

Two-Year College and University Collaboration in Creating Advanced Manufacturing Curricula and Programs

Dr. David I. Spang, Rowan College at Burlington County

Dr. David Spang is the Sr. Vice President & Provost at Rowan College at Burlington County in Mt. Laurel, NJ. Prior to being named Sr. Vice President & Provost, Dr. Spang served as Interim President, Provost, Vice President of Academic Programs and as Dean of the Science, Mathematics, and Technology division. Dr. Spang holds a PhD degree in Materials Science and Engineering and a MBA degree, with a concentration in Innovation and Technology Management. Prior to joining academia, Dr. Spang spent nearly twenty years in R&D and business development.

Dr. Eric Constans, Rowan University

Eric Constans is an Associate Professor in Mechanical Engineering at Rowan University. His research interests include engineering education, mechanical design and acoustics and vibration.

Dr. Edem G Tetteh, Rowan College at Burlington County

Edem G. Tetteh currently, serves as founding Dean of STEM at Rowan College at Burlington County. He was previously Interim Dean of Academic Affairs at Potomac State College of WVU. Prior to that position, he served as Assistant Vice President for Academic Affairs and Associate Professor at Paine College. He has previously held a faculty position in the Industrial and Logistics Technology (INLT) program in the Department of Technology at Virginia State University. He received his B.S. in manufacturing systems and an M.S. in industrial engineering both from North Carolina Agricultural and Technical State University. He received his Ph.D. in technology from Purdue University, West Lafayette. Tetteh has authored three books and several publications in the area of ergonomics and human factors, logistic and supply chain, and manufacturing productions.

Two-Year College and University Collaboration in Creating Advanced Manufacturing Curricula and Programs

Abstract

As colleges and universities work to align training and degree programs with the needs of high-growth industries, students will benefit from clearly articulated and cost-effective pathways in both two-year colleges and four-year universities for a baccalaureate degree. These pathways, often modeled on established formulas, must include and emphasize competencies most valued by industry throughout the entire curriculum. The valued competencies must encompass both hard and soft skills which have been identified as necessary for success in industry. This paper details the beginning efforts of a multi-year project between a two-year college (Rowan College at Burlington County) and a four-year university (Rowan University) to create curriculum, academic programs, and career pathways resulting in meaningful employment in the Advanced Manufacturing sector. Among the Advanced Manufacturing disciplines to be considered are machining, rapid prototyping, specialty welding, and lean manufacturing. Facilities focused on training students, incumbent workers, and unemployed persons in transition for these specific disciplines will also be considered. The desired competencies will be identified through close collaboration with industry partners as well as the College Workforce Development Institute and will be integrated in a comprehensive manner throughout the entire curriculum. Real-life examples of the underlying principles will include an applications library. The goals of this project include identifying technical and non-technical skills needed across the curriculum, developing a real-life applications library as a resource for faculty, and creating and strengthening continuous career pathways between secondary schools, higher education institutions, and industry partners. Through these collaborative efforts, associate and bachelor degrees and stackable certificate programs will be created, supported by an Advanced Manufacturing Training Facility designed with input from industry leaders and educators.

Background

Numerous industry-centered collaborations between higher education institutions and industry partners have been created in recent years to align curriculum, and more importantly, student competencies with the actual skills needed by employers [1,2]. These models seek to minimize the degree of on-site and on-the-job training that must be delivered to a new employee after hiring in order to immediately add value to a company's operations.

Rowan College at Burlington County (RCBC) and Rowan University (RU) have conducted past forums with New Jersey and regional industry partners and have similarly made direct observations supporting the fact that there is a tremendous need for graduates to possess the skills and competencies valued by industry.

Specifically, the skills and competencies supporting the advanced manufacturing sector are in high demand. For the purposes of the current effort, the definition of advanced manufacturing includes the "Use of innovative technologies to create existing products and the creation of new

products. Advanced manufacturing can include production activities that depend on information, automation, computation, software, sensing, and networking” [3].

