A Model for Aligning Engineering Technology Curriculum with Industry Needs

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Abstract

In order for students to master the skills and competencies required by industry, academic programs must be focused on, and oriented towards, the skills that have the most relevance and value. Achieving a well-designed academic program requires industry partners and faculty to work in tandem to provide input regarding curriculum development and delivery. This paper details the efforts of a multi-year project between a two-year college and a university to create curriculum, academic programs and career pathways resulting in meaningful employment in the Advanced Manufacturing sector. Curriculum developed will include both Associate of Applied Science (AAS) and Bachelor of Science (BS) degrees in Mechanical Engineering Technology (MET) with an emphasis on Advanced Manufacturing. Through a collaborative curriculum development process, Rowan College at Burlington County (RCBC) and Rowan University (RU) have created a clearly articulated pathway from the AAS degree to the BS degree. This academic pathway will include a "3+1" delivery model where the first three years of instruction are delivered by the two-year college, and the final year is delivered by the university, on the two-year college campus. This curriculum development effort has been achieved through activities including an industry forum as well as a week-long faculty curriculum development workshop. Additional work will include the development of real-life examples of underlying curricula principles through an applications library, as well as the creation of stackable certificates and continuous career pathways between secondary schools, higher education institutions, and industry partners.

Background

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

The findings of the survey indicated these manufacturers had five overarching needs: 1) employees with strong soft skills were in the highest of 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 apprenticeships were a self-identified need; and 5) millennials have very low interest in manufacturing as a career.
In order to ensure these, and other, requisite skills and competencies are obtained by students, close partnerships between curriculum developers, faculty, administrators, and industry partners are necessary, and are all planned as part of the proposed program. Further reinforcement comes from knowledge of the robust economic environment that the targeted regional employers

occupy. For example, New Jersey's Professional and Business Services industry sector is projected to grow at a rate comparable to the US as a whole. Specifically, the New Jersey Department of Labor and Workforce Development projects 7.5% employment growth for this sector between 2012 and 2022, which means 313,150 additional jobs. This sector is expected to achieve the second largest projected employment growth in New Jersey, behind educational and health services.

Regionally, Professional, Scientific and Technical Services is a basic industrial sector, meaning it is a segment of the local economy that serves non-local demand, with a location quotient of 1.45 and projected growth of 11.3% between 2012 and 2022. Location quotient measures the degree to which a given industry is concentrated in a given place and is used to identify basic industries in a specific area by comparing the percentage of employment in a particular industry in a local economy to that of the percentage of employment of the same industry in a larger/reference economy. Basic industries with location quotients greater than 1.0 have greater local economic shares of employment than their share within the reference economy. In this case, Burlington County has a 45% greater share of Professional, Scientific and Technical Services than the United States, which is the reference economy in this case.

While manufacturing in New Jersey is projected to decline overall, 90% of the projected net decline is in principally non-advanced manufacturing sectors: chemical manufacturing; plastics and rubber products manufacturing; printing and related support services; and paper manufacturing. Advanced Manufacturing is a significant industry sector for the state and the region. According to the Department of Labor and Workforce Development, New Jersey's Advanced Manufacturing Cluster contributed $30.6 billion to the Gross Domestic Product in 2012, or about 6.1% of all output. Three of its sectors are Fabricated Metal Product Manufacturing, Machinery Manufacturing and Computer/Electronic Product Manufacturing. Regionally, Burlington County's Machinery Manufacturing has a location quotient of 1.81 in reference to the State of New Jersey, and Fabricated Metal Manufacturing and Electrical Equipment Manufacturing have location quotients of 1.22 and 1.31, respectively, in reference to the State.

Curriculum and Pedagogical Developments

Associate of Applied Science in Mechanical Engineering Technology

The purpose of the Associate of Applied Science degree in Mechanical Engineering Technology (AAS.MET) is to prepare graduates to possess knowledge, problem solving ability, and hands-on skills to enter careers in the design, installation, manufacturing, testing, evaluation, technical sales, or maintenance of mechanical systems.

