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Establishing A Community College Pathway to Baccalaureate Systems Engineering Programs

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Abstract

A fundamental principle guiding engineering course schedules and student advisement at Piedmont Virginia Community College (PVCC) is to offer courses a student would take in his/her second year at target universities to minimize the chance that s/he would be on the "five (plus) year plan" after transfer. We describe how the model is implemented with respect to systems engineering in this paper. Planning for this new academic track took place in Fall, 2011; the pilot of the *Introduction to Systems Engineering* course occurred in Spring, 2012 and Fall, 2012. The course is consciously structured after the introductory course at the University of Virginia (UVa), the transfer target for a majority of PVCC students, to ensure that the transfer credit is accepted and students are prepared for success. Based on our experiences in the pilots, the syllabus became slightly modified to prepare students for study in other undergraduate programs in systems engineering. Course goals, objectives, and content are described. Finally, we offer student reflections on their experiences and course utility as they prepare to transfer to university engineering programs. The availability of the second year systems engineering courses proved to be attractive to both students who want to major in systems engineering as well as students wanting to fulfill technical electives. It is our hope that this model will inspire adoption by other community college – university partnerships as a means of increasing the number of students preparing for careers in systems engineering.

Introduction

Systems engineering is an increasingly valuable discipline, given the increasingly complex and inter-related products and processes we work and live with on a daily basis. Systems engineers, trained to visualize and manage the "big picture," have the knowledge, skills, and abilities (KSAs) to evaluate all facets of a system, such as stakeholder values, risk, quality, and policy implications in addition to the process or physical system, and develop sets of recommendations and action plans. The value of these KSAs to industry, government, and academia can be seen in the growing demand for systems engineers, with one source anticipating a 45% increase in demand for practitioners from 2009 to 2019.[1] However, systems engineering is not the only discipline in the science, technology, engineering, and mathematics (STEM) fields calling for increased numbers to meet projected demands, and therefore face competition for and potential shortage of students.[2] A root cause for this shortage is that the traditional K-16 pipeline has not provided sufficient numbers of practitioners for at least two decades.[3, 4] More tellingly, the traditional pipeline has not been able to deliver students from underrepresented populations in STEM - females, African Americans, Hispanic Americans, Native Americans and Alaskans, and Native Hawai'ian and Pacific Islanders as well as the disabled and those from disadvantaged socio-economic backgrounds – to practice in numbers representational to their share of the US population despite the many solid, research-based K-16 initiatives offered by universities throughout the nation. One reason, rarely acknowledged, is that K-16 students who "leak" out of the pipeline tend not to be re-recruited or otherwise face obstacles to rejoining their STEM studies. Students leave the pipeline for myriad reasons, such as lack of effective mentoring and lack of confidence in their math and science skills.[5] There are also students who realize that a

STEM career is a good fit for them once outside of the K-16 pipeline. For these students, and others, community colleges offer a reasonably priced educational alternative with a supportive atmosphere in which they can prepare for university studies in a STEM discipline.

Community colleges, therefore, are a good source of students – especially of students from underrepresented populations in STEM – for baccalaureate systems engineering programs.[6-8] It is a source, however, that is underutilized. The vast majority of community college engineering (science) for transfer programs concentrate on classes that support future studies in civil, computer (science), electrical, and mechanical engineering, leaving students who would like to study systems engineering to fit classes in the major into their third and fourth (and, likely, fifth) years.[9] Programs focusing on "systems engineering" train students to be maintenance technicians for electrical or mechanical-based systems or computer network administrators while duly acknowledging the work of and need for "systems engineers" in their mission statements; see, for example, the programs at the Community College of Allegheny County (PA)[10], Community College of Rhode Island[11], and Cuyahoga (OH) Community College[12]. There is, therefore, a great opportunity to create a pathway to a baccalaureate degree in systems engineering within the community college system.

An expansion of an interdisciplinary undergraduate engineering program at UVa, the Technology Leaders Program (TLP)[13], to PVCC, provided the opportunity to implement such a pathway. A required core course for the TLP is SYS 2001, *Systems Engineering Concepts*. Having an analogous course at PVCC meant that our students could participate fully in the TLP.

We begin with describing the engineering program at PVCC. The first course to be piloted in this new pathway, *Introduction to Systems Engineering*, is described. Preliminary conclusions on the efficacy of this course are provided, along with student testimony, and directions for future growth and partnerships.