While a national need has been demonstrated for graduates and employees with advanced manufacturing skills [4,5], a regional need has been demonstrated as well for New Jersey. According to the Department of Labor and Workforce Development, New Jersey’s Advanced Manufacturing Cluster contributed nearly \$33.1 billion to the Gross Domestic Product in 2014, or about 6.6% of all output. Further New Jersey Advanced Manufacturing statistics include that approximately two-thirds of all manufacturing jobs are classified as advanced, average wages paid in many advanced manufacturing industries are above the statewide private sector average, and there were nearly 157,000 employees in the advanced manufacturing sector in 2015. Advanced Manufacturing industries within this sector include food, chemical, and machinery manufacturing as well as fabricated metal and computer and electronic product manufacturing [6].

The above statistics further reinforce the motivating rationale for the current project, namely that there is a critical need for students to achieve the identified skills and competencies required by a critical and robust regional and statewide industry, i.e. advanced manufacturing.

The Needs of Industry

RCBC has a history of linking academic programs to the skills and competencies needed by industry. These linkages have occurred through a variety of projects and initiatives including various career and technical education (CTE) advisory committees, a previously funded NSF grant project, as well as on-site corporate training projects and on-campus industry forums.

For example, in 2007 RCBC was awarded a NSF-ATE grant for a project entitled “Institution-Level Reform of an Engineering Technology Program”. The goal of the project was to link students, educators, and administrators across two secondary schools, a two-year college, and a four-year university with representatives from industry and workforce development to improve RCBC’s Engineering Technology program. The overarching goal was to better meet the workforce demands of the manufacturing industry in central and southern New Jersey. A comprehensive list of technical and non-technical competencies was developed, and the identified competencies were introduced or emphasized throughout the academic program.

Additionally, in June of 2015, the Workforce Development Institute (WDI) of RCBC held an Advanced Manufacturing Forum with focus groups for regional fabricated metal, machinery, and electrical equipment manufacturers and conducted an online survey afterward. Four consistent themes of the focus groups were: 1) the need for employable skills, 2) the need for a manufacturing program, 3) the need to address public misconceptions about the manufacturing industry, and 4) employer interest in developing work-based learning experiences to engage young adults.

The findings indicated these manufacturers had five overarching needs: 1) employees with strong soft skills were in the highest demand, 2) employees with basic technical education and machine skills were in high demand, 3) specialized/advanced skills were in demand, but skill needs varied by employer, 4) training and apprenticeship opportunities were an identified need, and 5)

millennials have very low interest in manufacturing as a career. This last point is likely a contributory factor to the observed skills gap related to the advanced manufacturing industries. [7,8].

In order to ensure that these requisite skills and competencies are obtained by students, close partnerships between curriculum developers, faculty, administrators, and industry partners will be necessary and are all planned as part of the current project.

Additionally, RCBC's Workforce Development Institute and the Burlington County Workforce Development Board allow for the streamlined interaction between the college and industry partners. This collaboration allows for the aligning of local, state, and federal resources under one umbrella. The WDI provides a unified, integrated workforce development system for Burlington County to identify and provide skills, training, and the education needed for the workforce of today and tomorrow. The WDI diligently works to help prepare individuals for academic success, for employment, and to gain critical new career skills meeting the needs of industry. The WDI accomplishes its mission through a mix of delivery systems to educate and train participants, by partnering with private and public sectors, and by enriching the quality of life through community programs and continuing education.

Institutional Collaboration

In order to serve as a conduit for the creation of programs and educational pathways that address unmet training needs and the needs of emerging high-growth industries, RCBC, RU, and secondary school partners will outline an education-to-employment pathway within the advanced manufacturing discipline. This guided pathway will emphasize the skills and competencies valued by industry and will allow students to reach significant milestones as they progress by earning discrete certificates that may be combined to meet the requirements of an associates and baccalaureate degree. Students will have the opportunity to earn these certificates leading to an associate degree at RCBC, and then move toward the baccalaureate degree at RU. Furthermore, there will be opportunities for students to begin earning college credit while still in high school.