Graduates of associate degree programs typically have strengths in specifying, installing, fabricating, testing, documenting, operating, selling, or maintaining basic mechanical systems. Furthermore, Associate degree programs must demonstrate that graduates can apply specific program principles to the specification, installation, fabrication, test, operation, maintenance, sales, or documentation of basic mechanical systems depending on program orientation and the needs of their constituents [1].

Overall, MET programs, according to the Accreditation Board for Engineering and Technology, Engineering Technology Accreditation Commission (ABET-ETAC), must have an applied basis in engineering mechanics/sciences.

Need for the Program

The mission of the AAS.MET program is to support the needs of the manufacturing and service industry in Burlington County, the State of New Jersey, the United States, and worldwide. The program will prepare students to become technologists who can respond effectively to the changing needs of the global marketplace in the field of Mechanical Engineering Technology.

The latest available data from the Bureau of Labor Statistics (BLS) shows that the number of jobs in 2017 in Mechanical Engineering Technology fields was 46,100 with a prediction to increase up to the year 2026 [2]. An Associate degree was shown to be the typical entry-level education required in the industry with a median annual wage for machinery manufacturing to be $55,360. These figures justify the need and future viability of such a program.

The targeted population for this educational pathway includes those individuals who do not currently possess a college degree, as well as those who may already hold a college degree and seek training aligned with this viable career path. To prepare the targeted population to fulfill these needs, the program will focus on applying theories and hands-on skills in the development of marketable products, efficient processes, and designs that reflect an awareness of how technology meets the needs of society today and in the future. Further, the AAS.MET program will provide extensive classroom study along with laboratory explorations. The degree is being developed based on the Engineering Technology Accreditation Commission (ETAC) of the Accreditation Board for Engineering and Technology, Inc. (ABET) accreditation standards. One of the long term goals of the program is to obtain ABET accreditation ensuring the quality, efficiency and effectiveness of its future graduates.

Additionally, the Burlington County Institute of Technology (BCIT) has close ties to the regional K-12 community. BCIT's engagement with this educational segment will greatly enhance the number of prospective students who have an interest in the new MET program. By engaging young students with activity-filled learning opportunities, coupled with the efforts of RCBC, substantial awareness and interest can be achieved for the new MET program.

Program Outcomes

The AAS degree in MET will have a concentration in Advanced Manufacturing and will focus on MET principles which serve the developing industrial areas that are highly reliant on computer controlled and automated systems, as well as those making use of novel technologies including big data and analytics, automation and robotics, additive manufacturing, advanced materials, and biotechnologies.

The program is designed to be a two-year (AAS) degree that is transferable to the junior year of a Bachelor of Science degree program in Mechanical Engineering Technology (MET) that is under development through a partnership with Rowan University.

Aligning with the ABET-ETAC requirements, the student outcomes of the program will include:

a) an ability to select and apply the knowledge, techniques, skills, and modern tools of the discipline to broadly-defined engineering technology activities;
b) an ability to apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require limited application of principles but extensive practical knowledge
c) an ability to conduct standard tests and measurements; to conduct, analyze, and interpret experiments
d) an ability to function effectively as a member of a technical team
e) an ability to identify, analyze, and solve narrowly defined engineering technology problems;
f) an ability to apply written, oral, and graphical communication in both technical and nontechnical environments; and an ability to identify and use appropriate technical literature
g) an understanding of the need for and an ability to engage in self-directed continuing professional development;
h) an understanding of and a commitment to address professional and ethical responsibilities, including a respect for diversity
i) a commitment to quality, timeliness, and continuous improvement.

The above-listed student outcomes will be assessed through a variety of direct and indirect measures. Quiz and exam questions and project deliverables will be designed throughout the curriculum, such that all outcomes are assessed by these direct measures. Rubrics similar to those for the RCBC's current ABET accredited Electronic Engineering Technology (EET) program will be used for these assessments.

Additionally, indirect measures such as student, employer and alumni surveys will be used to determine if these stakeholders believe that the program is producing students who attain the identified student outcomes. The feedback from the surveys will also provide useful information to evaluate and improve the program, and "close the loop" per the requirements of the ABET.