Engineering at PVCC

The engineering program at PVCC, led by program director and associate professor Ali Bouabid, is designed to support transfer to a baccalaureate program in engineering. Computer science, which has programs both inside and outside schools/colleges of engineering, is a separate program, although the programs are in the same division, Business, Mathematics, and Technology.[14] The majority of students in the engineering program are preparing for transfer to UVa's School of Engineering and Applied Science. Other transfer targets are George Mason University, Fairfax; James Madison University, Harrisonburg; Old Dominion University, Norfolk; Virginia Commonwealth University, Richmond; and Virginia Polytechnic Institute and State University, Blacksburg. At this time, only two schools in the Commonwealth – UVa and George Mason – offer baccalaureate studies in systems engineering. Virginia Tech and ODU offer graduate degrees in systems engineering.

PVCC students are residents of an incorporated city and five surrounding counties; attending UVa would allow them to remain in their communities. Figure 1 shows the general location of PVCC and UVa. To support student transfer to these universities, engineering course offerings and sequences are deliberately set to provide a seamless transition to third year/junior studies.

That is, PVCC students take the same courses that their university cohorts take in the first two years. As will be seen in the student testimonies, this seamless transition is exceedingly important to all but especially so to students with families and/or funding limitations. They literally cannot afford a 2+3 or 4 – five or six year – timeline for obtaining their baccalaureate degree.

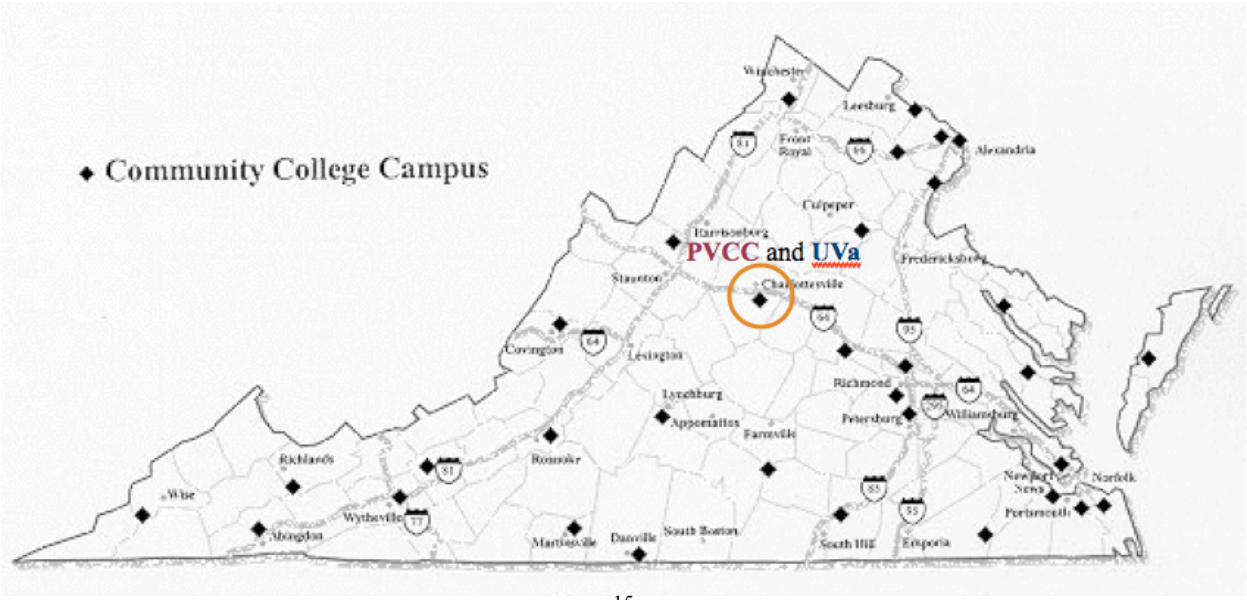

Figure 1 Community Colleges in Virginia[15]

This ability to provide a seamless transfer can be, unfortunately, difficult to offer for several reasons, including general education requirements[16] and a lack of major-specific courses. A review of transfer plans for several community college – university partnerships in Industrial and Systems Engineering (ISE) show that the university's second year courses, which are typically the first courses in the major, are not offered at the partnering community colleges.[10, 17] Community college students, therefore, transfer in at a disadvantage and start out on a 2+3 year plan primarily due to restricted offerings of core courses (e.g., fall only) and the structuring of pre-requisite sequences.

