Preparing The 21st Century Microsystems Engineering Technologist

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Abstract

The semiconductor industry anticipates that its current rate of rapid growth will be sustained for the foreseeable future, driven by the increasing growth of the electronic market. The construction of new fabrication units is creating a growing shortage of qualified technical support personnel. A unique curriculum is needed to educate the necessary personnel. Microsystems Engineering Technology (MSyET) is the unique curriculum, developed jointly with industry, which prepares technologists to support the design and manufacture of miniaturized electronic components and circuits in the semiconductor industry. New in this curriculum are its interdisciplinary contents, the method of course delivery and advanced learning techniques, integrating agility and concurrence through accelerated learning concepts and methods to establish a hands-on experiential learner-centered environment. A curriculum description, together with an impact, constitutes the paper's subject.

I. Introduction

A. Semiconductor Industry Growth

We stand at the dawn of the 21st Century. It appears that information is being discovered, related, and applied at an alarming rate. Technological innovations are reshaping every aspect of our lifestyles. As traditional methods and standards used for commerce development are extinguished before us, still others, new and technologically driven, appear on the horizon. The very ground into which we have driven the "stakes" of standards and progress measurement, is being “moved and shaken” by the tremors and full-scale earthquakes of technological change. The semiconductor industry has, in large part, been a catalyst in this process. Innovatively developing newer, smaller, denser and more efficient integrated circuit components, systems and devices to meet product demands, this industry has established an environment in which high function high technology products can be cost-effectively provided to the end user.

The semiconductor industry anticipates that its current rate of rapid growth will be sustained throughout the next decade and for the foreseeable future. Most notable among the drivers of this phenomenon is increasing electronic market growth. Consumer market demand for personal computers, cellular telephones and facsimile machines together with an emerging demand for high-definition television (HDTV), digital integrated camcorders and an array of other products yet to be introduced, is one segment of this growth. An expanded demand for broadband integrated services digital network (ISDN) services, together with the implementation of Asymmetric Digital Subscriber Line (ADSL), to support the coexistence of digital video, voice, and data within the same transmission medium is a second segment. This capability will enable the delivery of the next generation of services (electronic shopping, audio and video rentals and purchases, fully automated distributed banking) to the end user at home , in transit, at the office or wherever the end user is located. Another segment of the electronic market growth is the array of advanced display systems (flat panel, LED, Digital Light Processing) that will replace the cathode ray tube. These display units, supported by complex digital image processors, dynamic random access memories (DRAM), advanced sensors, and display drivers, will be integrated to form the human-machine interfaces that will provide easy access to, and greater control of, the environments in which we live, work, and travel. New technologies will greatly increase highway and automobile efficiency and safety. These technologies, referred to as the Intelligent Vehicle and Highway Systems (IVHS), will integrate satellite navigation (such as the Global Positioning System), voice and data communications, and radar-based collision avoidance systems in order to accomplish the intended goals.

B. Qualified Personnel Shortage

To support this phenomenal growth, many members of the global semiconductor industry are constructing multi-billion-dollar wafer fabrication units in record numbers. Entire technology parks are being devoted to the implementation of some of these units. Within the U. S. a record number of wafer fabrication units are being constructed with a significant percentage being located within the state of Texas in general, and in the Dallas/Fort Worth metroplex in particular. The equation that must be maintained in this process is a balance between facilities, materials, and personnel. An area of great concern within the semiconductor industry is the growing shortage of qualified technical personnel to support this industry. As new semiconductor fabrication units are constructed and put online, a significant number of new positions for people to support the technical needs of the facility are created.

The rate at which these new positions are developing by far outstrips the availability of people qualified to fill them. There does not exist a sufficient supply of semiconductor manufacturing equipment operators, technicians, equipment engineers, automatic test technicians, process engineers, yield enhancement specialists, failure analysis specialists, packaging specialists, safety engineers, and other technical specialists required to support the massive upsurge in semiconductor fabrication either to meet current or projected demands. This paper presents a proposed curriculum whose aim is to prepare qualified engineering technologists for Microsystems Engineering Technology (MSyET). In addition, the paper aims to serve as a template for the development and implementation of similar and related engineering technology programs at other universities.

The MSyET program, developed by this author for the Technology Department of the University of North Texas, has been designed to articulate with the Semiconductor Equipment Technician A.A.S.E.T. program implemented at Collin County Community College. Other local community colleges are also implementing programs to articulate with the University of North Texas' MSyET program. The preparation of qualified personnel from among workers already in the industry is further complicated by their unusual work schedule. Traditional methods of course and curriculum delivery are not acceptable.