The planned education-to-employment pathway will be strengthened by the close partnership between RCBC and RU in both "2+2" and "3+1" program offerings. In these programs, students can complete their first two-years at RCBC and the remaining two-years at RU, or the first three-years at RCBC and their senior year at RU, respectively. It is planned that RU will deliver the junior and senior year of select programs at the RCBC campus, including mechanical engineering technology with a concentration in advanced manufacturing.

Curriculum and Pedagogical Innovations

Several innovations will be incorporated into the curriculum design and development, which will allow students to gain the maximum benefit from the intended education-to-employment pathway.

Technical and Non-Technical Skills

Feedback from employers has consistently indicated that both technical and non-technical skills

are in high demand. Technical skills naturally support an advanced manufacturing environment, but a large emphasis is also placed on non-technical, or soft skills. An employee's ability to work in teams and communicate well, for example, are consistently of high importance to employers and valued in the professional world.

The most critical and timely technical and non-technical skills will be identified by working closely with industry partners and then will be incorporated across the curriculum, including in non-technical courses. This comprehensive approach will allow the required competencies to be introduced and emphasized in courses in order to support students' development throughout their educational pathway. An example of such a course specifically designed to focus on both technical and non-technical skills is RCBC's SOC-160 course, Society, Ethics, and Technology. This course provides students with a framework for understanding the ways in which technology affects society and to further understand the social, ethical, global, environmental, and professional implications.

Applications Database and Library

Another innovation will be the creation of an applications database and library. This database and library will serve as a resource for faculty to support the relevant curriculum and to present industry-relevant competencies within courses that meet predetermined learning outcomes. With a struggling global economy in many sectors and an increased focus on persistence and graduation rates, higher education institutions benefit from developing a meaningful approach to teaching the linkages between scientific principles and the critical applications upon which we rely so heavily.

For example, the importance and application of science and engineering principles in our daily lives cannot be overstated. Materials and devices from semiconductors to microprocessors to the vehicles we drive rely on a highly sophisticated understanding of application-based principles.

The formalized incorporation of applications will have the following elements:

- 1) The application must have some readily identifiable significance, both in terms of functionality and economic benefit, and the underlying and reliant principles must be readily identifiable and well understood.
- 2) The underlying relevant principles must be summarized in plain language and communicated with a simple figure or table, where appropriate.
- 3) The application and principles must have significance to an emerging student, both in future academic courses (in the undergraduate and graduate levels) and in their career experiences.
- 4) The introduction and development of the application must follow a sound pedagogical approach (i.e., the inclusion of Bloom's taxonomy in defining outcomes) as well as a standardized and consistent academic outcomes measurement approach.

After conducting a Technology Conference with industry partners, faculty, administrators, and advisory committee, members will compile the most important skills identified by industry and

develop application links between the identified skills and the principles taught. These formal and outlined linkages will populate an applications database, which will inform instructors of the best way to present topical material and relate it to real-world applications highlighted by the industry partners.

Contextualizing course material in this way will ensure that graduates not only possess the conceptual knowledge they need, but they will also have a deeper understanding of the application of the principles they have learned. Applications of learned principles will be developed for technical and non-technical areas, including advanced manufacturing, business, accounting, mathematics, and biology, to name a few.

An applications development team comprised of faculty, administrators, and advisory committee members will be formed and will meet regularly to further the development and incorporation of applications into the curriculum. Additionally, a training plan will be implemented and will provide training and guidance to high school, two-year, and four-year college instructors on how to develop the underlying principles and incorporate the relevant applications into the curriculum. As part of the training plan, assessments will be developed and incorporated to measure student learning. The applications database will be available on the web and will borrow elements of existing models of providing modular curricula components in support of relevant topics.