AAS.MET Curriculum and Structure

Students pursuing the AAS degree in Mechanical Engineering Technology must meet the following RCBC General Education requirements shown in Table I.

Table I. AAS General Education Requirements

Written and Oral Communication – 9 credits	**Arts and Humanities – 3 credits**
ENG 101 College Composition I ENG 105 Technical Writing SPE 102 Public Speaking	ART 101 Introduction to Art MUS 101 Introduction to Music PHI 101 Introduction to Philosophy THR 101Introduction to Theater
Mathematics – 3 credits	**Social Science – 3 credits**
MTH 130 Precalculus	SOC 160 Society, Ethics and Technology

Natural Science – 4 credits	**Additional Gen Ed Requirements – 3 credits**
CHE 115 General Chemistry I CHE 116 General Chemistry I Laboratory	MTH 118 Calculus I

The full AAS curriculum, including the sequence by year and semester for MET program courses, is outlined in Table II. Courses listed with "xx" in the course code have yet to be developed.

Table II. AAS.MET Course Sequence by Year and Semester

Fall Semester			**Spring Semester**		
First Year					
Freshman Tech Clinic I	2	EGR 151	Freshman Tech Clinic II	2	EGR 152
College Composition I	3	ENG 101	Society, Ethics and Technology	3	SOC 160
Precalculus	4	MTH 130	Calculus I	4	MTH 118
General Chemistry I with Lab	4	CHE 115/116	Mat Sci and Manufacturing	3	ENGR 01.283
Intro to Comp Sci I	4	CSE 110	Circuits I	4	EET 121
	17			**16**	
Second Year					
Sophomore Tech Clinic I	1	EGR 215	Sophomore Tech Clinic II	1	EGR 216
Technical Writing	3	ENG 105	Public Speaking	3	SPE 102
ART 101, MUS 101, THR 101	3		Strength of Materials	3	ENGR 01.273
General Physics I with Lab	4	PHY 210/211	Intro to Mechanical Design	3	ME 10.101
Engineering Statics	3	EGR 201	Applied Thermal Energy I	3	MET 2xx
CNC Programming I	3	MET 2xx			
	17			**13**	

Course prerequisite requirements will be emphasized through RCBC's standard advisement processes in order to ensure students' progress through the curriculum in a timely manner.

The new program will be housed within the Department of Science, Technology, Engineering, and Mathematics (STEM). Existing full-time and adjunct faculty will be on-hand to teach, and faculty with a specialization in MET will join the teaching staff. Laboratory facilities are also in development.

Bachelor of Science in Mechanical Engineering Technology

At Rowan University, the Mechanical Engineering program has the highest enrollment of all engineering majors, and it turns away large numbers of highly-qualified students every year, owing to space and staffing limitations. Offering Mechanical Engineering Technology, as a "3+1" completion program, at RCBC will help to satisfy increasing student demand as well as provide employers in the state of New Jersey with a new source of highly skilled and talented workers.

Graduates of Baccalaureate programs in MET are expected to possess knowledge, problem solving ability, and hands-on skills to enter careers in the design, installation, manufacturing, testing, evaluation, technical sales, or maintenance of mechanical systems. Baccalaureate degree graduates typically have strengths in the analysis, applied design, development, implementation, or oversight of more advanced mechanical systems and processes. Baccalaureate degree programs must demonstrate that graduates can apply specific program principles to the analysis, design, development, implementation, or oversight of more advanced mechanical systems or processes depending on program orientation and the needs of their constituents.

Overall, MET programs, according to ABET-ETAC, must have an applied basis in engineering mechanics/sciences.

Need for the Program

The primary motivation for developing a program in MET at RCBC comes from the direct observations and experiences (of both RCBC and Rowan University) supporting the fact that there is a tremendous need for graduates to possess the skills and competencies valued by a critical and robust regional and state-wide industry.

