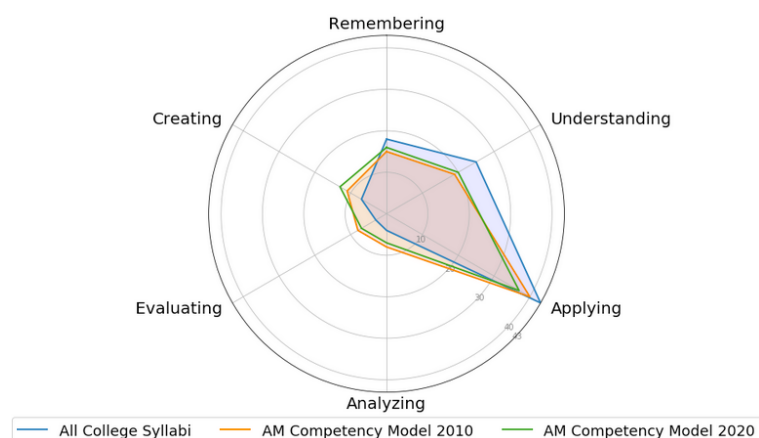
Figure 3. Comparison between syllabi and DOL competency models

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 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.
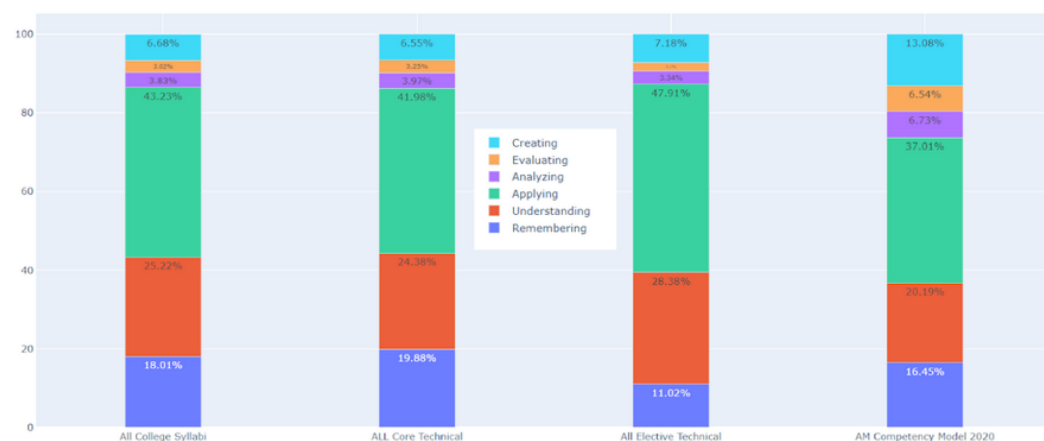

Figure 4. Comparison between verb levels in syllabi and 2020 DOL Competency Model

Higher level verbs appeared more frequently in the technical elective syllabi than in the technical core syllabi. The balance between introductory material and coverage has to 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 then 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.

Conclusion

As the team embarks on Y4 of the project, the researchers are able to report successful Y1, Y2, and Y3. The team has held four annual 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 complete. 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 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.

References

[1]   Society of Manufacturing Engineers [SME]. (2016). *Debunking the myths about manufacturing* [Online]. Available: http://www.sme.org/manufacturing-myths-infographic/.

[2]   Deloitte and Manufacturing Institute. (2015). *Minding the manufacturing gender gap: How manufacturers can get their fair share of talented women* [Online]. Available: http://www.themanufacturinginstitute.org/Initiatives/Women-in-Manufacturing/~/media/9E6ED78EACB84084BD7A7C98B52B0E5C.ashx.

[3]   U.S. Department of Labor Bureau of Labor Statistics. (2016). *Labor force statistics from the Current Population Survey: Employed persons by detailed industry, sex, race, and Hispanic or Latino ethnicity.* [Online]. Available: http://www.bls.gov/cps/cpsaat18.htm.