C. Microsystems Engineering Technology (MSyET)

Microsystems Engineering Technology (MSyET) involves the application of knowledge that includes the industrial arts, applied sciences, and engineering which support the design and manufacture of miniaturized electronic components, circuits, and subsystems in the semiconductor industry. Microsystems Engineering Technology is an educational discipline that prepares qualified candidates to competently perform professional duties of a Microsystems Engineering Technologist at the Bachelor of Science or Master of Science degree level. The Microsystems Engineering Technologist must have a clear overview understanding of the electronics industry, integrated circuit concepts and their construction. In addition, the Microsystems Engineering Technologist must possess vivid awareness of the semiconductor business environment, the product development cycle, and the organization of the semiconductor industry. Finally, the Microsystems Engineering Technologist is concerned with the particulars of integrated circuit fabrication, including chemistry and physics of semiconductor materials, crystal growth and wafer preparation, oxidation of silicon, photolithography, impurity introduction and redistribution, epitaxial deposition, nonepitaxial chemical vapor deposition, metallization, device processing, device and IC technologies, the wafer fabrication environment, semiconductor measurements, advanced silicon technology, and nonsilicon technology. Adequate steps to assure quality must be well understood. These include measurement techniques and statistical process control.

Since Microsystems Engineering Technology is a new interdisciplinary curriculum, it is important that faculty members, who lack appropriate industry experience and who intend to teach courses therein, spend time becoming acquainted with the semiconductor industry. One method to time-efficiently accomplish this task is through a faculty internship.

II. Summer Faculty Internship

During the summer of 1996, this author participated in a unique Summer Faculty Internship at TwinStar Semiconductor in Richardson, Texas. This internship was unique from two perspectives. First, TwinStar, a relatively new joint venture between Texas Instruments and Hitachi, had never offered an internship; and second, this author had little expertise in the semiconductor industry. TwinStar was still in the startup phase of its new $500,000,000.00 semiconductor fabrication unit. Mr. James Watson, TwinStar's President, recognized the need for his employees to have the educational opportunity to continually upgrade their technical competencies. He had been working with the Advanced Technology Advisory Board of Collin County Community College to develop and implement a curriculum template to provide these needs at the associate and bachelor levels. Dr. Albert B. Grubbs, Jr., UNT Engineering Department Chair, had been involved in a number of activities involving microelectronics and the semiconductor industry including actively participating as a member of the Partnerships for Advanced Manufacturing Technology coalition. This coalition consists of Collin County and Richland County Community Colleges, and the University of North Texas as the collegiate partners, together with Cyrix, TwinStar, and Texas Instruments as the industry partners. Dr. Grubbs requested the internship and Mr. Watson arranged for it to occur. Because Texas Instruments had a companion interest in a new educational program, they jointly sponsored the internship.

For twelve weeks the author was assigned to the Failure Analysis Group, which provided exposure to problems encountered in early production phases. In addition, Mike Watson, the Plant Manager, provided open access to the daily plant meeting in which all of the day's production problems were presented and discussed. This opportunity enabled the author to gain a clear overview of production process steps and the technical challenges accompanying them. These meetings also gave the author access to process and systems engineers, who assisted greatly in tailoring a list of advanced manufacturing technical competencies to meet the needs of the semiconductor industry, together with the curriculum development and review.

III. Microsystems Competency Requirements

In order to meet the challenge of an ever-increasing rate of technological change, education must respond by creating an environment that is conducive to the effective competencies and the transfer of technological skills. Two widely used advanced manufacturing terms are agility and concurrency. Agility means flexibly adapting to unexpected system changes, while concurrency means the simultaneous execution of multiple manufacturing stages. These very concepts of agility and concurrency must be applied to the technology education process. Curriculum should not be developed in the absence of industry involvement. The educational needs of industry must be clearly defined, articulated, and warmly received by the educational community. For appropriate learning to occur near optimal demonstration or simulation of the object of learning must be provided. "Show and tell" is still the best concept or idea translator since "a picture is worth a thousand words".

In order to perform his or her duties productively, the Microsystems Engineering Technologist must possess a specific set of competencies. The semiconductor industry understands what these competencies are. Viewed from the highest level these macro-competencies are stated below. They are modifications of those developed by the Coalition for New Manufacturing Education.