The purpose of the BS MET program is to provide high quality educational opportunities needed to assist a diverse student population to achieve career goals in the field of mechanical engineering technology. Mechanical engineering technology involves understanding how products and machinery work as well as how to design, fabricate or use them. Examples of societal improvements due to mechanical engineering technology range from engines, air-conditioned environments, and jet aircraft.

The MET program is a career-oriented program that is expected to lead to an ABET accredited degree in Mechanical Engineering Technology. Owing to the broad nature of the MET program, graduates will have a variety of careers options. These include the design and development of products, machines, and processes, as well as manufacturing, operations, or technical sales. Industries that hire mechanical engineering technologists include transportation, power, climate control, machine design, manufacturing, materials, and automation. Based on regional technology program enrollment and job demand, the projected initial enrollment is 30 students per year.

Program Outcomes

The program educational objectives are that students will be able to:

•Communicate effectively
•Work effectively in teams
•Work within standards of professional integrity and conduct
•Problem-solve and work hands-on to be productive in the profession in areas involving analysis, applied design, specification, testing, development, implementation, and/or overseeing of more advanced mechanical systems and processes
•Be active participants in ongoing professional development, professional growth and increasing professional responsibility

The program is designed to be a two-year program that follows a two-year Associate of Science (AAS) in Mechanical Engineering Technology (MET) that is under development by RCBC. The first two years of the program (AAS.MET) will be followed by two additional years, and result in a four-year Bachelor of Science degree (BS MET). The third year of the program will be taught by RCBC as part of a "3+1" program, while the fourth year will be taught by RU on RCBC's campus, as will be discussed in the next section.

Accreditation of the program will be sought by the Engineering Technology Accreditation Commission (ETAC) of ABET. The following Baccalaureate degree requirements are taken directly from the ABET accreditation criteria:

a) an ability to select and apply the knowledge, techniques, skills, and modern tools of the discipline to broadly-defined engineering technology activities;
b) an ability to select and apply a knowledge of mathematics, science, engineering, and technology to engineering technology problems that require the application of principles and applied procedures or methodologies;
c) an ability to conduct standard tests and measurements; to conduct, analyze, and interpret experiments; and to apply experimental results to improve processes;
d) an ability to design systems, components, or processes for broadly-defined engineering technology problems appropriate to program educational objectives;
e) an ability to function effectively as a member or leader on a technical team;
f) an ability to identify, analyze, and solve broadly-defined engineering technology problems;
g) an ability to apply written, oral, and graphical communication in both technical and non-technical environments; and an ability to identify and use appropriate technical literature;
h) an understanding of the need for and an ability to engage in self-directed continuing professional development;
i) an understanding of and a commitment to address professional and ethical responsibilities including a respect for diversity;
j) a knowledge of the impact of engineering technology solutions in a societal and global context; and
k) a commitment to quality, timeliness, and continuous improvement.

The outcomes a-k will be assessed through a variety of direct and indirect measures. Quiz and exam questions and project deliverables will be designed throughout the curriculum, such that all outcomes are assessed by these direct measures. Rubrics similar to those for the ABET accredited Rowan Mechanical Engineering program will be used for these assessments.

Additionally, indirect measures such as student, employer and alumni surveys will be used to determine if these stakeholders believe that the program is producing students who attain the student outcomes. The feedback from the surveys will also provide useful information to evaluate and improve the program, and "close the loop" per the requirements of the ABET.

As an aside, an AAS (Associate of Applied Science) degree is designed to prepare students for employment and is, in many cases, a terminal degree. An AS (Associate of Science) degree is designed to enable students to transfer to a four-year Bachelor of Science degree program. RCBC has chosen the AAS over an AS degree in order to allow a student the option to enter the workforce after completing the two-year AAS MET program. The Rowan University BS MET program is designed such that a student wishing to pursue the BS degree can enter the BS MET degree completion program seamlessly and complete the degree with two additional years of study.

Students pursuing the BS degree in Mechanical Engineering Technology must meet the RCBC General Education requirements as outlined in Table I, as well as any additional Rowan University General Education requirements as outlined in Table III.