A seamless transfer as a third year to UVa's Department of Systems and Information Engineering (SIE) means that the department's second year courses, *Systems Engineering Concepts* (SYS 2001, fall only) and *Data and Information Engineering* (SYS 2202, spring only), need to be reproduced at PVCC. We developed the PVCC *Introduction to Systems Engineering* course first and piloted it in the Spring, 2012 semester. This course is also required for participation in the TLP, regardless of major. The PVCC version of *Data and Information Engineering* was piloted in the Spring, 2013 semester.

The PVCC and the Department of Systems and Information Engineering (for the first two years) Undergraduate Plans of Study are provided in Appendix A.

EGR 295: ***Introduction to Systems Engineering***

The goals and content of the pilot version of this course were based directly on those of the Fall, 2011 offering of SYS 2001. The personal relationships among the principals admittedly facilitated this connection. Susan Donohue was the teaching assistant for SYS 2001 in Fall, 2005, working with one of the current SYS 2001 instructors. She was also the teaching assistant for the graduate version of the course, SYS 6001, when Benjamin Blanchard, professor emeritus of Systems Engineering, Virginia Polytechnic Institute and State University and co-author of a seminal text[18] in the discipline, taught the course. Ali Bouabid is completing his dissertation in the department. The current SYS 2001 instructors, Reid Bailey and Michael Smith, gave Donohue full access to course materials. See Appendix B for the description, goals, and objectives of the PVCC course, which are based on those for SYS 2001. Course topics are also outlined in Appendix B.

The Spring, 2012 pilot also used the same text[19] as SYS 2001: *How to Do Systems Analysis*. The primary author was a founder of the Department of Systems and Information Engineering, John (Jack) E. Gibson; William T. Scherer and William F. Gibson, a student and child, respectively, of Gibson's, got Gibson's notes text-ready and published. Both courses used the case study method as the primary method of instruction. Case studies were team assignments, and homework and exams were completed individually.

Case study topics are non-trivial issues facing local communities, some of which may have regional or national impact. Using local issues helps the students focus on the analysis; they are familiar with the issues, the actors, and background and so do not have that learning curve to deal with. The issues are carefully selected to appeal to the students' wide ranges of age and experience. Topics include:

- Alternative Transportation for the Downtown Corridor[20]
  West Main Street is the main transportation artery connecting UVa and downtown. Pedestrians, cyclists, public transportation, and automobiles compete for space and passage on this narrow two-lane street. The study starts with looking at the competition between on-street parking, essential to the operations of businesses on West Main, and bike lanes. The problem is generalized to the issue of alternative transportation. Students review the traffic management solutions of other cities, such as Portland, Oregon and London in developing and evaluating possible solutions.

- Belmont Bridge Repair or Replacement[21]
  Belmont Bridge connects the north end of Charlottesville's Downtown Mall to the neighborhood of Belmont, a popular restaurant and bar district. Its maintenance, however, has been delayed and ignored for decades and the City Council is sponsoring a competition for repair or replacement solutions. Students review the issue of aging and fragile infrastructure locally, across the Commonwealth, and nationally as part of the case study.

- Legislation to Eliminate Distracted Driving[22]
  A series of laws has been enacted in Virginia to restrict cell phone use while driving. Currently, there is a total ban on cell use by drivers under the age of 18 and school bus drivers, a total ban on texting while driving for all drivers, and violation of these laws is a secondary offence (primary for school bus drivers). Bills regulating cell phone use continue to be introduced, however, every General Assembly session. We review selected bills from the points of view of a policy analyst and an engineer, considering issues such as risk management, safety, and technical feasibility.

- Water Supply for Our Area[23]
  Implementing the 2055 Community Water Plan for Charlottesville and Albemarle County has not been without controversy. The two main alternatives – the proposed enlargement of a current reservoir, including the construction of a new dam, and the dredging of another – have their adherents and the public meetings have been fairly contentious. We deconstruct analyses performed by various engineering consulting firms regarding the plan since 2006, review the proposed alternatives using several indices of performance/technical performance measures, and develop recommendations for various stakeholders.