1. Know Self & Work With Others
2. Plan, Implement, & Manage High Value Added Production/Process Systems
3. Solve Unstructured, Unsolved Problems
4. Lead Change

The macro competency "Know Self & Work With Others" includes teaming, mentoring, self-examination and personal growth, together with written and verbal communications. **"**Plan, Implement, & Manage High Value Added Production/Process Systems" is the technical competency which embraces strategic planning, process system design and development, quality assurance, continuous improvement, and operation of process equipment. The ability to access information and knowledge, design experiments, develop predictive models, apply and refine models, and develop and present knowledge, constitute the "Solve Unstructured, Unsolved Problems" competency. Finally, the competency "Lead Change" incorporates the ability to seize opportunities, leverage history, innovate, value other cultures, optimize globally, articulate a vision, and continuously improve. Each of these macro-competencies is expanded into sub-competencies in Appendix A.

IV. Curriculum Content

A draft of a curriculum to meet the industry-approved competencies has been developed. It is entitled the Microsystems Engineering Technology (MSyET) Program. August 1997 is the planned date for the initial offering of the Microsystems Engineering Technology (MSyET) Program. A complete draft of this program is presented in Appendix B.

Although the first year of this innovative program is primarily devoted to the study of mathematics, sciences, and communication skills, the Microsystems Engineering Technology student is exposed to the semiconductor manufacturing process during the first semester. More semiconductor manufacturing knowledge is presented during the second year, together with electronics, physics, and political science. Technology details are further presented in year three, along with world literature, history, English and economics. Year four enables the student to technically specialize for the area of his or her specific interest. Senior Project, a capstone course, encourages the application of essentially all of the student-acquired competencies.

The entire curriculum is being developed to articulate with community college two-year programs like the Semiconductor Manufacturing Technology program being developed by Collin County Community College. The university's cooperation with a large number of the regional community colleges assures exposure of this educational opportunity to a wider audience of potential students.

The Microsystems Engineering Technology (MSyET) Program has been designed to meet or exceed the requirements for accreditation of the Technology Accreditation Commission (TAC) of the Accreditation Board for Engineering and Technology (ABET). In addition, MSyET also meets all of the University of North Texas and College of Arts & Sciences core curriculum requirements (see Appendix C.).

V. Curriculum Delivery

Can you remember the last time that learning was fun for you? After considering this question carefully, you'll probably conclude that at about third or fourth grade, learning in school stopped being fun and became hard work. As Dr. Michael Kozak states, "Learning does not occur in total control nor in total chaos; learning occurs in controlled chaos." Have you ever watched kindergartners and first graders functioning in their learning environments and wondered what caused the great joy they exuded, or pondered how they could possibly be learning anything in the midst of all the excitement surrounding them? If you're anything like me, you may even have commented, "What a crazy house environment!" "I could never teach in a setting like this."

It is this author's conviction that this is exactly the environment that needs to be recreated and established for all education in general, and in college and university environments in particular. In order to be classified as a near-optimal learner-centered environment, it must be an environment in which knowledge is transferred most efficiently and learning occurs at a highly accelerated pace. The learner becomes engrossed in and a part of the learning process and the acquisition of knowledge becomes desirable and actively sought.

This concept is easy and simple to prove. Simply observe any youngster in the process of operating a video game. It is not necessary to inform the youth that s/he is exercising a sophisticated computer-based environment. It isn't even necessary to tell them that complicated application and systems software is operating. Expose them to how the system is started, and they'll figure the rest out. This is learning at its best.

Economic competition has become a global matter. Educational institutions worldwide need to reexamine and modify the manner in which the principles, concepts and ideas that affect technology transfer and competency building are expressed and conveyed. These institutions need to produce an environment in which location and distance are removed as learning inhibitors by a real-time, hands-on, learner-centered, virtual-reality, computer-driven, next generation distance learning platform (NGDLP). In order to migrate to this environment, the capability for learner-centered teaming must exist across all selected learner node sets, thereby producing the virtual laboratory.

Today's learners are rapidly loosing interest in the bulk-packaged educational extravaganza deals offered in the mass production lecture-centered teaching environment of the past and present. The informed student is expecting a creativity-stimulated, interest-quickened, knowledge-based, learner-centered environment in which knowledge is transferred via a communications-sensitive, knowledge-based, dual-team-oriented, professional class facilitator. The expectation is for an environment in which learner-centered information is computer-based; an environment in which location and distance are made ineffective learning inhibitors by a real-time, hands-on, learner-centered, next generation distance learning platform (NGDLP).