Table III. BS.MET Curriculum by Course Category

Category	**Number of Credits**
General Education	24 credits
Technology Clinic	14 credits
Mathematics	16 credits
Natural Sciences	16 credits
Engineering Fundamentals	16 credits
Advanced Manufacturing	15 credits
Engineering Science	16 credits
MET Electives	9 credits
Total	126 credits

Tables IV. and V. outline the Rowan University General Education and Core requirements, respectively.

Table IV. BS.MET General Education Requirements

Communications – 6 credits	**Social and Behavioral Sciences – 6 credits**
• ENG 101 College Composition I • ENG 105 Technical Writing	• SOC 160 Society, Ethics and Technology • ECO 203 Principles of Microeconomics
Science and Mathematics – 7 credits	**History, Humanities and Languages – 6 credits**
• MTH 130 Precalculus • CHE 115 General Chemistry I • CHE 116 General Chemistry I Laboratory	• PHI 101 Introduction to Philosophy • Course chosen from list of Humanities General Education courses
Artistic and Creative Experience	
ART 101 Introduction to Art MUS 101 Introduction to Music THR 101 Introduction to Theater	

Table V. Rowan University Core Requirements

Artistic Literacy	3	Class chosen from Artistic Literacy Rowan Core list
Communicative Literacy	9	ENG 101 College Composition I ENG 105 Technical Writing SPE 102 Public Speaking
Global Literacy	3	SOC 160 Society, Ethics and Technology
Humanistic Literacy	3	PHI 101 Introduction to Philosophy
Quantitative Literacy	3	MTH 130 Precalculus
Scientific Literacy	3	CHE 115 General Chemistry I

The full BS curriculum, including the sequence by year and semester for MET program courses, is outlined in Table VI. Courses listed with "xx" in the course code have yet to be developed.

Table VI. BS.MET Course Sequence by Year and Semester

Fall Semester			**Spring Semester**		
First Year					
Freshman Tech Clinic I	2	EGR 151	Freshman Tech Clinic II	2	EGR 152
College Composition I	3	ENG 101	Society, Ethics and Technology	3	SOC 160
Precalculus	4	MTH 130	Calculus I	4	MTH 118
General Chemistry I with Lab	4	CHE 115/116	Mat Sci and Manufacturing	3	ENGR 01.283
Intro to Comp Sci I	4	CSE 110	Circuits I	4	EET 121
	17			**16**	

Second Year					
Sophomore Tech Clinic I	1	EGR 215	Sophomore Tech Clinic II	1	EGR 216
Technical Writing	3	ENG 105	Public Speaking	3	SPE 102
ART 101, MUS 101, THR 101	3		Strength of Materials	3	ENGR 01.273
General Physics I with Lab	4	PHY 210/211	Intro to Mechanical Design	3	ME 10.101
Engineering Statics	3	EGR 201	Applied Thermal Energy I	3	MET 2xx
CNC Programming I	3	MET 2xx			
	17			**13**	
Third Year					
Junior Tech Clinic I	2	EGR 351	Junior Tech Clinic II	2	EGR 352
Calculus II	4	MTH 119	Humanities Course	3	
General Physics II with Lab	4	PHY 212/213	Calculus III	4	MTH 220
Engineering Dynamics	3	EGR 202	Applied Fluid Mechanics	3	MET 3xx
Applied Thermal Energy II	3	MET 3xx	Machine Design	4	ME 10.301
	16			**16**	
Fourth Year					
Senior Tech Clinic I	2	EGR 451	Senior Tech Clinic II	2	EGR 452
Introduction to Philosophy	3	PHI 101	Principles of Microeconomics	3	ECO 203
Advanced Manufacturing	3	ME 10.440	CNC Programming II	3	MET 3xx
Applied Heat Transfer	3	MET 3xx	Quality & Reliability	3	ME 10.342
MET Elective I	3	MET 4xx	MET Elective III	3	MET 4xx
MET Elective II	3	MET 4xx			
	17			**14**	

Novel “3+1” Program Delivery

As outlined through RCBC’s and RU’s partnership, RCBC will deliver the third year (of four) in the MET program, providing an affordable and accessible pathway toward the baccalaureate degree.