Undergraduate Research

Another area of curriculum innovation to be expanded is undergraduate research opportunities. RCBC is one of a select group of two-year colleges in the nation that provides students with an opportunity to participate in original research and has created a robust undergraduate research (UGR) program which allows students to work directly under faculty supervision on innovative and creative projects. Students directly utilize the skills and competencies gained through their coursework. RCBC's UGR program has produced student and faculty presentations and publications and helped RCBC solicit and receive funding from industrial partners.

While learning in a classroom setting is an important component of achieving success, having the opportunity to put those learned skills to practical use by doing innovative research and developing critical thinking skills gives RCBC students a distinct advantage. Students who have participated in the research program have gone on to industry internships, university research programs, and professional programs in healthcare, in addition to being successful at transfer institutions. Students also have the opportunity to publish in peer-reviewed journals. In 2014, for example, UGR students and faculty mentors were successful in publishing in *The Journal of Undergraduate Chemistry Research*.

Students will also be exposed to undergraduate research where they can work in a multitude of different areas like advanced manufacturing, biology, chemistry, physics, astronomy, and computer areas such as cyber security. Students will take Undergraduate Research as a one or two credit course, with a mentor from RCBC's faculty, in the fall and/or spring semester. Industry leaders will be invited to lunch-and-learn sessions during the academic year to engage students in discussions about their industries and describe the types of projects most important to them. Students will then have the opportunity to learn about available research projects and work

with a mentor in a UGR project.

At the end of each academic year, students present their research project at an undergraduate research symposium held at the college. This symposium has groups presenting their research from chemistry, physics, biology, mathematics, astronomy, and computer science.

RCBC's UGR program is made possible in part through funding provided by local industry partners. This program provides students a definite advantage when transferring to four-year colleges and universities and when applying to highly competitive internships and summer programs.

Career Readiness Course

Through close collaboration with industrial partners and the College Workforce Development Institute, a career readiness course will be developed to provide career exploration relevant to students at all levels. The course will contain both professional development and field components. Students will become familiar with the work environment and specific tasks, perform personal and career assessments, and develop job search and interviewing skills. The field portion will focus on specific careers to help build connections between students and employers for future job placement and significant resume boosters. The course will have the flexibility to take a number of formats, including job internships, cooperative education, company field trips and job profiling, a directed-study job mentorship, and job shadowing. Students will use a combination of the available course elements of the career exploration component with the approval of the instructor.

New Academic Program with an Advanced Manufacturing Focus

A major goal of the current project is to create a new academic program in Mechanical Engineering Technology, with a concentration in Advanced Manufacturing. An associate degree at RCBC, comprised of discrete certificate elements that can be combined, will be developed through the adaptation of relevant models from national and regional programs. The certificates will provide students with the opportunity to be recognized for reaching relevant milestones as they progress through the program, and can be combined in an additive or stackable fashion. This associate degree will directly link to a baccalaureate degree at RU through a clearly defined and continuous educational pathway.

The certificate and degree programs will be aligned with the skills and competencies identified by industry partners, as well as with the standards of professional organizations such as the National Association of Manufacturers, Manufacturing Skills Standards Council, and Society of Manufacturing Engineers.

Facilities and Infrastructure

When the skills and competencies needed by industry have been fully identified, an Advanced Manufacturing Facility will be outfitted to support student education and development.

Unmet training and educational needs, previously identified in various disciplines, will be

supported and include machining, rapid prototyping, specialty welding, and lean manufacturing. Facilities focused on training students, incumbent workers, and unemployed persons in transition for these specific disciplines are either non-existent or scarce within Burlington County and the southern New Jersey region.