For an engineering technology program, the requirements are further tightened. The accrediting-imposed mandate of these programs require that the graduate, at any exit point (associate, bachelor, master) have an immediately employable skill. To accomplish this mandate, the learning environment must be hands-on experiential. The engineering technology laboratory provides for this requirement in the traditional learning environment. In the 21st Century distributed or virtual learning environment, this hands-on experiential requirement demands that the virtual laboratory be a part of the Next Generation Distance Learning Platform (NGDLP).

The University of North Texas has recently funded a project to implement the first phase of a virtual laboratory for the NGDLP. The investigator's work in this project will focus on developing and demonstrating a learner friendly virtual laboratory environment that readily lends itself to remote access. The investigator will use the LabView (graphical Programming for Instrumentation) computer application programs as the fundamental development platform. LabView enables a microcomputer to simulate a variety of electronic instruments. LabView, the computers and the interface boards are already installed in the Engineering Technology Department's Analog Electronics Laboratory. The investigator will integrate these components into a learner friendly system conducive to providing laboratory access at a distance.

It's quite common for the modern undergraduate engineering technology student to be middle-aged and employed full-time. The twelve-hour dynamic work shift, typical of the semiconductor fabrication industry, makes on-site course delivery highly desirable. Course delivery via a distance learning platform incorporating hands-on experiential capabilities, is the goal of this uniquely delivered curriculum.

VI. Summary

The semiconductor industry is currently experiencing a severe shortage of Microsystems Engineering Technologists. Working cooperatively with education, the semiconductor industry is depending upon education to implement a curriculum to address this need. The University of North Texas, in cooperation with Collin County Community College, has developed a Microsystems Engineering Technology (MSyET) Program with plans to initiate onsite delivery via distance learning methods in August 1997. Ultimately, this course delivery mechanism must be highly experiential, that is, the delivery platform must incorporate hands-on, practical, industrial virtual experiences which are accessible by the learner. In order to implement this kind of learning environment widely, innovative products and educational tools must be introduced to the educational marketplace. Appropriate emerging products and tools include Mathlab and Virtual Instruments.

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Biography

ROY C. SHELTON, JR. is an Associate Professor in the Engineering Technology Department at the University of North Texas in Denton, Texas. He teaches and conducts research in the Electronics Program. Mr. Shelton has participated in the NSF sponsored Advanced technical Education (ATE) Alliance coordinated by the Consortium for Advanced Manufacturing International (CAM-I). He is a participant in the development of the MSyET Curriculum.

Appendix A. Expanded Competencies of the Microsystems Engineering Technologist

A modified expansion of these competencies, reviewed by representatives from Texas Instruments and TwinStar Semiconductor, is presented below.

1. Know Self & Work With Others

A. Examine & Evolve Self
B. Act Ethically
    Act Professionally
C. Communicate
    Media
    Communicate Technical Data in Layman's terms
    Foreign Languages
D. Team
    Able to contribute effectively and develop into leadership of interdisciplinary and multicultural product/process team with understanding of group dynamics and the ability to apply a variety of problem solving or team process "tools" (e.g., value engineering)
    Lead technical teams and supporting personnel; Supervise, coordinate and review the work of a staff of technologists, technicians, and designers; schedule and assign tasks.
E. Mentor

2. Plan, Implement, & Manage High Value Added Production/Process Systems

A. Develop a Production/Process Strategic Plan
    Create a vision for the production process.
    Create design for production guidelines for the vision
    Participate in product and process feasibility reviews

Develop a business plan

B. Design & Implement Process Systems

Participate with product engineers, technologists & technicians to design product

Design Processes

Specify equipment and tools to be purchased

Analyze material handling systems

Analyze facilities

Integrate human elements

C. Insure that product and process meet quality objectives

Understand the principles of total quality management and control, product and process reliability, process safety, testing and certification, and developments in the field of quality engineering and management

Ability to perform wide variety of inspection. Perform laboratory measurements and geometric inspection and interpretation of data obtained from tools for precision engineering and technology measurement.

Strong skills in statistical analysis and ability to apply statistical tools (SPC)for troubleshooting and problem solving

Develop a control system and prepare associated logic diagrams

Understand, develop and apply instrumentation for the control of automated systems.