- Western Bypass for US 29[24]
  As with the dam *v*. dredging discussion for the Community Water Plan, the long-proposed Western Bypass has also seen its share of controversy. There is no argument that traffic volume on US 29, a main north-south artery, is far beyond capacity; the arguments revolve around proposed solutions, their impacts, and costs. We research the main problem and related issues and perform an analysis similar to the one for the Community Water Plan.

Because of the writing-intensive nature of the course, second-year standing became a pre-requisite for the second offering of the course. This change ensured that students would have had the PVCC English Composition sequence before the class. Students who had not completed this sequence had some issues completing the case studies, and we wanted to support student success in this course as well as at UVa, where they will have several writing intensive courses as part of the major's requirements: SYS 3023, *Human-Machine Interaction*; SYS 4053/4054, *Systems Design I* and *II* ("Capstone"), which culminates in a submission to and presentation at the IEEE Systems and Information Engineering Design Symposium; and STS 4500/4600 – *Science, Technology, Science and Engineering Practice* and *The Engineer, Ethics, and Professional Responsibilities*, the classes in which the fourth year thesis is written.

Another change for the Fall, 2012 offering of the course was the expansion of the readings. To provide additional insight on the practice of systems engineering, selections from Blanchard and Fabrycky[18] and Kossiakoff, *et al*.[25] became part of the reading list. These readings provide exposure to traditional systems engineering activities not covered in *How to Do Systems Analysis*. This exposure to other approaches to systems engineering is valuable if a student chooses to transfer to a non-UVa program.

Preliminary Qualitative Evaluation

Six students – three each from Spring, 2012 and Fall, 2012 – are now committed to majoring in systems engineering when they transfer to a four-year program. Two have received offers of admission to George Mason's Department of Systems Engineering and Operations Research. Interest in the systems engineering track is growing at PVCC as evidenced by the increasing enrollment in the courses. Student testimonials regarding the opportunity to transfer seamlessly follow.

> That opportunity has been very important to me because it makes the difference between spending four years in school versus five or even six. Having already spent four years in school for a degree, adding another four is difficult enough, let alone nine or ten years total. I am thrilled that this class will transfer seamlessly to UVa as a Systems Engineering class, seeing as that is my intended major. It is one more class that I can check off my list. But even better is the knowledge of the Systems Engineering profession, and how I can incorporate the methods I have learned this semester into my career path.
>
> The seamless transfer to a four-year school is important to me because the opportunity costs associated with every semester that I am a student impacts me and my family. This *Introduction to Systems Engineering* class has helped me by allowing me to have some systems class experience before declaring a major at a four year school. If more classes were offered at PVCC that would count toward the four year program I would take them in the community college setting.
>
> It is very important to me that there be a seamless transfer to a four-year school. I am a single parent, who is attending school full time and does not work. I will be using the GI Bill when I transfer so I have a fixed amount of time in which to accomplish my degree. If the transfer is not seamless, I will be forced to take classes in order to meet prerequisites or take an overburdened schedule of classes. Either solution will most likely push back my graduation date. This would put getting a degree in jeopardy because I cannot afford to pay for a more expensive school on my own and I don't have the income to stay in school longer than I had already planned.
>
> I believe this class has helped me stay on course to achieve that goal. This class is a requirement for the four year degree program at the school I intend to transfer to. Meeting any requirements I can before I get to the school significantly outweighs being forced to take them in a stressful or overworked time period.
>
> It is extremely, extremely important to me to be able to transfer seamlessly as a third year student to a major university. Even beyond guaranteed admission, the ability to transfer without creating an unmanageable schedule is the main appeal of the transfer programs at PVCC. Having all classes covered for the first two years means that you are able to have an optimal schedule in your third year. It also means that you have the same opportunities as your peers to work on

research or take internships over the summer, because you do not have to take additional courses to catch up. This course has helped me because it satisfies elective requirements for the guaranteed transfer program, and since it is made to align with the UVa syllabus, I have confidence it will fulfill their graduation requirements and I will not need to play catch up.