The state-of-the-art Advanced Manufacturing Facility will be designed and outfitted in two phases: Phase 1 of the facility will be completed during the summer of 2018 and will be used for summer camps and workshops prior to the first cohort of certified students entering the following fall semester. The facility will house machining equipment, including four CNC milling machines, four CNC lathes, as well as supporting equipment including band saws, grinders, parts washing stations, sandblast cabinets, etc. Phase 2 will include the creation of welding stations, including MIG (metal inert gas), TIG (tungsten inert gas), SMAW (shielded metal arc or stick welding), and spot welding. Additional equipment will include 3-D printers, programmable logic controllers (PLC), variable frequency drives, and other equipment supporting the industry-relevant skills and competencies identified in the planned industry forums.

Next Steps

Currently in the planning stages is a two-day Industry Forum scheduled during the Spring 2017 semester. At this Forum, industry representatives across advanced manufacturing and engineering businesses will participate in roundtable discussions, focus groups, as well as complete surveys. They will provide critical input regarding the required skills and competencies which graduates must possess in order to secure gainful employment and add value to a company's operations.

After the Industry Forum, a four-day Technology Conference will be held for faculty to incorporate identified skills and competencies into the curriculum. This Conference will involve approximately 75 faculty, working in subgroups, and will include members of the secondary, two-year college, and four-year university education partners. Faculty will review and develop curriculum, provide input on applications, conduct presentations on applications, and participate in outcome assessment development. The subgroups will then continue to work and communicate throughout the summer and compile and present their results in the Fall 2017 semester. Faculty will critically examine the incorporation of identified skills and competencies, the assessments to measure predetermined outcomes for each, and the likelihood of an employer's needs being met. Faculty consideration will include examination of prerequisite courses, text complexity, and content rigor.

Deliverables from these activities will include updated curricula with aligned texts, advising outlines detailing prerequisite pathways, and a firm continuity between secondary, two-year, and four-year educational partners.

Acknowledgments

The authors wish to acknowledge the support of the NSF-TUES program in the Division of Undergraduate Education, DUE-1601487, which made this effort possible. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors

and do not necessarily reflect the views of the National Science Foundation.

The authors also wish to acknowledge RCBC and RU personnel who have contributed to the current effort and have helped to create and maintain a culture of innovation and excellence. Special thanks are given to RCBC's President, Mr. Paul Drayton, and to the RCBC Board of Trustees, as well as to RU's President, Dr. Ali Houshmand, for their support of innovative educational endeavors. Additional thanks go to RCBC's Workforce Development Institute, under the leadership of Vice President Anna Payanzo Cotton, for their work in creating meaningful employment pathways.

Bibliography

- (1) “Why Higher Ed and Business Need to Work Together,” Michael D. King, Harvard Business Review, July 17, 2015.
- (2) “TUEE: Transforming Undergraduate Education in Engineering. Phase I. Synthesizing and Integrating Industry Perspectives,” a workshop held jointly by the American Society for Engineering Education (ASEE) and the National Science Foundation (NSF), May 2013.
- (3) “Glossary of Advanced Manufacturing Terms,” www.manufacturing.gov, February 2017. <https://www.manufacturing.gov/news-2/news/glossary-of-advanced-manufacturing-terms>.
- (4) “Help Wanted: American Manufacturing Competitiveness and the Looming Skills Gap,” Craig A. Giffi, et al. Deloitte Review Issue 16, January 2015. <https://dupress.deloitte.com/dup-us-en/deloitte-review/issue-16/manufacturing-skills-gap-america.html>.
- (5) “America’s Advanced Industries, What they Are, Where They Are, and Why They Matter,” Mark Muro et al., The Brookings Institution, February 2015.
- (6) “New Jersey’s Advanced Manufacturing Industry Cluster,” New Jersey Department of Labor and Workforce Development, Office of Research and Information, Bureau of Labor Market Information, Winter 2016.
- (7) “The Growing Skills Gap in Manufacturing,” E. McMnamin, Quality, 54(9), 22, September 2015.
- (8) “The Skills Gap in U.S. Manufacturing, 2015 and Beyond,” sponsored by The Manufacturing Institute and Deloitte, 2015.