[4]   Florida Department of Economic Opportunity [FLDEO]. (2016, January 12). *Rural manufacturing study: An assessment of manufacturing in Florida's rural areas and the opportunities for growth and expansion* [Online]. Available: http://www.floridajobs.org/REDI/Rural%20Manufacturing%20Study%20v3.pdf.

[5]   R. A. Burgelman, "A process model of internal corporate venturing in the diversified major firm," *Administrative Science Quarterly,* vol. 28, pp. 223-244, 1983.

[6]   R. A. Burgelman, "A model of the interaction of strategic behavior, corporate context, and the concept of strategy," *Academy of Management Review,* vol. 8, no. 1, pp. 61-71, 1983.

[7]   M. H. Morris, P. S. Lewis, and D. L. Sexton, "The concept of entrepreneurial intensity: A conceptual and empirical assessment.," in *Thirteenth Annual Babson College Entrepreneurship Research Conference*, Babson Park, MA, 1993: Babson College Press, pp. 441-442.

[8]   P. J.W. and J. W. Carland, "Intrapreneurship and innovation in manufacturing firms: An empirical study of performance implications," *Academy Entrepreneurial Journal,* vol. 1, no. 2, pp. 87-96, 1996.

[9]   S. Devaraj and M. J. Hicks. (2016). *Advanced manufacturing in the United States: The shift toward diversified industries & an educated workforce* [Online]. Available: http://conexus.cberdata.org/files/Conexus2016-AdvMfg.pdf.

[10]   G. R. Stuart, C. Rios-Aguilar, and R. Deil-Amen, "" œHow much economic value does my credential have?" Reformulating Tinto' ™s model to study students' ™ persistence in community colleges," *Community College Review,* vol. 42, no. 4, pp. 327-341, October 1, 2014 2014.

[11]   K. Hughes and M. Karp, *Strengthening transitions by encouraging career pathways: A look at state policies and practices*, New York, NY: Community College Research Center, 2006. [Online]. Available: http://ccrc.tc.columbia.edu/media/k2/attachments/strengthening-transitions-career-pathways.pdf.

[12]   Institute of Education Sciences [IES] and National Science Foundation [NSF]. (2013). *Common guidelines for education research and development* [Online]. Available: http://ies.ed.gov/pdf/CommonGuidelines.pdf.

[13]   U.S Department of Labor [DOL]. (2010, February 2). *Advanced manufacturing competency model* [Online]. Available: http://careeronestop.org/Advanced-Manufacturing.pdf.

[14]   U.S Department of Labor [DOL]. (2020). *Advanced Manufacturing competency model* [Online]. Available: https://www.careeronestop.org/competencymodel/competency-models/advanced-manufacturing.aspx.

[15]   C. C. Chen, P. G. Greene, and A. Crick, "Does entrepreneurial self-efficacy distinguish entrepreneurs from managers?," *Journal of Business Venturing,* vol. 13, pp. 295-316, 1998.

[16]   J. Cheng, "Intrapreneurship and exopreneurship in manufacturing firms: An empirical study of performance implications," *Journal of Enterprising Culture,* vol. 9, no. 2, pp. 153-171, 2001.

[17]   E. J. Douglas and J. R. Fitzsimmons, "Intrapreneurial intentions vs.entrepreneurial intentions: Distinct constructs with different antecedents," *Small Business Economics*, vol. 41, no. 1, pp. 115-149[Online]. Available: http://www98.griffith.edu.au/dspace/bitstream/handle/10072/55296/80979_1.pdf?sequence=1

[18]   Enterprise Florida. (2008). *Statewide strategic plan for economic development: Rural priority* [Online]. Available: http://www.floridajobs.org/REDI/EFI_2006-08_RuralStrategicPlanofWork.pdf.

[19]   U.S. Department of Agriculture. (2015). *Rural America at a glance. 2015 edition* [Online]. Available: http://www.ers.usda.gov/media/1952235/eib145.pdf.