A transfer experience that is easy and seamless is very important to me. The transition from one school environment to the other is going to be stressful enough; the better organized and well thought out the transition is, the better. The ability to transition in as the level that I really am is also important to me. I think it would feel rather demoralizing to have to go back and take second year courses, and the closer to a regular 4 year college schedule I can stay, the more I will feel accomplished and on track. I believe this class has fulfilled that need, since it mirrors classes I may have to take, and has helped me get the credits for my transfer degree without causing me to take something drastically outside my major. This allows me to stay focused on the major I will have to declare immediately when I transfer.

Reproducing This Initiative

The success of this initiative is directly related to two factors: the positive relationship between PVCC and UVa, and mirroring PVCC classes after their counterparts at UVa. This initiative can be reproduced within existing articulation agreements and university-community college partnerships under certain circumstances. The following factors will have the most impact on seamless student transfer and success of the partnership:

Flexible Plan of Study: Community college engineering transfer programs should consider adopting the flexible plan of study used by PVCC and others[11, 16, 26], thus allowing students to take classes for their intended major as they would if they were in a four-year program. Basically, the community college program needs to provide students the opportunity to mirror the plans of study of the programs to which they will transfer. At PVCC, engineering or technical elective slots are used for systems engineering courses.

Transferability of Credits: One difficulty that community college students face in transferring to a four year program is the possibility that not all of their credits will be accepted. Some four-year schools have caps on the number of transfer credits they will accept. Students whose credits were not all accepted might find that, despite their efforts, it will take more than two years to complete their degree. As noted above, students beginning their postsecondary studies in engineering at a community college do so primarily due to cost. The cost of an in-state credit hour, including fees, at CC for Spring, 2013 is $127.65[27]; in-state undergraduate tuition for AY 2012-2013 is $12,026 at UVa.[28] Asking students to assume additional monetary and opportunity costs is not a preferable course of action; likely responses include termination of their studies or transfer to a more welcoming environment. Articulation agreements and plans of study should be reviewed and revised, as needed, to insure that students with an Associate's in Science will be admitted as a third year student.

Admission into Chosen Major: Articulation agreements detail circumstances under which students will be accepted as transfers. UVa's agreement guarantees admission to the School of Engineering and Applied Science when certain conditions are met, such as GPA, but not to a given major. Departments with enrollment caps should consider reserving space for transfer students. If a department develops a reputation for not accepting students transferring from a community college, then the pathway may fail.

Conclusion

With at least 223 engineering transfer programs[29] at 1,729 two-year schools[30], there are many opportunities to establish pathways to a seamless transfer from a community college to baccalaureate studies in systems engineering. Such a pathway is attractive to students and offers a low-cost, low-risk opportunity to meet the increasing demands for systems engineers. However, establishing a successful pathway requires a positive and sustained commitment from both the four-year school and the community college.

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Appendices

A: SIE and PVCC Plans of Study

SIE Plan of Study (first two years)[31]

Course requirements are listed below by semester. For advising and planning purposes, please (i) check (✓) the courses for which you are currently enrolled (or enrolling) and (ii) record your grade for each course previously completed.

✓	First Semester		
___	APMA 1110	Single Var Calculus	4
___	CHEM 1610	Intro Chem for Engr	3
___	CHEM 1611	Intro Chem Lab	1
___	ENGR 1620	Intro to Engineering	4
___	STS 1500	Sci, Tech, & Cntmp Iss	3
			15

✓	Second Semester		
___	APMA 2120	Multivariable Calculus	4
___	PHYS 1425	General Physics I	3
___	PHYS 1429	General Physics I Lab	1
___	CS 1110	Intro to Computer Sci	3
___	_____	Science Elective I (1)	3
___	_____	HSS Elective (3)	3
			17

✓	Third Semester		
___	APMA 2130	Ordinary Diff Eqns	4
___	CS 2110	Software Devel Methods	3
___	SYS 2001	Sys Engr Concepts	3
___	PHYS 2415	General Physics II	3
___	PHYS 2419	General Physics II Lab	1
___	_____	HSS Elective (3)	3
			17

✓	Fourth Semester		
___	APMA 3080	Linear Algebra	3
___	APMA 3100	Probability	3
___	SYS 2202	Data & Information Engr	3
___	_____	Science Elective II (2)	3
___	_____	STS 2000/3000 Elective	3
			15

PVCC Plan of Study (AS Degree)[32]