Automate material handling system control

Basic knowledge of PLC operation and rudimentary programming

Develop training plans for people

Specify environmental equipment and controls

Validate the cost effectiveness and reliability of operations

D. Support the Continuous Improvement of Process Operations

Recommend objectives for schedule, people, quality, equipment performance, and material.

Maintain equipment and associated control logic.

Actively participate on team to troubleshoot process problems

Analyze performance of and continuously improve fab process

E. Run Process Equipment

Operator

Test and Analysis

Quality Control

Supervisor

3. Solve Unstructured, Unsolved Problems

A. Access Information and knowledge

Leverage Information Systems

Grasp scientific principles

B. Design Experiments

C. Develop Predictive Models

Visualize and articulate geometric concepts

Leverage existing deterministic and stochastic models

D. Apply & Refine Models

Apply scientific principles

Apply computer technologies

Analyze engineering and technology problems, detail

E. Create & Present Knowledge

4. Lead Change

A. Seize Opportunities

Identify gaps in customer satisfaction

Respond rapidly and urgently to customer demand

B. Leverage History
C. Innovate
D. Value Other Cultures
  Respect Diversity
E. Optimize Globally
  Plan strategically and tactically to gain competitive edge in the international market place
  Monitor global developments
  Understand the framework within which semiconductor fabrication operates
F. Articulate a Vision
G. Continuously Improve
  Profit
  Quality
  Customer Satisfaction
  Competitive position
  Profession
  Society

Appendix B. The Microsystems Engineering Technology (MSyET) Program Draft

D-R-A-F-T : Microsystems Engineering Technology (MSyET) Program
University of North Texas; Engineering Technology Department

FIRST YEAR

Fall Semester

CHEM1420	***General Chemistry***	***3***
CHEM1440	***General Chemistry Lab***	***1***
ENGL 1310	***College Writing I***	***3***
MATH1650	***Pre-Calculus***	***5***
MSyET 1700	***Semiconductor Manufacturing 1***	***3***
		15

Spring Semester

COMM2040	***Public Speaking***	***3***
CSCI 1110	***Program Development***	***3***
ELET 1700	***Circuit Analysis I***	***4***
MATH1710	***Calculus 1***	***4***
PHYS 1710	***Mechanics***	***3***
PHYS 1730	***Lab in Mechanics***	***1***
		18

SECOND YEAR

Fall Semester

ELET 1710	***Circuit Analysis II***	***4***
ELET 1720	***Electronics I***	***4***
ENGL 2700	***Technical Writing***	***3***
GNET 1030	***Technological Systems***	***3***
MATH 1720	***Calculus II***	***3***
		17

Spring Semester

ELET 2720	***Digital logic***		***4***
ELET 2740	***Electronics II***		***3***
MSyET 2370	***Semiconductor Manufacturing Process***		***3***
PHYS 2220	Electricity & Magnetism		3
PHYS 2240	Lab in WM,Elec,Mag, & Optics		1
PSCI 1040	***American Government***		***3***
			17

THIRD YEAR

Fall Semester

ENGL 2220	***World Literature***	***3***
HIST 2610	***United States History to 1865***	***3***
MEET 4XXX	Thermal Science Applications	3
MSCI 3700	Statistics I	3
MSyET 3510	Electronic Properties of Materials	4
		16

Spring Semester

ENGL 2210	***World Literature***	***3***
ECON 1110	***Principles of Macroeconomics***	***3***
HIST 2620	***U.S. History Since 1865***	***3***
MFET 4190	Quality Assurance	3
MSyET 3530	VLSI Design and Technology	4
		16

FOURTH YEAR

Fall Semester

MSyET 45xx	Technical Elective	4
MSyET 45xx	Technical Elective	4
PSCI 1050	***American Government***	***3***
PHED 1000	Scientific Principles and Practices of Health-Related Fitness	2
XXXX 3XXX	Visual & Performing Arts	3
		16

Spring Semester

MFET 4190	Fusion Joining &Adhesive Bonding	3	
MSYET 4540	Process Instrumentation		3
MSYET 4590	Senior Project		2
MSYET 4XXX	Technical Elective		3
XXXX 3XXX	Understanding of Ideas & Values		3
			14
			129

MSyET 1700 Semiconductor Manufacturing 1

An introduction to the high technology field of reliably manufacturing very high-density micro-electronic circuits onto silicon wafers. Safety considerations: Facility emergency actions, hazardous communications, personal protective equipment, chemical safety, electrical safety, compressed gasses, laser safety, radiation safety, ergonomics, and fire safety. Manufacturing Process Overview; introduction to CMOS devices. Introduction to the semiconductor process. Statistical Process Control guidelines. Prerequisite: consent of instructor.