The partnership includes the following key provisions relating to delivery of the third year curriculum at RCBC:

- Rowan University will determine the content and the learning outcomes for the courses, ensuring that the learning outcomes will be the same.

- Rowan University will specify the credentials required for the professors chosen to teach the courses, and have the ability to review and comment on the curricula vitae of the professors who are being considered to teach the courses, but RCBC will be solely responsible for making the appointment.
- RCBC will be solely responsible for hiring the faculty and delivering the courses for freshman to junior-level courses.
- Faculty at both institutions will periodically review the operation and success of the program.

The fourth year of the degree program will be delivered by Rowan University, as RU courses in the RU degree programs, on the RCBC campus. The student's candidacy for the bachelor's degree will be evaluated solely by RU, and any certificates and degrees coming from this program at the baccalaureate level will be awarded solely by RU. RCBC has already been approved as an additional location where RU may offer degree completion programs.

"3+1" Program Delivery and Benefit to Students

The need for the proposed "3+1" program model stems from the rising affordability and debt crisis affecting many students who pursue higher education to improve the quality of their lives [3]. Far too many students find themselves saddled with insurmountable debt incurred through the process of earning college degrees. Many students have difficulty finding timely employment in a challenging economy or eventually become underemployed, thereby making it difficult if not impossible to pay off their student loan debt. The proposed "3+1" program gives students an extension of the already affordable community college pathway towards a baccalaureate degree, in industrially relevant disciplines, with the ability to take 300-level courses at a more affordable rate. Students will then transfer to the four-year university, i.e. Rowan University, to complete their baccalaureate degree.

Among the many benefits to students are:

- Being able to take the course at a location that is more convenient for them, in classrooms and with classmates that are already known to them.
- Paying tuition for the 300-level courses at the county college tuition rate.
- Paying tuition for the 400-level courses at a discounted RU rate if the course is taken on RCBC's campus.
- Avoiding many student fees that would be required if the student were to transfer and complete the degree on RU's campus.

Students participating in this "3+1 Program" will also be able to utilize the career services and placement office at RCBC which is more directly tied to the locale for in-field and internship requirements of the programs (where they exist), in addition to the career services (and larger alumni network) available at, and through, Rowan University.

Next Steps

The immediate next steps in the creation of the AAS.MET degree at RCBC, and the BS.MET degree at Rowan University include securing internal institutional approvals, as well as New Jersey State approvals.

An industry forum will be held during the Spring 2018 semester to bring industry partners together to review the curriculum outlines and to ensure that the previously identified technical and non-technical skills have been incorporated appropriately.

Additionally, an applications database highlighting real-word applications of the identified technical and non-technical skills will be created. Faculty will then have a source of examples from which to draw to clearly demonstrate to students the meaning and applications of the principles they are learning. The development of the applications database will include the creation of an Applications Database Team as well as faculty training.

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.

Contextualizing course material in this way will ensure that graduates possess the conceptual knowledge they need and have a deep 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.

Finally, courses developed for both the AAS.MET and BS.MET degree programs will be examined in terms of their cumulative impact for the purposes of creating stackable certificates and completion milestones within both the AAS and BS degree programs. For such stackable certificates, students may earn micro credentials in recognition of achieving competency milestones, based on select course completion, as they progress through the program.

Summary

The current project describes the close partnership between Rowan College at Burlington County (RCBC) and Rowan University (RU) in the development of an Associate of Applied Science degree in Mechanical Engineering Technology (AAS.MET) and a Baccalaureate of Science degree in Mechanical Engineering Technology (BS.MET). Both degree programs have been designed to meet the requirements of the ABET Engineering Technology Accreditation Commission (ETAC).

Both degree programs will be delivered on RCBC's campus, in newly created facilities, with RCBC teaching the first three years and RU teaching the fourth year as part of a novel "3+1" delivery model.

The outlined AAS.MET and BS.MET curricula will be well-aligned and will offer a seamless transition from the two-year program into the baccalaureate program.

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