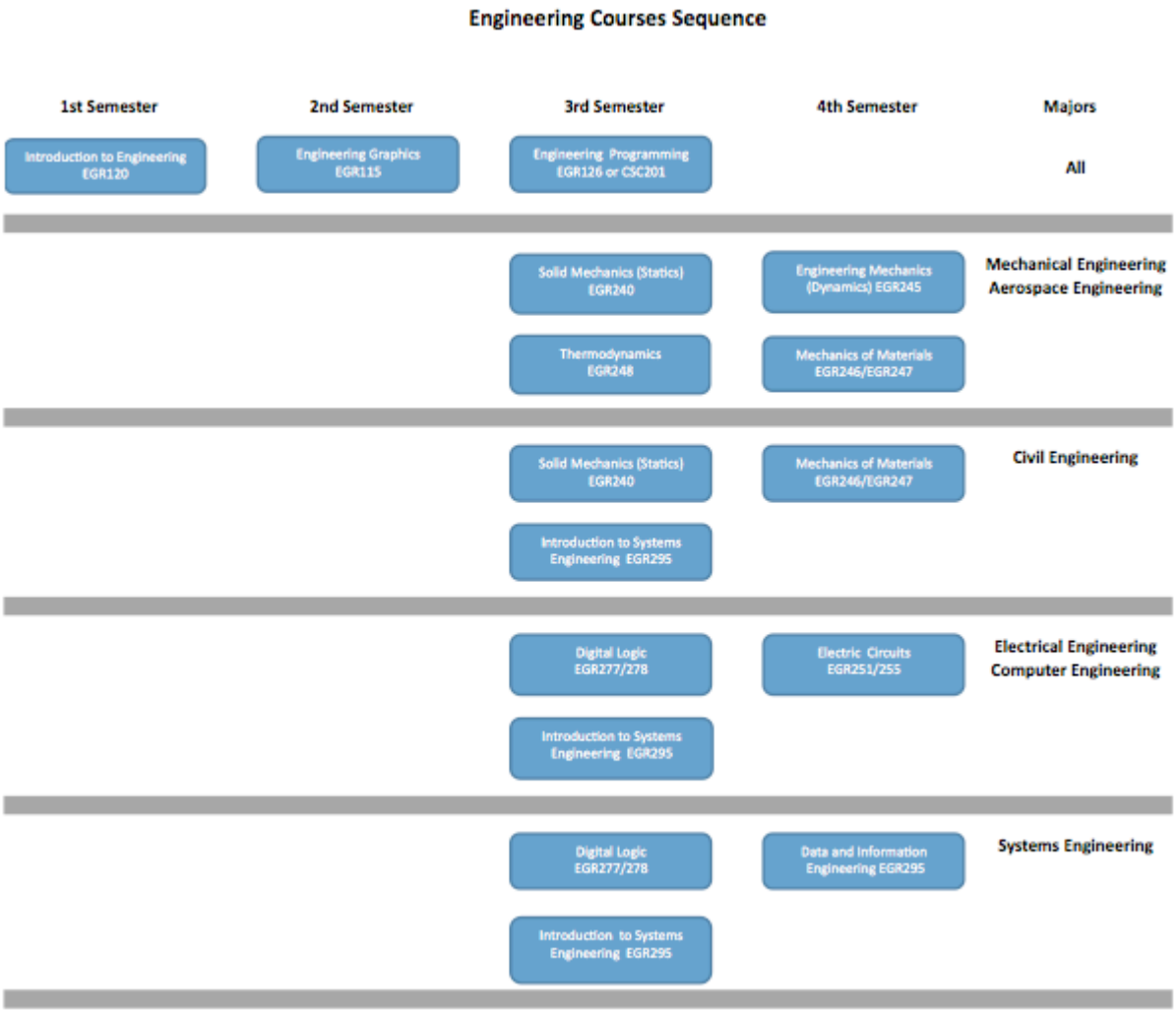
First Year

Fall Semester		Credits	Planned	Completed	Spring Semester		Credits	Planned	Completed
CHM 111	College Chemistry I	4	_____	_____	EGR 115	Engineering Graphics	3	_____	_____
CSC 110	Introduction to Computing	3	_____	_____	___ ___	Principles of Macroeconomics or Social Sciences Elective[1]	3	_____	_____
EGR 120	Introduction to Engineering	2	_____	_____	___ ___	Humanities Elective[1,2]	3	_____	_____
ENG 111	College Composition I	3	_____	_____	ENG 112	College Composition II	3	_____	_____
MTH 173	Calculus with Analytic Geometry I	5	_____	_____	MTH 174	Calculus with Analytic Geometry II	5	_____	_____
SDV 100/101/108	Orientation	1	_____	_____					
	Total Credits	**18**				**Total Credits**	**17**		