MSyET 2510 Semiconductor Manufacturing Process
An in-depth study of the semiconductor manufacturing process including: material preparation, epitaxial growth and thin film deposition, oxidation, photolithography, plasma processing, diffusion, ion implantation, metallization, wafer-probe test, assembly and final test. Prerequisites: CHEM 1410, MSYET 1700 Semiconductor Manufacturing 1, CSCI 1110.

MSyET 3510 Electronic Properties of Materials
To introduce the student to the electronic structure and properties of crystalline and non-crystalline materials. Band theory is discussed and applied to conducting, semiconducting, and insulating materials. Structure and properties are related. Prerequisite: consent of instructor.

MSyET 3530 VLSI Design and Technology
An in-depth study of the current technology employed in the design capabilities and limits of very large scale integrated analog and digital circuits. Prerequisite: Consent of instructor.

MSyET 4540 Process Instrumentation
A study of process instrumentation principles and their application. Analog, digital and hybrid instrumentation techniques are studied and applied in a laboratory setting. The principles of automatic testing, data acquisition, and data logging are surveyed. Prerequisite: ELET 1720, ELET 2720.

MSyET 4590 Senior Project
The implementation of a significant engineering technology project. Project teams specify, plan, design, patent search, market validate, implement, test and demonstrate an integrated circuit electronic product or fabrication process modification. Substantial oral and written documentation required.
Prerequisites: completion of all required Microsystems courses.

MSyET 4581 Design of Electronic Experiments
A study of the fundamental concepts involved in the design and analysis of engineering experiments, with a strong emphasis on practical applications. The organization of experiments so that the results will be statistically significant; methods of analysis and presentation of data. Prerequisite: MFET 4190.

MSyET 4582 Failure Analysis Techniques
A study of the methods and procedures for the identification, quantification, and analysis of various failure modes in semiconductor materials, integrated circuits, and packaging. Prerequisite: MSYET 3XXX

MSyET 4583 Yield Enhancement
A study of the methods and procedures for increasing the production yields of semiconductor devices through the reduction of defects the enhancement of manufacturing controls. Prerequisite: MSYET 4XXX Failure Analysis Techniques taken concurrently.

MEET XXXX Thermal Science Applications
To introduce the engineering technology undergraduate not majoring in mechanical engineering technology to the basic concepts of thermodynamics, fluid dynamics, and heat transfer.

MFET 4XXX Fusion Joining &Adhesive Bonding
Principles of brazing, soldering and adhesive bonding are studied. Relationships between processing conditions, filler materials and adhesives, base materials, joint geometry, and their influence on joint integrity are discussed. Applications to microelectronics processing are emphasized.

Appendix C. University of North Texas and College of Arts & Sciences Core Curriculum Requirements

University of North Texas
Core Curriculum Requirements

1. Written and Information Access (6 hours): This requirement is satisfied by ENGL 1310 College Writing I and ENGL 2700 Technical Writing.

2. Literature (6 hours): This requirement is satisfied by ENGL 2210 World Literature and ENGL 2220 World Literature.

3. American History (6 hours) This requirement is satisfied by HIST 2610 United States History to 1865 and HIST 2620 U.S. History Since 1865.

4. Political Science (6 hours) This requirement is satisfied by PSCI 1040 American Government and PSCI 1050 American Government.

5. Economics (3 hours) This requirement is satisfied by ECON 1110 Principles of Macroeconomics.

6. Physical and Life Sciences (6-8 hours): This requirement is satisfied by CHEM 1420 General Chemistry, CHEM 1440 General Chemistry Lab, PHYS 1710 Mechanics PHYS 1730 Lab in Mechanics.

7. Mathematics (3 hours) This requirement is satisfied by MATH1710 Calculus 1.

8. Wellness Skills (2 Hours) This requirement is satisfied by PHED 1000 Scientific Principles and Practices of Health-Related Fitness.

9. Visual and Performing Arts (3 hours)): This requirement is satisfied by XXXX 3XXX Visual & Performing Arts.

10. Understanding of Ideas and Values (6 hours)

    Group I Social Sciences and Philosophy (3 hours): This requirement is satisfied by XXXX 3XXX Understanding of Ideas & Values.

Group II Cross-cultural and Global Studies (3 hours): This requirement is satisfied by GNET 1030 Technological Systems.