Second Year

Fall Semester		Credits	Planned	Completed	Spring Semester		Credits	Planned	Completed
MTH 277	Vector Calculus	4	_____	_____	___ ___	Engineering/ Technical Elective[3,4]	3-4	_____	_____
PHY 241	University Physics I (and Lab)	4	_____	_____	EGR ___	Engineering Elective[3]	3	_____	_____
EGR 126	Computer Programming for Engineers or CSC 201 Computer Science I	3	_____	_____	PHY 242	University Physics II (and Lab)	4	_____	_____
EGR ___	Engineering Elective[3]	3	_____	_____	___ ___	Humanities Elective[1,2]	3	_____	_____
EGR ___	Engineering Elective[3]	3-4	_____	_____	___ ___	Social Science Elective[1]	3	_____	_____
					HLT/PED	Health or Physical Ed Elective	1	_____	_____
	Total Credits	**17-18**				**Total Credits**	**17-18**		

Total Minimum Credits: 69



B: PVCC Course Goals and Objectives and Class Schedule for *Introduction to Systems Engineering*[33]

Course Description

This course introduces students to the discipline of systems engineering, which is centered on the design, development, maintenance, and the retirement of large-scale systems in need of optimization. The main topics are (1) the history and philosophy of systems engineering; (2) problem/issue analysis, evaluation, and solution using a systems engineering approach; and (3) project and product management processes, including life-cycle analysis. These topics will be investigated via case studies using basic tools of systems engineering and analysis including problem identification and research, goal definition, requirements analysis, mathematical modeling, and decision support methods. The pre-requisite is MTH 174; the co-requisite is MTH 277. You should have second-year standing.

Learning Goal and Objectives

The main goal of this course is for you to become a systemic thinker who uses a systematic approach, based on methodologies in the course materials, to analyze open-ended, ill-defined problems and issues. You will accomplish this goal by:

1. Demonstrating and effectively applying the following during the appropriate phase of analysis

    a. formulate a problem and develop a clear statement of needs
        - goals, objective trees, indices of performance
        - functional requirements and design specifications based upon system trades

    b. identify solutions to a problem
        - creativity and innovation, brainstorming, researching existing/near solutions to the same/similar problems

    c. evaluate and select solutions to a problem
        - assess what information is necessary information for evaluation (iterative and error embracing)
        - gather necessary information
        - apply appropriate modeling and analysis tools
            - decision trees
            - multiattribute value theory, introduction to utility theory
            - group/team decision making
            - fitting distributions to data (as applied in decision making, using software such as @risk)
            - monte carlo analysis (as applied in decision making, including sensitivity analysis, using software such as @Risk or Premium Risk Solver)
            - engineering economic analysis
            - pre- and post- analysis work, including understanding the meaning of data, cleaning data, performing sensitivity analysis, and asking "do my results make sense"

    d. explain and apply iteration as needed both within steps and through an entire process

2. Articulating your personal view of systems engineering based on your experiences in the course
3. Demonstrating effective oral and written communication skills
4. Working collaboratively on complex systems problems involving technology and multiple stakeholders

PVCC *Introduction to Systems Engineering* Course Topics

Spring 2012	Fall 2012
Introduction and History of Systems Engineering	Introduction and History of Systems Engineering
Team and Project Management	Team, Project, and Systems Engineering Management
Basics of Systems Analysis	Basics of Systems Engineering
Basics of Systems Analysis	Basics of Systems Analysis
Goal Development I	Goal Development
Goal Development II	System Modeling Language (SysML)
Indices of Performance	Solution Development and Evaluation I
Basics of Systems Engineering Analysis, Revisited	Solution Development and Evaluation II
Solution Development I	Solution Development and Evaluation III
Solution Development II	System Maintenance, Logistics, and Retirement
Solution Selection	System Life Cycle Analysis
Iteration and Action	Human-Computer Interaction, Integration, and Iteration/Action
Final Case Preparation and Presentation; Review for Final	Final Case Preparation and Presentation; Review for Final